RPPforCS

The Intersection of RPPs and BPC in CS education

A culmination of papers from the RPPforCS Community

Fall 2021

Using a Research-Practitioner Partnership approach to developing a shared evaluation and research agenda for Computer Science for All: RPPforCS is a National Science Foundation funded project. (DRL 1745199)

RPPforCS is a partnership between SageFox Consulting Group and CSforALL

SageFox is a lead research partner on several NSF projects. All of our research efforts are based on values of collaboration, transparency and meaningful contribution to the education community. Projects to date have focused on retrospective studies to uncover the long-term impacts of programs, aggregating knowledge across programs and/or states and understanding emerging needs in STEM education.

CSforALL, shorthand for "Computer Science for All," is the central hub for the K-12 national computer science education movement. We are the community organizers of school districts, nonprofits, government agencies and corporations that share the goal of rigorous, inclusive and sustainable CS education in the U.S. Find out more about CSforALL at www.csforall.org.

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Refer to the table of contents or the individual paper.

Preface

Over the past four years the National Science Foundation has significantly invested in the creation of research-practice partnerships (RPPs) in the K12 CS education space. Complementary to that investment, the CS education community has embraced the methods of research practice partnerships in order to understand the ongoing problems of practice in CS education, and the interventions designed to address them. The goal of RPPs, especially in the CS education arena, is to elevate the voices of teachers, practitioners, and students in the research and decision making around the design and development of high quality CS education approaches. Although RPPs often come together initially in response to a particular opportunity for funding, RPPs themselves are meant to transcend individual funding opportunities or projects and result in long term partnerships building deep knowledge.

RPPforCS fosters knowledge creation and exchange, cultivates leadership within the community and provides an organizational structure to steward a connected community of practice of awardees. RPPforCS shapes and amplifies the impact of the individual awardees by addressing key problems of practice in CS education.

As research practice partnerships mature, it is worthwhile to explore the partnerships, activities, and measurement which contributes to the success of individual projects. The RPPforCS project has engaged with the community through webinars, research briefs, theme studies, and sharing of information in more informal outputs.

This set of workshop papers focuses on the aspects of research practice partnerships that have contributed to project learnings or outcomes. Recognizing the description of the research practice partnership and design-based approach to the research, these papers focus on the problem of practice and iterative nature of RPPs and recognize that research questions about CS education may shift over time.

The call-for-papers specified that papers should include as a core part a description of the research practice partnership and address how the RPP connects to the learnings about CS education in an effort to promote generalizable knowledge in this unique space.

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Making an Original Computing Curriculum Accessible for Students with ASD

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ABSTRACT

This is a collaborative research practitioner partnership (RPP) study between expert practitioners and researchers to develop and implement an accessible computing curriculum for student with Autism Spectrum Disorders (ASD). The RPP team members include two researchers from a regional public higher education institution in Midwest and three practitioners from two local schools (PDMS and RCA) for students with ASD.

This study has three purposes. The first one is to document specific project activities that took place to sustain the RPP partnership and to involve the RPP team members in analyzing students' characteristics, examining an original computing curriculum, and co-designing adjustments to make an original computing curriculum accessible to students with ASD. The second purpose is to report activities that contributed to the overall project goals, including 1) the analysis of participating students' characteristics, 2) identifications and definitions of the adaptations and accommodations applied to make the existing computing curriculum accessible to the participating students, and 3) documentation of specific adjustments made to the original curriculum in terms of learning objectives, instructional design, information presentation, assessments, feedback, and learning environment. The third purpose of the study is to demonstrate how the RPP structure affected the design of the adjustments made to the original computing curriculum.

CCS CONCEPTS

- Social and Professional Topics → Computational Thinking

The intersection of RPPs and BPC in CS education: A culmination of papers from the RPPforCS Community [White paper], CSEdResearch.org.

KEYWORDS

Accessible computing curriculum, Students with autism spectrum disorders, Adjustments to an original computing curriculum

1 RPP-Specific Project Activities

The RPP team consisted of three researchers; a faculty in Computer Science department, a faculty in Special Eduaction department, a faculty in Psychology department; two practitioners; two program coordinators from a local middle school for students with ASD. The project activities that took place to sustain the RPP partnership and that involved the RPP members consisted of weekly meetings to determine how to 1) analyze learners, and 2) identify & develop adaptations and accommodations.

1.1 Weekly RPP Meetings to Analyze Learners

After obtaining IRB approval, the RPP team started with reviewing participating students' files, and defining the tests and surveys to understand participating students' aptitudes in terms of what method of information presentation they prefer and what kind of learning activities would be most engaging or useful to them due to their individual differences including prior knowledge, physiological, affective, social characteristics, neurological differences, interests, and cultural differences. Obtaining information about students helped to design and develop instructions and presentations of information in different formats specifically for students with ASD, who benefit from different modes of instruction. The RPP team met once a week for about an hour to determine the specific surveys and/or tests needed to analyze the characteristics of the participating students and to decide how the surveys/test to be administered.

During these meetings, a list of fourteen test & survey instruments, including what they are, what learner characteristics they measure, how they are administered, their origins, and their descriptions, were discussed in detail. After these discussions, five surveys, as listed below, were determined to be administered. Each student's characteristics based on their responses to the tests & surveys were recorded.

The five surveys administered are:

1. Learner Channel Preference Test [4]
2. Individual vs Group Study Preference Survey [1]
3. Locus of Control Scale [3]
4. State & Trait Anxiety Scale [5]
5. BRIEF 2 - Executive Functioning Test [2]

1.2 Weekly RPP Meetings to Identify & Develop Adaptations and Accommodations

1.2.1 Adaptation & Accommodation Meetings (AAMs). During each week, the researchers worked on developing adaptations and accommodations for two CT curricular sessions of an instructional unit. Once every Monday, the researchers, a graduate student assistant and a representative of external evaluators, met over video conferencing (WebEx) for about an hour to go over the adaptations and accommodations developed, which included learning objectives, instructional design, information presentation, handouts, instructional videos, assessments and rubrics, and pre-teaching activities.

1.2.2 RPP Team Meetings. Once every week, the RPP team, external evaluators, a graduate student assistant, a few undergraduate students met every week for one to 2 hours to go over the adaptations and accommodations developed. These lead to the adjusted CT instructional sessions. All participants provided their input and requests for further revisions. The practitioners were provided with the final versions of the adjusted CT instructional sessions to share with their classroom teachers to obtain their inputs and requests for revisions. Thus, input from the classroom teachers via the practitioners were elicited to make further adjustments. A total of 30 instructional sessions were adjusted to be accessible to students with ASD, which are uploaded to ISAC_Public public GitHub repository at https://github.com/arslanyilmaz/ISAC_Public for public to access.

1.2.3 Meetings with Classroom Teachers. Once the assessments to identify students' learning characteristics were completed, the researchers met twice with practitioners, the current classroom teachers of the student participants, to discuss the accommodations, modifications, and instructional needs of the students.

1.2.4 End-of-Year Workshop. The RPP team, classroom teachers, and external evaluators met at the end of the year to go over the instructional materials designed and developed, including adjusted CT curricular sessions, the visual handouts, instructional videos, and assessments and rubrics. The classroom teachers provided inputs regarding the changes made to the instructional activities, assessments, and other curricular materials. Their inputs were recorded and adopted.

2 Contribution of the RPP-Specific Activities to the Overall Project Goals

These RPP-specific activities directly contributed to the overall project goals, one of which is to make an existing CT curriculum accessible for students with ASD. Specifically, these activities led to 1) the analysis of participating students' characteristics, 2) identifications and definitions of the adaptations and accommodations applied to an existing computing curriculum, and documentation of specific adjustments made to the original curriculum in terms of learning objectives, instructional design, information presentation, assessments, feedback, and learning environment.

2.1 Analysis of Participating Students

2.1.1 Learner Channel Preference Test. A revised version of the learner channel preference test [4] was utilized to determine the medium (visual, auditory, and kinesthetic) students preferred to learn CT-related knowledge and to obtain information about students' aptitudes toward different methods of information presentation, including visual, auditory, and kinesthetic.

The test consisted of 10 items with three options (Never applies to me, sometimes applies to me, and often applies to me) for each item. Google forms were used to present the test and administer it. Parents and teachers were involved in the administration. It took about two weeks to complete the administration of the test. After the responses were received, they were recorded on the local machine and analyzed to make decisions on the adaptations and accommodations applied to the original CT curriculum.

Students' responses to each item were assigned a numerical value, i.e., 1: Never applies to me, 2: Sometimes applies to me, and 3: Often applies to me. The numerical scores to each response were tallied for each of the three sets of 10 items for each modality (visual, kinesthetic, and auditory) to determine students' preferences. The higher the score showed, the stronger preference toward the modality. If the student showed a relatively high score in two or more sections, the student was considered to have strength toward more than one modality. If the student's score in multiple sections is roughly equal, the student was considered not to have a preferred learning channel.

The learner channel preference test results (see Figure 1) showed that 10 out of 13, 8 out of 13, and 10 out of 13 students scored at or above 20 on visual, auditory, and kinesthetic channels, respectively. This result was not surprising because RPP team expected that more students with ASD would prefer visual followed by kinesthetic and auditory learning channels. Figure 1 shows the students with stronger preferences toward a specific channel and those with multi-channel preferences.

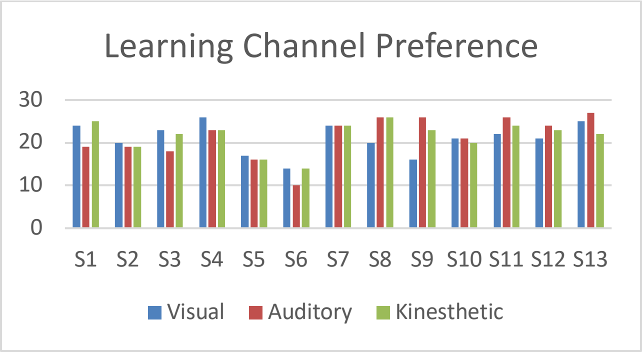


Figure 1: Students' learning channel preference scores

Based on the results, the RPP team were able to report the number of students showing a preference for each of the channels and toward a combination of the channels (see Figure 2). In addition, the results indicated that four of the students were multi-sensory, who did not have a stronger preference toward any single channel, and the remaining four students preferred learning via auditory and kinesthetic at the same level of strength.

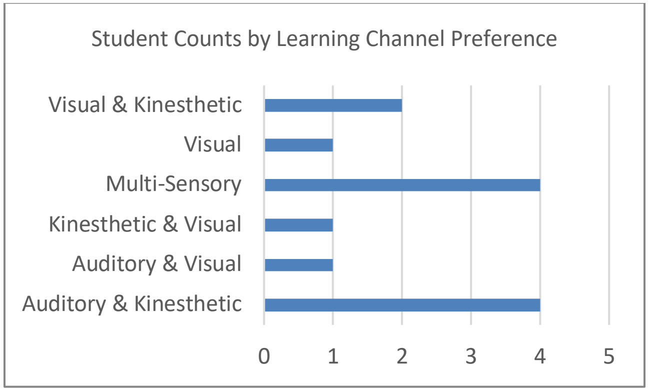


Figure 2: Count of students by learning channel preference

2.1.2 Individual vs. Group Study Preference Survey. The items used in this survey were adapted from the CITE learning styles inventory [1]. There were ten sentences presented to the students to figure out whether they like to work/learn in a group or alone. Five of the ten sentences were designed to explore students' preferences toward working in a group, and the remaining five were designed to find out their aptitude for working alone.

Students were helped/asked to read each sentence carefully to determine which four responses they agree with based on how they feel about the statement. For example, a sample statement for a preference in working alone is "I get more done when I work alone," and a sample statement for a preference toward working in a group is "If I need help in a subject, I will ask a classmate for help." Students were asked to select among these four options on a scale from 4 (Most like me) to 1 (least like me), and the selected option was assigned a numerical value as presented here: Most like me (4), More like me (3), Less like me (2), Least like me (1). The marked numerical scores (1 to 4) were tallied and multiplied by two to determine students' preferences toward working/learning in a group and/or alone.

This survey was prepared and administered on google forms with the assistance of teachers and parents. It took about two weeks to complete the administration of the survey. The results were saved locally and analyzed to determine whether students preferred working/learning individually and in groups.

In terms of preference for working/studying alone (see Figures 3 & 4), 10 of the 13 students scored above 20, which indicates a choice above "Less Like Me (2)". As for preference toward working/studying in a group, eight out of 13 students scored above 20. However, when compared their preference toward working/studying in a group to working/studying alone, seven students scored higher to working/studying alone than working/studying in groups. These results showed that these seven students indicated that they would get more work done by themselves. They would think best and remember more when they learn alone and care more for their own opinions than for the ideas of others.

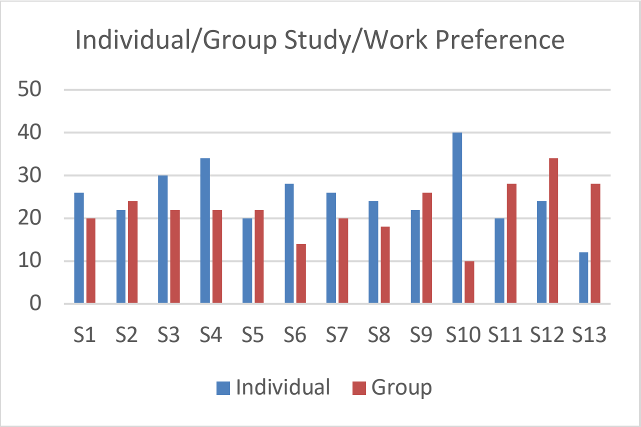


Figure 3: Individual/group study/work preference

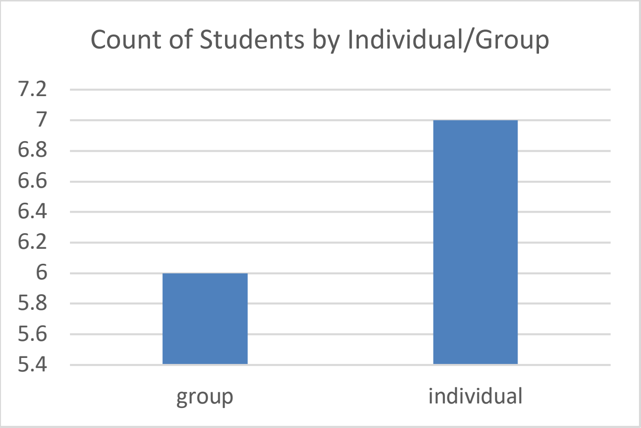


Figure 4: Count of students by individual/group work/learning preference

On the other hand, six students scored higher for working/studying in groups compared to their preference toward working/studying alone. These students would not get much done studying alone and would strive to study with at least one other student. They value others' opinions and preferences, and group interaction increases their learning and later recognition of facts.

2.1.3 Locus of Control Survey. The Nowicki-Strickland Locus of Control survey [3] was utilized to determine students' feelings about the placement of control over events in their lives (i.e., internal or external) and whether they attribute the responsibilities for these events to themselves or external forces. The purpose was to figure out students' beliefs regarding the cause of their experiences and how they attribute their successes and failures (i.e., internal vs. external forces).

The survey consisted of 40 questions that are answered either yes or no as multiple-choice answers. The items described reinforcement situations across interpersonal and motivational areas such as affiliation, achievement, and dependency. For example, a sample item was "Do you believe that most problems will solve themselves if you just stop yourself from catching a cold?". The items were written at the 5th-grade readability level.

The survey was created and administered on google forms, and both parents and teachers assisted in administering the surveys. The administration was completed within approximately two weeks. Students' responses were compared to responses by a group of clinical psychology staff members, and the total count of responses for internal as well as external was tallied to figure out how students place the control of events in their lives, i.e., internal and/or external.

The results indicated that 10 out of 13 students attribute the causes of their successes and failures to themselves (see Figures 5 & 6). Two students tend to attribute their successes and failures to external forces that control their performances. One student was equal in terms of attributing the responsibility of the events in his/her life.

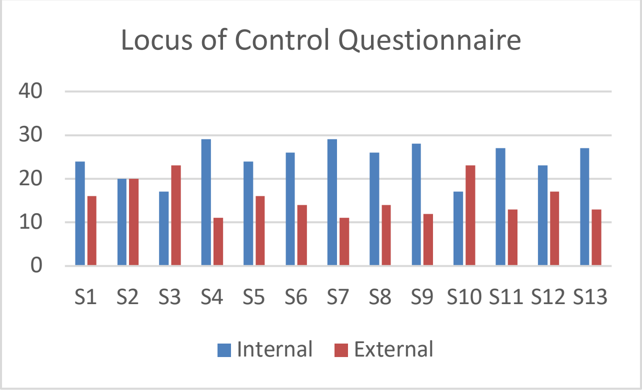


Figure 5: Locus of control questionnaire

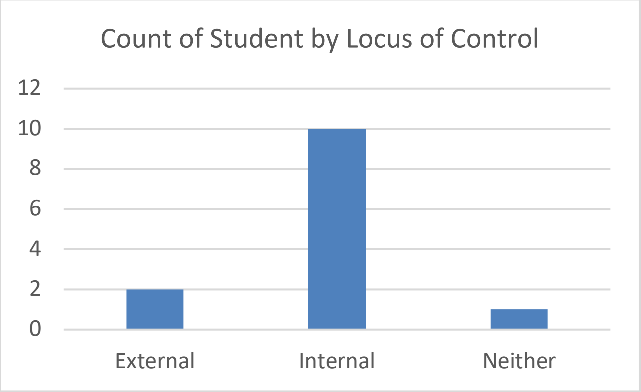


Figure 6: Count of students by locus of control

2.1.4 State & Trait Anxiety Scale. The state-trait anxiety inventroy for children [5] was utilized to determine students' state and trait anxiety levels. Each of these surveys (state and trait anxiety surveys) consisted of 20 statements which students use to describe themselves. Parents and/or teachers assisted in the administration of the survey. The survey was developed and administered utilizing google forms, and it took about two weeks to complete the administration of the survey.

Students were asked to read each statement to describe how they feel right now (state) and decide if the statement is hardly-ever, sometimes, or often true for them (trait). The survey was developed and administered utilizing google forms, and it took about two weeks to complete the administration of the survey. Based on students' choices, they were asked to select the statement that seems to best describe them or how they felt. A sample statement for the state anxiety scale is "I feel: Not Calm (1) Calm (2) Very Calm (3)". A sample statement for the trait anxiety scale is "I feel unhappy Often (1) Sometimes (2) Hardly Ever (3)."

Numerical values for responses to all items were assigned and tallied to determine their state and trait anxiety scores from 20 (very anxious) to 60 (not anxious at all). All 13 students scored above 40 on state anxiety scale (see Figure 7), indicating that none of the students had state (situational) anxiety. Again, 4 students out of 13 scored below 40 on trait anxiety scale (see Figure 8), showing that these four students had trait (general) anxiety.

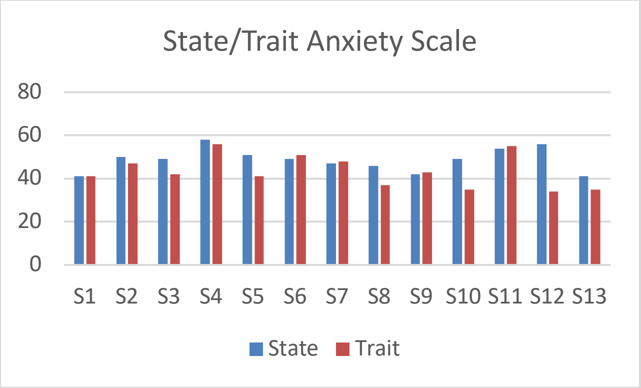


Figure 7: State/Trait Anxiety Scale

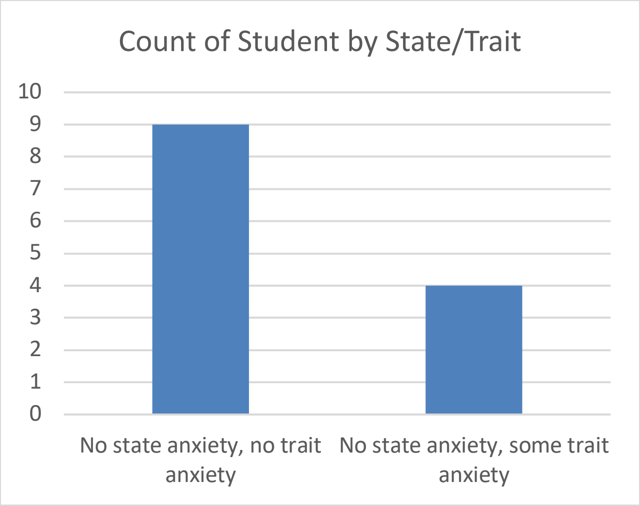


Figure 8: Counts of students by State/Trait Anxiety

2.1.5 Executive Functioning Test. Brief2 assessment [2] was administered to assess executive functions including inhibit, self-monitor, shifting, emotional control, initiation, working memory, planning, organization, and task monitoring. https://www.parinc.com, the official portal for BRIEF2 assessment, was utilized to administer the tests. Parents and teachers helped in administering the tests, which took about two weeks to complete.

The survey results showed that one student is able to resist urges, but 12 have trouble resisting urges and stopping actions before they act; all students have trouble with monitoring overall behavior; 2 students are able to shift attention from task to task or from place to place without difficulty, but 11 students have some problems with shifting; 4 student have appropriate level of emotional control, react to events in an appropriate level, and do not have regular or strong emotional outburst, but 9 students have trouble expressing and regulating their feelings; 3 students are able to start on tasks and activities at an age-appropriate level, are able to come up with their own ideas when problem solving is needed, but 10 students have difficulty with their ability to start on tasks, and have trouble when problem solving is needed; 2 students are able to hold an appropriate amount of information in 'active memory,' likely have the ability to sustain working memory to stay attentive and focused, but 11 have difficulty holding information in 'active memory'; 4 students are able to plan their behavior and approach to problem solving, but 9 of them have planning and organizational problems, may not understand the difficulty of a task, and may have trouble carrying out the steps needed to reach a goal; 3 students are reasonably organized, are able to keep things in place in their world, and able to find their things when needed, but 10 of them have trouble organizing things, may have trouble keeping things in order, and organizing what is needed for projects or assignments; one student shows an appropriate level of task-monitoring, but 12 of them have trouble with task-monitoring (see Figures 9 & 10). These analyses were uploaded into the ISAC_Public repository at https://github.com/arslanyilmaz/ISAC_Public for public access.

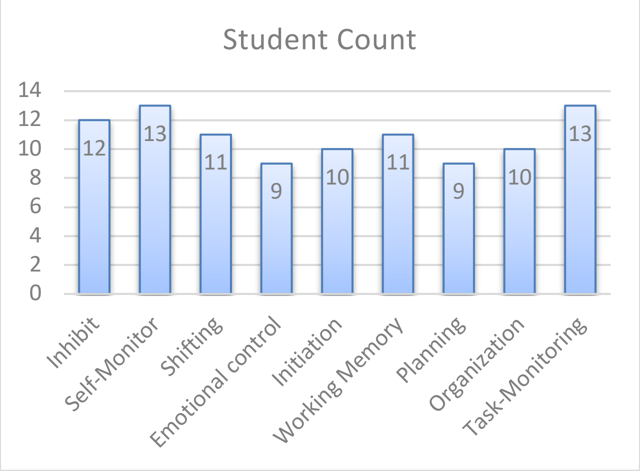


Figure 9: Student Counts for Each Executive Functioning Skill

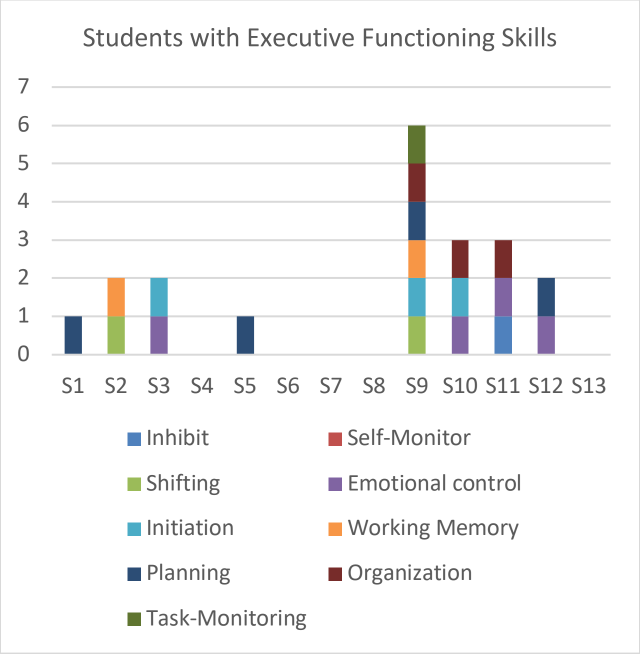
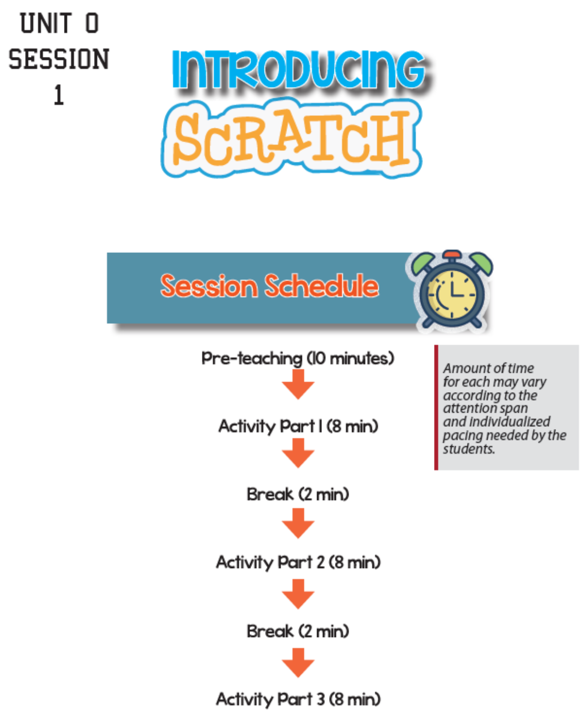


Figure 10: Individual Students with Executive Functioning Skills

When all executive functioning skills are considered for all students, it was determined that one, two, three, and two students did not seem to have problems in the six, three, two, and one of the nine areas, respectively. Five students had problems in all nine areas. When looking at the executive functioning areas, it was found that 13, 12, 12, 11, 11, 10, 10, 9, and 9 students had problems in self-monitoring, inhibit, task-monitoring, shifting, working memory, initiation, organization, emotional control, and planning executive functioning areas, respectively.

2.2 Identifications and Definitions of the Adaptations and Accommodations

2.2.1 Session Schedule. Each of the 36 sessions follows the same order of instructions, even though the depth and breadth change based on the topics covered in each session. Each session starts with a session schedule (see Figure 11). The reason for this is to ease any anxiety issue experienced by students. This way, students are informed of what is expected and how much time will be spent on the scheduled items in each session. The session schedule is presented on its own page so the teacher can print them to post on the classroom walls and place them on student desks. Time for tasks and breaks will be individualized based on attention span and behavior needs.



UNIT 0
SESSION
1

INTRODUCING SCRATCH

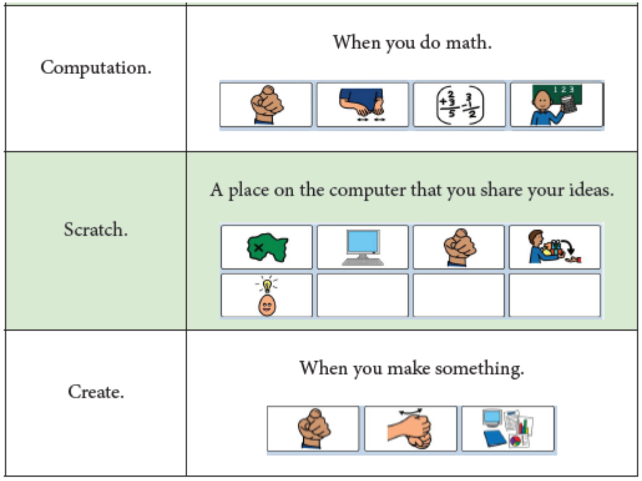
Session Schedule

Pre-teaching (10 minutes)
Activity Part 1 (8 min)
Break (2 min)
Activity Part 2 (8 min)
Break (2 min)
Activity Part 3 (8 min)

Amount of time for each may vary according to the attention span and individualized pacing needed by the students.

Figure 11: Session Schedule

2.2.2 Pre-Teaching Activities. This is the next instructional item after the session schedule in each session. Students with more severe cognitive function issues, those who are having a harder time comprehending information presented, and those who cannot keep up with the pace of the instructions because of behavioral, psychological, social, or other reasons will be given further assistance and time with these pre-teaching activities. The three instructional elements of pre-teaching activities are topics, terms, and expectations. Specific terms of the session that may be unfamiliar to the students are presented with their description and visual (symbols) representations (see Figure 12). The reading level of the descriptions was simplified to students' reading level. Students are informed of what is expected of them in the session to both ease their anxiety and get them ready for the session activities.



Computation.	When you do math.
Scratch.	A place on the computer that you share your ideas.
Create.	When you make something.

Figure 12: Terms and Symbols

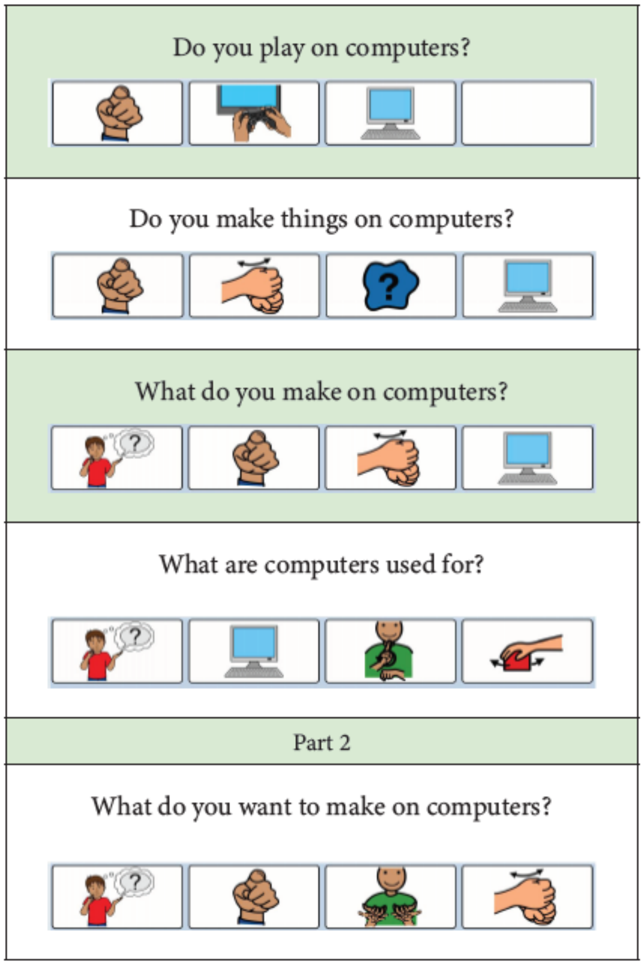
2.2.3 Session Learning Objectives. The objectives of the original curriculum were adjusted to be presented in two sets of objectives. One set of objectives is to inform the classroom teacher of the session targets to achieve, which are called "session objectives." The other set of objectives is to inform students on what they will reach by the end of the session. The reading level of the learning objectives was simplified to students' reading level. The learning objectives were adjusted to make them measurable, achievable, and observable. As needed, additional learning objectives were added, and some of the learning objectives from the original curriculum were removed. Furthermore, learning objectives were adjusted to reflect visual, oral, and written comprehension and response.

2.2.4 Instructional Activities. The instructional activities were simplified and divided into multiple manageable sections. They were modified to be inclusive of students with different characteristics (visual/verbal/kinesthetic, work alone/in small or big groups, visual and/or verbal response, presentation to class/peer/USAT/on a notebook, etc.). Modeling activities were integrated into the instructions so students could follow along with the classroom teachers to complete the session activities. Additionally, instructions for classroom teachers to pair some students with unique characteristics with undergraduate students to work one-on-one are included. Furthermore, instructions to allow students to work alone are included for students who prefer studying independently.

2.2.5 Visual Handouts. A total of 27 handouts (see the PDF documents for the Visual Handouts at https://github.com/arslanyilmaz/ISAC_Public) were designed and developed. These are developed as visual guides for students to follow step-by-step toward completing a project or task as part of a session. These are prepared as a standalone PDF document for the teachers to print and post on classroom walls and put on student desks.

2.2.6 Instructional Videos. A total of around 60 individual instructional videos were designed and recorded. These are developed for students who prefer visual channels for information presentation. All of these videos are uploaded to the YouTube channel created for this project, which can be found at https://www.youtube.com/channel/UCE2RvGLMnVWDZun7YH6bE8g.

2.2.7 Reflection Prompts. Each session included one set of reflection prompts. The reflection prompts are presented in both verbal and visual formats (see Figure 13) and prepared as separate PDF documents for the classroom teacher to be able to print them for students to give their reflections on the physical papers. Students are given the option to express their responses in multiple formats, i.e., visual, print, and/or oral.



Do you play on computers?

Do you make things on computers?

What do you make on computers?

What are computers used for?

Part 2

What do you want to make on computers?

Figure 13: Reflection Prompts

2.2.8 Work Evaluation Rubrics. A rubric for each session was designed and developed to assess the achievement of learning objectives defined for the session. A total of 36 rubrics were created in PDF formats so that the classroom teachers may print them and use them in the class to assess each student's learning. The assessments were designed to be aligned with the learning objectives and developed to be objective, observable, and measurable. The rubrics were designed to assess student achievement in three levels for each item; with physical assistance, with verbal and/or visual cues, and independently.

2.2.9 Notes to the Teacher and Generic Recommendations. These are general recommendations to the teacher to keep in mind when executing the instructions of the session considering the special needs of students with ASD. Some sample ones are 1) offering extended time to students with certain cognitive characteristics, encouraging students to get creative by responding with drawings, giving students frequent breaks as needed, offering individualized assistance to students with certain social and communicational characteristics, moving students to individualized workstations and/or calming area, and providing positive feedback.

2.2.10 Notes by the Teacher. A page with empty lines was included in the curriculum document for the classroom teacher to record their observations of the curricular implementation. These notes will be examined and discussed during our weekly meetings in the second year of the project to implement the curriculum to make additional revisions as needed.

2.2.11 Additional Adaptations and Accommodations. In addition to the above-mentioned adjustments applied to the computing curriculum, a few additional adaptations and accommodations included symbols, breaks, individual workstations, and groupings. Symbol communication pictures are also included to augment instruction. RPP Team developed visual symbols for the visual handouts, reflection prompts, and instructional sessions based on Boardmaker Symbols. Frequent breaks are provided based on individual student data or are specified in the Individual Education Plan (IEP). For students who appear agitated or are demonstrating inappropriate behavior, a quiet or calming area or an individual workstation is provided as needed. Grouping was established as homogeneously as possible for students with Autism Spectrum Disorder (ASD). It was based on communication, reading levels, and academic performance. The RPP team is currently in the process of revising the rubrics to identify prompting levels needed to ensure mastery. For example, a student may need a verbal or visual cue for multiple trials, but at the end of the level, the student can complete the task independently, or the student may complete the task with a verbal cue or "hint" on one step but can then perform the task independently. This will help practitioners to identify needed changes in instructional strategies.

3 How the RPP Structure Affected the Design of the Adjustments

The RPP team consisting of program coordinators and teachers from a local school for students with ASD as practictioners, and researchers at a regional public higher education institution produced several adjustments and instructional materials to make an original computing curriculum accessible to students with ASD.

In addition to analyzing students with ASDs' learning characteristics, the instructional materials developed included 36 adjusted instructional sessions to teach coding to students with ASD, around 60 instructional videos on a YouTube channel created for the adjusted curriculum, around 27 visual handouts to use by students to complete small-scale project in a step-by-step fashion, and around 36 work evaluation rubrics developed to evaluate student work.

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REFERENCES

[1] Babich, Burdine, Albright, and Randol. 1976. C.I.T.E. Learning Styles Instrument.

[2] G. A. Gioia, P. K. Isquith, S. C. Guy, and L. Kenworthy. *Behavior Rating Inventory of Executive Function*. Retrieved August 22, 2021 from https://www.parinc.com/products/pkey/24

[3] Stephen Nowicki and Bonnie Trickland. 1973. A Locus of Control Scale for Children. *Journal of Consulting and Clinical Psychology* 40, 1 (1973), 148–154.

[4] Lynn O'Brien. Learning Styles: Make the Student Aware. *National Association of Secondary School Principals Bulletin* 73 , 85–89.

[5] C.D. Spielberger. 1973. *Manual for the State-Trait Anxiety Inventory for Children*. Consulting Psychologists Press, Palo Alto, California, USA.

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Middle School Teachers' Self-efficacy in Teaching Computer Science and Digital Literacy: Impact of the CS Pathways RPP professional development program

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ABSTRACT

Background: Researcher-practitioner partnerships (RPPs) have gained increasing prominence within education, since they are crucial for identifying partners' problems of practice and seeking solutions for improving district (or school) problems. The CS Pathways RPP project brought together researchers and practitioners, including middle school teachers and administrators from three urban school districts, to build teachers' capacity to implement an inclusive computer science and digital literacy (CSDL) curriculum for all students in their middle schools.

Objective: This study explored the teachers' self-efficacy development in teaching a middle school CSDL curriculum under the project's RPP framework. The ultimate goal was to gain insights into how the project's RPP framework and its professional development (PD) program supported teachers' self-efficacy development, in particular its challenges and success of the partnership.

Method: Teacher participants attended the first-year PD program and were surveyed and/or interviewed about their self-efficacy in teaching CSDL curriculum, spanning topics ranging from digital literacy skills to app creation ability and curriculum implementation. Both survey and interview data were collected and analyzed using mixed methods 1) to examine the reach of the RPP PD program in terms of teachers' self-efficacy; 2) to produce insightful understandings of the PD program impact on the project's goal of building teachers' self-efficacy.

Results and Discussion: We reported the teachers' self-efficacy profiles based on the survey data. A post-survey indicated that a majority of the teachers have high self-efficacy in teaching the CSDL curriculum addressed by the RPP PD program. Our analysis identified five critical benefits the project's RPP PD program provided, namely collaborative efforts on resource and infrastructure building, content and pedagogical knowledge growth, collaboration and communication, and building teacher identity. All five features have shown direct impacts on teachers' self-efficacy. The study also reported teachers' perceptions on the challenges they faced and potential areas for improvements. These findings indicate some important features of an effective PD program, informing the primary design of an RPP CS PD program.

CCS CONCEPTS

• Computer Science Education • Education • Collaborative learning

KEYWORDS

teacher self-efficacy, researcher-practitioner partnership (RPP), teacher professional development, middle school, computer science education

1 Introduction

Computer Science (CS) education is a vibrant and quickly evolving field, where the state-of-the-art applications and programming languages change frequently. Students also see the world of computers and technology change around them. This creates challenges unique to the CS education field. Teachers must not only stay abreast of all these developments but develop the self-efficacy to teach these new concepts. Researchers have confirmed the significant role of teachers' self-efficacy in predicting their behavior and performance [21], as well as their students' academic outcomes and motivation [11, 23, 28]. Preliminary research in computer science education shows that professional development (PD) is an important way for building teacher self-efficacy [29], one that must be explored further to continue chasing the highest-possible student success.

Researcher Practitioner Partnerships (RPPs) have gained increasing prominence within education, since they are crucial for identifying partners' problems of practice and seeking solutions for improving district (or school) problems [4, 5]. The impact of meaningful partnerships includes positive changes in teachers' self-efficacy in various educational research fields [4, 5, 12] However, adopting RPPs in K-12 computer science education is relatively rare [12]. Therefore, this paper reported results from our CS Pathways RPP project that explored the teachers' self-efficacy development. The ultimate goal was to gain insights of how the project' PD program under the RPP framework prepared teachers and built their self-efficacy in teaching the curriculum, in particular its challenges and success of the partnership. The study is guided by the following research questions:

1. Which attributes (factors) can account for teachers' self-efficacy profiles after their first year of the PD participation?

2. How did teachers' participation in the RPP project influence their self-efficacy in teaching the project's CSDL curriculum?

2 Background

2.1 Computer Science Teacher Self-efficacy

Although teacher self-efficacy has been the major research strand for decades [10, 15, 20], it is not until Bandura [1] transformed the research by validating the construct of teachers' self-efficacy. According to Bandura's Social Cognitive Theory, "the self-efficacy belief system is not a global trait, but a differentiated set of beliefs linked to distinct realms of functioning." [2]. Therefore, self-efficacy should be conceptualized as a domain-specific trait. Teachers' self-efficacy may vary according to different types of tasks, students, and circumstances in class [19, 24]. Following the Bandura-based definition of self-efficacy, Dellinger et al. [6] further defined teachers' self-efficacy as "individual beliefs in their capacities to perform specific teaching tasks at a specific level of quality in a specific situation". Wyatt [26] also contributed to the definition by defining teachers' self-efficacy as "teachers' beliefs in their capability of supporting learning in various tasks and context-specific cognitive, metacognitive, affective and social ways." Both definitions focused on the domain-specific trait of teachers' self-efficacy. Wyatt [26] expanded it to include the outcomes of teachers' self-efficacy. Zee and Koomen [28] reviewed Bandura's triadic reciprocal causation model that indicated teachers' self-efficacy in relation to classroom processes. In the model, domain-specific teachers' self-efficacy can have consequences for students' academic adjustments, quality of the classroom, and teachers' well-being.

Given the importance of teachers' self-efficacy and its impacts, researchers have examined teachers' self-efficacy in various subjects, such as STEM subjects and literacy development [9, 17]. However, there have been relatively few studies examining self-efficacy for computer science education teachers; therefore, the need to research on such an important topic has been proposed by many computer science education researchers [18, 27, 29]. Rich et al. [18] examined US-based elementary teachers' self-efficacy towards the integration of computing and engineering after participating in a weeklong professional development in computing and engineering. The authors used the modified Teacher Efficacy and Attitudes Toward STEM Survey (cited in [18]) to measure both the differences and similarities of the teachers' self-efficacy between a study school and a comparison school. An independent-sample t-test on the survey data showed that teachers from both schools were likely influenced by the PD on their self-efficacy beliefs towards the importance of computing and engineering and on their confidence to teach the subjects. The results from teacher interview data showed varied individual self-efficacy beliefs for teaching the subject. The authors also found that teachers' self-efficacy and their prior experience with teaching STEM are positively correlated. Their perceived experience of implementing the curriculum successfully was an important factor for increasing their self-efficacy.

Borowczak and Burrows [3] also reported how their NetLogo PD program helped enhance content knowledge and self-efficacy in integrating CS into existing lessons and curricula. The PD program provided a constructivist environment for the pre-collegiate teachers to increase their content knowledge and self-efficacy. The pre- and post-survey results showed a significant increase in teachers' self-efficacy, which proved that the PD program had a positive impact on CS teachers. The authors concluded that the short-term PD experience can often provide beginning CS content knowledge and bolster teachers' self-efficacy. However, a long-term effect required teachers to dedicate more time to internalize the modeling software with real-world applications, as well as on-going expert support.

Besides the aforementioned studies in which the authors examined teachers' self-efficacy as an impact of the professional development program, there are a few fairly new studies that made contributions to the variety of CS teachers' self-efficacy research. For example, Zhou et al. [29] developed an instrument to measure secondary school teachers' self-efficacy in teaching computer science. The instrument was also implemented in a nine-week hybrid PD program to validate the instrument. The designed self-efficacy survey aimed to assess teachers' self-efficacy on both content knowledge (e.g., algorithm, computing impact, and programming) and pedagogical content knowledge. The examination on the instrument validity showed positive results. The implementation of the survey in the nine-week PD also showed a significant increase in teachers' self-efficacy in content and pedagogical content knowledge. The study made a contribution to computer science education by providing a validated self-efficacy instrument which can be potentially used to measure CS teachers' self-efficacy in various settings.

Yadav et al. [27] conducted a quantitative study to identify different levels of teachers' self-efficacy profiles. The authors further investigated the confounding factors that potentially contributed to the disparity in teachers' self-efficacy. To identify the profiles, the authors performed cluster analysis on the sum score of the three dimensions of teachers' self-efficacy identified in the Teachers' Sense of Self-efficacy scale (TSES). The analysis identified three clusters: low, moderate, and high. The further analysis on teachers' self-efficacy group against teachers' background showed that no difference in teachers' self-efficacy related to their teaching experience, nor their prior knowledge on computer science or programming. Teachers' academic background regarding their undergraduate education was the only factor reported that impacted teachers' self-efficacy.

The reviewed studies showed that many of the studies have recognized the significance of conducting context-specific studies on computer science teachers' self-efficacy. As Yadav et al. [27] stated, CS teachers' development still needs to be further explored, with self-efficacy remaining a focus since the methods to increase it are highly specific to CS teachers. This encouraged our study to delve deeper into CS teachers' self-efficacy and ways to enhance it through ongoing PD.

2.2 Effective CS Professional Development

Professional development has been used as an effective way to train novice computer science teachers and keep them up to date with the latest developments in the field, as well as strengthen their knowledge and improve teaching practices. Previous studies on computer science teacher professional development have identified some core features of effective PD [13, 16]. These features are believed to have positive impacts on teachers' self-efficacy.

First, Menekse [13] reviewed PD programs from 2004-2014 and concluded five core features for an effective PD program. The five core features were: 1) PD collaboration with teachers and school leadership; 2) providing adequate time for implementation and practice; 3) organizing active learning methods to demonstrate how to implement new teaching practices; 4) supporting teachers building up pedagogical content knowledge; 5) offering follow-up support for teachers and establishment of professional learning communities. These features are believed to be efficient ways to build teachers' CS-specific pedagogical content knowledge, as well as establish the network for CS teachers. In return, teachers' participation in high-quality PD can help enhance their self-efficacy. Reding and Dorn [16] studied a Midwestern PD program and found the best ways PD developed teachers, by analyzing their daily journal records. The PD program provided a wealth of novel resources for these teachers, who came from various backgrounds, as the PD went week by week through different core topics and lesson plans. Teachers explored new resources. When they took them back to the classroom, teachers found students to be noticeably more engaged in the lesson materials. The authors were also able to distill out three aspects that should be front and center when designing a PD program: "Comfort Level", "Practical Application" and "Student Success." In the paper, Reding and Dorn's [16] also reported the definition of three interdependent facets of knowledge that an effective PD program supported, namely explicit knowledge, implicit knowledge, and emancipatory knowledge. Explicit knowledge encompasses the direct content knowledge and traditional process of learning, whereas the implicit knowledge refers to teachers' learned behaviors and personal know-how about which ways are effective. Emancipatory knowledge delves deep into the emotional aspects of learning, in which the authors believe that the emotional components largely impact teachers' beliefs, attitudes, and actions. Therefore, it is also a significant contribution to teacher self- efficacy.

These studies both showed the promise of PD in strengthening CS teachers' self-efficacy and laid out some key concepts a successful PD program could incorporate. Our study sought to go further and deeper to study how our first-year PD program under the RPP framework encompassed some of the reviewed features of effective PD, and explained how the PD had a measurable impact on teacher self-efficacy.

2.3 Research Practice Partnership (RPP) Framework

Although adopting RPP to K-12 computer science education is fairly new, the framework has been used in the US for several decades to address general problems in K-12 education [22]. McGill et al. [12] recently reviewed RPP research in terms of its definition and component, the theoretical framework, the benefits it brought to education in general, as well as the challenges that RPPs are facing. In the report, the authors conceptualized four major partnership models and the major components within them, drawn from the similarity and shared functions among different ways of implementing RPPs. The partnership models include: 1) RPP Research Alliances focused on local problems in a specific region (district, state, etc.); 2) RPP Co-design programs focused on collaboration to design best practices for the classroom, drawing heavily from theory and empirical evidence; 3) Networked Improvement Communities offered a continuously improving iterative model for new methods to address shared challenges; 4) Hybrid RPP framework incorporating two or more of these aforementioned models.

The authors also presented *a Guide Map to Research-Practice Partnership* produced by the Education Develop Center (EDC) and the Research + Practice Collaboratory [12]. The map illustrated the method for establishing and sustaining an RPP program. The method starts by establishing an equitable partnership and agreeing on a shared framework where problems can be mutually identified. It is then branched out to all relevant stakeholders for brainstorming of solutions, and research questions. The RPP sustains itself with "cycles of inquiry" in which findings are studied and communicated, while the group goes back to agree on its next set of problems, continuing for the life of the program. In addition, the authors reiterate that the collaborative steps (e.g. collaboration to identify the problems, collaboration to identify and implement solutions, and collaborative inquiry) are the most critical elements for RPP effectiveness. Collaboration is the core of an RPP, which is valuable for ensuring the most-pressing problems are addressed, which keeps the RPP effective and relevant. Collaboration is also critical for within-district research and inquiry, so that the findings may be shared effectively and used to develop realistic solutions. Identifying and implementing solutions is crucial as well, which requires a strong collaborative infrastructure of meetings, communication, and professional support across the RPP community in order to achieve mutual and effective results within the partnerships.

Based on the RPP framework, we report the results in the following sessions on how our CS RPP PD program built teachers' self-efficacy.

3 The Project Professional Learning

This study is based on the CS Pathways RPP project [14]. The program is a three-year project funded by the National Science Foundation, in which two universities - The University of Massachusetts Lowell and The State University of New York at Albany - partnered with three urban school districts in two neighboring states. The goal of the project is to establish inclusive computer science programs at all the middle schools at the partnership districts. All stakeholders work in collaboration under the RPP, applying the SCRIPT framework [30]. The project implemented a wide range of activities during the first year to create the partnership among project researchers, district leads, and teachers. The project's PD program aims to help the middle school teachers to build their capacity in implementing the project's CSDL curriculum that eventually engages middle school students from these three districts in both digital literacy and computer science as they develop mobile apps for social and community good [14].

In the first year, the CS Pathways PD program was developed under a team of researchers from higher education, school district administrators, and teachers. The RPP team members worked closely to provide a collaborative inquiry experience for teachers who participated in the PD. The first year PD included 52 hours of meetings, combining both in-person and online activities. Since 2019, we have hosted a few face-to-face meetings at each partner school district. Starting from March 2020, the whole project moved to all virtual meetings due to the pandemic. The PD activities included discovering priorities using the SCRIPT Visions Toolkit [31] learning CSDL knowledge, learning experiences in building mobile apps, and conversations about teachers' own learning challenges [14].

4 Methodology

4.1 Data Collection

During the first year of the PD program, the participants consisted of nineteen middle school teachers teaching various disciplines, among whom twelve were teaching technology or computer related courses (e.g., Computer Application and Technology Education); and seven teachers were in other content areas including four math teachers, three science teachers. Eleven of the teachers were female, and the other eight were male.

The teacher data was collected via both the end-of-year survey and semi-structured interviews at the end of the first year PD program with the aim to examine teachers' self-efficacy profile and to gain insightful understandings of their perceptions of self-efficacy. All teachers completed the survey pertaining to their self-efficacy; more than half of the teachers (n = 10) accepted the interview.

The survey was also designed to assess the teacher participants' perceived capabilities by asking "How confident are you with the ability to do…?" There were 23 self-evaluated items spanning CSDL content knowledge and capacity to implement the CSDL curriculum. These items were created to capture three constructs of teacher self-efficacy. Table 1 shows the survey items and the corresponding constructs those items aim to measure. The survey asked the teacher participants to rate their confidence in the ability to perform the tasks on a five-point Likert scale, ranging from "Not at all" (point 1) to "Very" (point 5). Cronbach's alpha was measured to check the validity and reliability of the set of survey items. The internal consistency of the survey items is Cronbach's alpha = 0.93, which indicates that the survey items are closely related as a group of survey questions to evaluate teachers' confidence and self-efficacy.

Subsequently, all teacher participants were invited to a semi-structured interview. The interview was developed to supplement the survey to dive into the teachers' perceptions on their self-efficacy. Interview items were designed to capture teachers' experience and the impact of the our RPP PD program, which reflects their self-efficacy in knowledge growth and confidence to implement the curriculum. Sample questions asked during the interview include "What do you like or dislike about professional learning? What has been challenging or helpful?", "In which your participation in the project has impacted you regarding teaching computer science and digital literacy (CSDL)? e.g., your beliefs, decisions, or plans you made regarding teaching CSDL.", "How has this group prepared you for your teaching course load?". The teachers who participated in the interviews were almost evenly distributed across three districts. Among them, four were non-technology or content area teachers who taught subjects such as science, math and civics; the other six teachers were technology or computer teachers. The interviews were conducted through Zoom with the duration ranging from 30 – 45 minutes. The conversations were transcribed, and the transcriptions were analyzed in NVivo 12.

Table 1: Survey items and corresponding CSDL capacity

Item Index	Survey Items	Self-efficacy Constructs
F1	Set up new software on tablets	Digital literacy knowledge
F2	Ensure the tablets are charged and ready for use by students	
F3	Implements a system of distributing tablets to students for class use	
F4	Implement a system of gathering tablets and returning	
F5	Trouble shoot hardware problems with tablets	
F6	Trouble shoot software problems with tablets	
F7	Use any apps	CSDL knowledge on creating apps (with computer science concepts)
F8	Use an app to help you solve a problem in your community	
F9	Create an app using App Inventor	
F10	Create an app to solve a community problem	
F11	Create an app that is relevant and exciting to students	
F12	Create an app that has an image	
F13	Create an app that has multiple images	
F14	Create an app that has sound	
F15	Create an app that has multiple screens	
F16	Create an app that uses variables and lists	
F17	Teach digital literacy skills as part of a computer science curriculum	Ability to implement the CSDL curriculum
F18	Teach students file naming management that is relevant to apps	
F19	Teach students how to use resize images to use in an app	
F20	Teach students how to edit or select audio files for use in an app	
F21	Manage teams of students working collaboratively to develop apps	
F22	Integrate app development into my existing curriculum	
F23	Create multimedia presentations	

4.2 Data Analysis

In our former study [14], we assessed teachers' confidence in the CSDL content and their ability to implement the project curriculum through the pre-and post- surveys. The results indicated that there was a significant increase in teachers' overall confidence after their first-year participation in the project's PD. The present study aimed to further investigate in detail the attributes of teachers' self-efficacy profiles after their first-year participation in the PD program. Therefore, Principal Component Analysis (PCA) was used to explore the teachers' self-efficacy profile. In this study, PCA was carried out on the survey data to explore the salient features that could logically cluster response factors (e.g., survey items) together and explain the correlations to self-efficacy. In general, this quantitative analysis attempted to explore patterns in the data and estimate the level of structures. The teachers' self-efficacy profiles were interpreted through the feature indices that load onto each principal component. The quantitative data analysis was performed in RStudio. The dataset contains survey responses from all 19 teachers with some missing values where teachers skipped some survey items. To manage missing values in the dataset, we applied the Ipca method, which was studied as the best performed method to impute missing values under the widest range of conditions [17]. For the inclusion of factors to each dimension, we set the cut-off for eigenvalues of $\lambda > +/- .20$. We noticed that the cut-off value is lower than the conservative ones, and this is due to small numbers of factors evolved in this study. The cut-off insured only salient feature indices would be included and interpreted in each dimension.

The next portion of this study sought to understand 1) the teachers' perceptions of how their self-efficacy is influenced by the PD, and 2) whether or not technology and other subject area teachers differ in their self-efficacy. We chose the data-driven inductive approach of thematic analysis to analyze the interview data, which allows the data to determine the emerging themes [8].

This descriptive and exploratory inquiry of interview data involved an iterative and reflective process. The first step concerning the inductive thematic analysis was the initial coding of the interview conversation. The coding strategy "open, axial, and selective" [25] was employed. As illustrated in Figure 1, open coding was the initial level of coding, in which we took the vast interview transcripts and distilled the teachers' responses into discreet, individual feedback about particular constructs of the PD, which teachers reflected either beneficial or challenging to their self-efficacy. Going interview by interview, any applicable content from the answers was assigned its code, with each code corresponding to a tangible theme, such as teacher support, collaboration and community, app creation ability, etc. By doing this, we aimed to capture a rich description of the teachers' perceptions. As the interview analysis progressed, the categories of each code were continuously reviewed to make sure they were distinct and did not overlap, or as needed, separating the codes out into two separate ones when the responses covered separate constructs. Axial coding, as the second level, took place after all the transcripts were reviewed and coded. This step dynamically transformed the data into five broad categories, such as collaboration and community, which all teachers had personal experience with throughout their experience in the PD. The findings will be discussed in detail in the next section. Finally, the selective coding, while sound in the theory presented by [25], was not performed in this study as the five axial groups are better left independent of each other to provide understanding on how each one impacts the teachers' self-efficacy. NVivo 12 was used to support the whole process of coding cycles and the final capture of the construction of meaning.

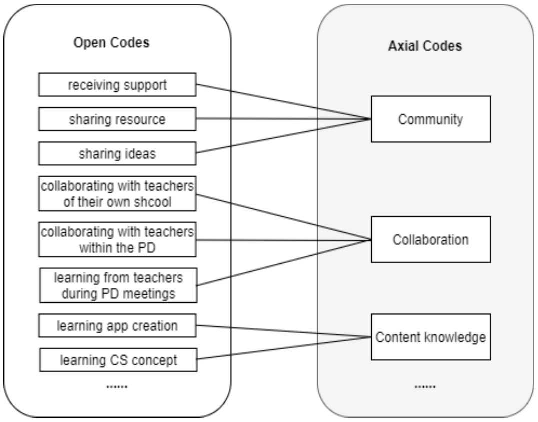

Figure 1: Open and axial coding model

The second step involved dividing the coded responses based on each teachers' backgrounds, specifically whether they were a CS/technology teacher or from another subject area. Afterwards, the interviews were re-coded where the teachers indicated a difference in how the PD impacted their self-efficacy. For example, a CS teacher was quoted that a meeting helped them "teach better" whereas a non-CS teacher instead said it helps them "learn better". This encompassed all five constructs from the axial coding to examine where teachers did in fact perceive their self-efficacy differently.

5 Findings and Discussions

5.1 Teachers' Self-efficacy Profile

The eigenvalues from the PCA analysis for the top ten dimensions are reported in Table 2. As shown in Table 2, the first dimension alone accounts for about 44% of the total variance. The scree plot (shown in Figure 2) was also generated to visualize the variance explained by each dimension. The scree plot (Figure 2) also shows the cut-off point, where most of the variations are explained by the chosen dimensions. Adding more dimensions beyond this cut-off point would not show significantly conclusive results as those dimensions accounted for a smaller and smaller fraction of the overall variance. The clearest cut-off in Figure 2 appears to be in between Dimension 3 and 4 where the variance percent drop from about 13% to only 8%, which means three dimensions should be included to interpret the teachers' self-efficacy pattern. In total, the first three dimensions can account for 76.7% of the total variance.

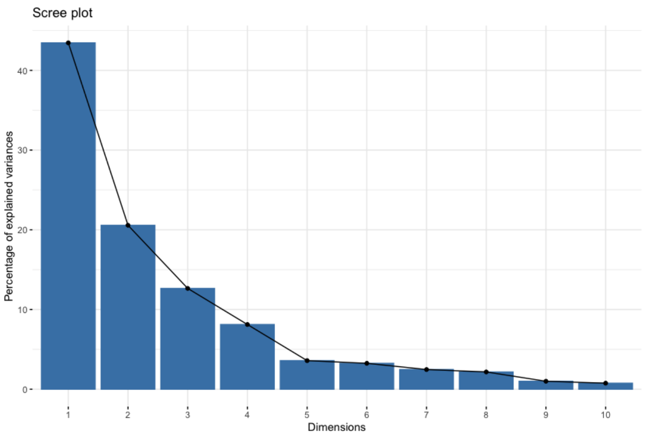

Figure 2: Scree plot of principal component analysis

Table 2: Eigenvalues from the PCA analysis

Dimension No.	Eigenvalue	Variance percent	Cumulative variance
Dim.1	3.16	43.49	43.49
Dim.2	2.17	20.54	64.03
Dim.3	1.7	12.61	76.64
Dim.4	1.38	8.13	84.77
Dim.5	0.91	3.6	88.36
Dim.6	0.87	3.26	91.62
Dim.7	0.76	2.48	94.1
Dim.8	0.71	2.17	96.27
Dim.9	0.48	1.01	97.28
Dim.10	0.42	0.76	98.05

The factor loadings (λ > +/-.20) for attributes in each of the three dimensions are presented in Table 3. And it is the correlations among all factors that consist of the teachers' self-efficacy profile. Eventually, there are three resulting groups of teacher participants showing their self-efficacy profiles. The first dimension captures teachers with strong self-efficacy in their ability of app creation and confidence in teaching CSDL after the PD (Dim.1 = 43.5%); Dimension 2 indicates that teachers who had relatively less self-efficacy on their digital literacy knowledge, but showed more confidence in app creation after participating in our PD program for one year (Dim.2 = 20.6%); Dimension 3 represents teachers who believed themselves having strong digital literacy knowledge but very low capacity in teaching CSDL (Dim.3 = 12.7%). Accordingly, about half of the teacher participants demonstrated high self-efficacy (Dim.1), and the rest of them showed moderate (Dim.2) to low (Dim. 3) self-efficacy. High self-efficacy teachers showed high perceived capability on all the three aspects (DL skills, app creating, and implementing the curriculum), while moderate and low teachers showed their perceived capacity on two or less aspects.

Table 3: Factor loading of attributes in three dimensions

Dimension 1	
Teacher Self-efficacy Feature Indices	Loadings
F1: Set up new software on tablets	-0.24
F7: Use any apps	-0.21
F8: Use an app to help you solve a problem in your community	-0.22
F9: Create an app using App Inventor	-0.26
F10: Create an app to solve a community problem	-0.24
F11: Create an app that is relevant and exciting to students	-0.26
F12: Create an app that has an image	-0.24
F13: Create an app that has multiple images	-0.22
F14: Create an app that has sound	-0. 22
F16: Create an app that uses variables and lists	-0.22
F17: Teach digital literacy skills as part of a computer science curriculum	-0.24
F18: Teach students file naming management that is relevant to apps	-0.25
F20: Teach students how to edit or select audio files for use in an app	-0.22
F22: Integrate app development into my existing curriculum	-0.2
F23: Create multimedia presentations	-0.27
Dimension 2	
Teacher Self-efficacy Features Indices	Loadings
F2: Ensure the tablets are charged and ready for use by students	-0.38
F3: Implements a system of distributing tablets to students for class use	-0.41
F4: Implement a system of gathering tablets and returning	-0.41
F12: Create an app that has an image	0.23
F13: Create an app that has multiple images	0.26
F14: Create an app that has sound	0.26
F15: Create an app that has multiple screens	0.26
F16: Create an app that uses variables and lists	0.23
F21: Manage teams of students working collaboratively to develop apps	-0.27
Dimension 3	
Teacher Self-efficacy Feature Indices	Loadings
F5: Trouble shoot hardware problems with tablets	0.38
F6: Trouble shoot software problems with tablets	0.46
F7: Use any apps	0.33
F8: Use an app to help you solve a problem in your community	0.25
F19: Teach students how to use resize images to use in an app	-0.33
F21: Manage teams of students working collaboratively to develop apps	-0.24

The study also drew conclusions of the teachers' self-efficacy by examining the similarities and differences between the groups. A comparison across three groups highlighted the distinct features of teachers' self-efficacy in each group (high, low and moderate self-efficacy). Teachers with high self-efficacy (Dim.1) showed a strong perceived capacity to create apps and to teach CSDL curriculum, whereas low self-efficacy teachers (Dim.3) showed no such perceived capacity. Comparing the group of teachers with high self-efficacy (Dim.1) and those with moderate self-efficacy (Dim.2), the moderate teachers presented characteristics of high perceived capacity in creating apps, but lacking capacity in teaching the curriculum. A notable distinction of teachers' self-efficacy among three groups is that only teachers with high self-efficacy showed perceived capacity in creating apps relevant and exciting to students (see F10 and F11 in Dim.1). Although moderate teachers perceived an increase in their app creation capability (see F12 to F16 in Dim.2), they did not report the capability in creating apps that were highly relevant to their students. This significant finding was further investigated in the teacher interviews to further understand this phenomenon.

5.2 Impact of the CS Pathways RPP PD on Teachers' Self-efficacy

To develop further understandings of how teachers' PD experience impacted their self-efficacy, this section presents the emerging themes from the thematic analysis of the interview data. Teachers' reports of RPP PD experience were organized into five features of the PD program. Each feature appeared as a significant factor, which teachers perceived as influencing their self-efficacy in both learning and teaching CSDL. The feedback was broken out into positive evidence and opportunities for improvement, both of which provide valuable insights that can inform the design of the PD program.

Collaborative Resource and Infrastructure Building. The majority of the teacher participants appreciated that the RPP PD program introduced the vast existing resources on learning and teaching computer science, such as resources from *Code.org* and *ScratchEd* community. This served as a gateway into the computer science education community. Teachers with strong confidence in their computer science and digital literacy knowledge also found the discussions of computer science education research articles during the PD group meetings solidified and challenged their thinking in terms of teaching computer science concepts and enhancing computational thinking skills for their students. In addition, the project sponsored teachers to attend the Computer Science Teachers Association (CSTA) Annual Conference. Teachers who attended the conference spoke highly of the opportunity for their content knowledge growth and network building.

Besides the aforementioned resources that teachers perceived as beneficial to their self-efficacy development, a number of teachers also suggested that they wanted to see the PD program progress - specifically to accumulate social capital and build infrastructure, such as a repository of curricular resources shared among the PD members. Notably, one teacher (Teacher I) suggested that the PD program could develop summative or formative assessments to evaluate teachers' knowledge growth over the PD.

Content Knowledge. On one hand, some teachers claimed that they learned much more about coding and app creation knowledge, which made them comfortable to introduce computer science concepts and troubleshoot for students when they encountered technical problems. On the other hand, several teachers expressed that while the PD provided much-needed exposure to a wide range of CS topics, they felt it moved too fast for them to fully comprehend everything. Therefore, they hoped the PD program would work on building their basic knowledge on computer science concepts through didactic instruction rather than an inquiry-based approach. As Teacher E stated, "I don't know what I don't know." Teacher I suggested that the PD program could better support their learning through more group activities and assignments with feedback provided afterward.

> Teacher E: "*Even though I just said that I didn't know what I didn't know, I feel like I still learned a lot just from being thrown in and being like 'oh god am I gonna know anything about any of this?' I still got some kind of an introduction*."

> Teacher I: "*I think those short little quick testing to see how we're doing in that kind of thing again within the small group would be really helpful. In addition to more content knowledge, I would absolutely appreciate it.*"

Furthermore, those teachers who were deficient in content knowledge also found themselves intimidated by some technical conversations during group meetings, which indicates that the PD program needs to better engage teachers with low prior CSDL knowledge.

> Teacher G: "*So I did have some software experience. But in terms of coding, in creating apps, I had never done anything like that. So, I was a little bit nervous during the very fast meeting.*"

Pedagogical Content Knowledge. As mentioned in the Resource and Infrastructure section, some teachers appreciated being introduced to pedagogies and best practices from computer science education research. For example, Teacher G said it was fascinating to learn pair-programming as a new teaching strategy, and he/she could not wait to apply it to his/her classroom. Other teachers also found the strategy of bringing industry professionals into their classrooms as a good way to motivate their students. Notably, teachers who shared positive opinions on PD enhancing their pedagogical content knowledge, were those who had strong self-efficacy on their CSDL content knowledge. On the contrary, teachers with lower CSDL knowledge showed less confidence on their pedagogical content knowledge growth. As a consequence, they also showed less confidence in teaching the curriculum. This finding is also aligned with the PCA result that moderate to low self-efficacious teachers perceived themselves having less capacity in teaching the CSDL curriculum. The interview result showed that this phenomenon is due to the group of teachers feeling they were less confident in their CS base knowledge (e.g., debugging).

> Teacher E: "*I think I can guide them through some of it for sure and I'm always willing to try, but I don't want to lead the heavier stuff until I have a better knowledge base, because I want to make sure if they get stuck I can help debug them if they can't figure it out themselves*."

Collaboration and Community. Enhancing collaboration and building a professional learning community is one of the most significant goals of the RPP PD program. All the teachers regardless of their content areas provided fairly positive feedback during the interviews on how collaboration and community helped them build self-efficacy. First, the PD program organized group meetings to promote network building among teachers. Teachers stated that the group meetings prompted ideas and allowed them to expand their teaching ideas and challenge themselves. For example, Teacher I thought it was nice to sit in the PD meetings to listen to other teachers and brainstorm ideas, and then bring the idea back to his/her own school district.

> Teacher I: "*Yeah, I mean I think that I definitely developed a more collaborative relationship with the tech teacher that's in my own building. We met in our building. Definitely afforded me the opportunity to do that. So yeah, that's been great.*"

Second, the PD program made teachers realize the power of collaboration between content area teachers and technology teachers. Specifically, content area teachers were eager to expand the scope of their curriculum, but may lack the full technical know-how. The PD program helped bridge this gap through building the network between the two groups of teachers.

> Teacher F (Science Teacher)*: "So a couple times in class, my colleague was starting to do Scratch with Girls Who Code, and she would come over and talk to me. And I was like well, if you do this, this, and this, and she was like 'I don't know what that means. Can you talk to my students? Yeah, I'll just make sure nobody's punching someone over here.' So, I'll go talk to the kids, and that's fun. I can give my expertise, like okay, these are the two pieces that you're missing. You have 3 of the 4 things that you need, but the one piece here you don't have. Once they have that, then all of the sudden their project is taking off."*

> Teacher G (Technology): "*The knowledge I have in terms of graphing linear functions. You know, like I can handle that piece, and then what kind of app can we build that will graph this linear function for you, for example. And then for me to kind of explain to [Colleague's name removed] what a linear function is, how it works, what an input output value means, and then she/he takes care of the technical piece. I think it would be almost like a nice marriage of the two, you know, the content specific to computer science.*"

Although teachers spoke highly of our RPP PD's effort to enhance the collaboration and community building, they also see other opportunities for the PD program to better build teachers' self-efficacy. For example, several teachers suggested the program to organize small group meetings within the same school district after big group meetings. They believed a smaller group within their own district would break some intimidation caused by peer-pressure. The PD providers also believe this idea would provide an opportunity to sustain and consolidate the PD results to each district.

> Teacher I: "*Well, I definitely feel more comfortable sharing everything with the teachers in our own district. So, I think, from there, once you realize that there's a lot of us feeling the same way. Then I think you feel more comfortable sharing with the larger group..... People in my own district, they know me, they know I am a decent teacher, they know I'm not a fool. When I say to them, I have a hard time with this. They're not going to judge me even though I think starting out that way and then bringing it to the larger group would be helpful.*"

Teacher Identity. The results showed teachers also changed their own sense of identity and perceptions of their roles in implementing the CSDL curriculum under the RPP PD. Teachers recognized their own roles and values in teaching the CSDL curriculum. Most content area teachers saw themselves in computer science education with the role centered around building their students' curiosity and excitement about learning CSDL, while having technology teachers work with students to deal with the more technical parts. In particular, teacher G stated that she wanted to send an encouraging message to his/her students that even as a "non-computer teacher", he/she can give them the skills they need through the way of cooperation with CS/Technology teachers.

> Teacher G: "I will say this, that I feel like What I can bring to the table is very much how we can integrate this into a content area class. I think that sometimes I get caught up in, you know, why isn't this if-then statement working and you know the ins and outs of building an app. And I lose sight on sort of what my role as the content teacher is... I think the more kids see that a quote unquote 'non-computer teacher' can give them the skills they need. It's like, wow, anybody can do this."

Our findings indicate the above five aspects provided by our RPP PD program as the most significant factors impacting teachers' self-efficacy development. There were external factors that emerged from the thematic analysis, which also contributed to, or negatively impacted teachers' self-efficacy. Issues such as the lack of support from local school administrators, Covid-19-related challenges (e.g., remote setting delayed the curriculum implementation), and limited access to resources for students (e.g., Chromebooks and tablets) were unfortunately all too common. These significant restrictions and challenges will require greater attention from school districts in order to resolve than PD alone can provide, but these can be highlighted as long-term improvement opportunities.

6 Conclusion and Implication

The goal of this study was to explore the impact of the CS Pathways RPP PD program on the teachers' self-efficacy development in teaching a middle school CSDL curriculum. This study examined the attributes that describe the teachers' self-efficacy profiles, and the full reach of the RPP PD program to the participating teachers. The overall findings from both quantitative and qualitative analysis are highlighted in this section.

The PCA resulted in three distinctive dimensions that accounted for about 77% of the total variance, with each dimension representing a profile of teachers' self-efficacy. A comparison among these three resulting groups showed that the higher the teacher's self-efficacy, the more likely they were to be dynamic and successful CSDL teachers, engaging students with full confidence; as a consequence, the more competent they are in the CSDL skills and the more confidence they have in teaching CSDL curriculum. Thematic analysis on the interview data yielded results on both how the program RPP model provided teachers with active learning experience that enhanced their self-efficacy and potential opportunities for the PD program to better support teachers. The interview results identified five features of the PD program that helped teachers build their self-efficacy. These five features reflect how the RPP framework results in a higher quality PD program that builds capacity for teachers, which is likely to have a positive and timely impact. In addition, throughout the interviews, teachers unanimously stated that the PD's collaborative environment helped build their self-efficacy. This is by far the main benefit of the PD program under the RPP framework, despite some external headwinds such as resource constraints, and school administrative support, and RPP provides a framework to highlight the need to improve these in the future.

The main contribution of this research is that this study added clarity to the limited body of research around CS teachers' self-efficacy, especially since the study was conducted based on a PD program under an RPP framework, for which the prior study is even sparser. Findings from this study offer insights directly informing the PD program of its potential improvements. The five identified features of the PD program can enlighten future PD design. Currently, the project is also working on developing the project curriculum repository and working with a few teachers to co-design curriculum resources, which reflect the culmination of all the RPP project efforts to date. Conducting research on whether and how the co-design and implementation of the curriculum influence teachers' self-efficacy can be a future direction.

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REFERENCES

[1] A Bandura. 1997. *Self-efficacy: The exercise of control*. Freeman, New York.

[2] A Bandura. 2006. Guide for constructing self-efficacy scales. *Self-Efficacy Beliefs of Adolescents* 5, 1 (2006), 307–337.

[3] M Borowczak and A C Burrows. 2019. Ants Go Marching-Integrating Computer Science into Teacher Professional Development with. *NetLogo. Education Sciences* 9, 1 (2019), 66–66.

[4] Cynthia E Coburn and William R Penuel. 2016. Research-practice partnerships in education: Outcomes, dynamics, and open questions. *Educational researcher* 45, 1 (2016), 48–54.

[5] Cynthia E Coburn, William R Penuel, and Kimberly E Geil. 2013. Practice Partnerships: A Strategy for Leveraging Research for Educational Improvement in School Districts. *William T. Grant Foundation* (2013).

[6] A B Dellinger, J J Bobbett, D F Olivier, and C D Ellett. 2008. Measuring teachers' self-efficacy beliefs: Development and use of the TEBS-Self. *Teaching and Teacher Education* 24, 3 (2008), 751–766.

[7] S Dray and J Josse. 2015. Principal component analysis with missing values: a comparative survey of methods. *Plant Ecology* 216, 5 (2015), 657–667.

[8] J Fereday and E Muir-Cochrane. 2006. Demonstrating rigor using thematic analysis: A hybrid approach of inductive and deductive coding and theme development. *International Journal of Qualitative Methods* 5, 1 (2006), 80–92.

[9] Y Guo, C M Connor, Y Yang, A D Roehrig, and F J Morrison. 2012. The effects of teacher qualification, teacher self-efficacy, and classroom practices on fifth graders' literacy outcomes. *The Elementary School Journal* 113, 1 (2012), 3–24.

[10] Woolfolk Hoy, A Hoy, W K Davis, and H A. 2009. *Teachers' self-efficacy beliefs*.

[11] R M Klassen and M M Chiu. 2011. The occupational commitment and intention to quit of practicing and pre-service teachers: Influence of self-efficacy, job stress, and teaching context. *Contemporary Educational Psychology* 36, 2 (2011), 114–129.

[12] Monica M McGill, Alan Peterfreund, Stacey Sexton, Rebecca Zarch, and Maral Kargarmoakhar. 2021. Exploring research practice partnerships for use in K-12 computer science education. *ACM Inroads* 12, 3 (2021), 24–31.

[13] M Menekse. 2004. Computer science teacher professional development in the United States: A review of studies published between. *Computer Science Education* 25, 4 (2004), 325–350.

[14] L Ni, F Martin, G Bausch, R Benjamin, H Y Hsu, and B Feliciano. 2021. Project, District and Teacher Levels: Insights from Professional Learning in a CS RPP Collaboration. *Proceedings of the 52nd ACM Technical Symposium on Computer Science Education* (2021), 746–752.

[15] R C Pianta, K M La Paro, and B K Hamre. 2008. *Classroom Assessment scoring system: Manual K-3*. Paul H Brookes.

[16] T E Reding and B Dorn. 2017. Understanding the" teacher experience" in primary and secondary CS professional development. *Proceedings of the 2017 ACM Conference on International Computing Education Research* (2017), 155–163.

[17] M R Reyes, M A Brackett, S E Rivers, M White, and P Salovey. 2012. Classroom emotional climate, student engagement, and academic achievement. *Journal of Educational Psychology* 104, 3 (2012), 700–712.

[18] P J Rich, B Jones, O Belikov, E Yoshikawa, and M Perkins. 2017. Computing and engineering in elementary school: The effect of year-long training on elementary teacher self-efficacy and beliefs about teaching computing and engineering. *International Journal of Computer Science Education in Schools* 1, 1 (2017), 1–20.

[19] J A Ross, J B Cousins, and T Gadalla. 1996. Within-teacher predictors of teacher efficacy. *Teaching and Teacher Education* 12, 4 (1996), 385–400.

[20] J B Rotter. 1966. Generalized expectancies for internal versus external control of reinforcement. *Psychological Monographs: General and applied* 80, 1 (1966), 1–28.

[21] E M Skaalvik and S Skaalvik. 2016. Teacher stress and teacher self-efficacy as predictors of engagement, emotional exhaustion, and motivation to leave the teaching profession. *Creative Education* 7, 13 (2016), 1785–1799.

[22] Jessica Thompson, Jennifer Richards, Soo-Yean Shim, Karin Lohwasser, Kerry Soo Von Esch, Christine Chew, Bethany Sjoberg, and Ann Morris. 2019. Launching networked PLCs: Footholds into creating and improving knowledge of ambitious and equitable teaching practices in an RPP. *AERA Open* 5, 3 (2019), 2332858419875718.

[23] E E Thoonen, P J Sleegers, T T Peetsma, and F J Oort. 2011. Can teachers motivate students to learn. *Educational Studies* 37, 3 (2011), 345–360.

[24] M Tschannen-Moran, A W Hoy, and W K Hoy. 1998. Teacher efficacy: Its meaning and measure. *Review of Educational Research* 68, 2 (1998), 202–248.

[25] M Williams and T Moser. 2019. The art of coding and thematic exploration in qualitative research. *International Management Review* 15, 1 (2019), 45–55.

[26] M Wyatt. 2010. An English teacher's developing self-efficacy beliefs in using groupwork. *System* 38, 4 (2010), 603–613.

[27] A Yadav, A Lishinski, and P Sands. 2021. Self-efficacy Profiles for Computer Science Teachers. *Proceedings of the 52nd ACM Technical Symposium on Computer Science Education* (2021), 302–308.

[28] M Zee and H M Koomen. 2016. Teacher self-efficacy and its effects on classroom processes, student academic adjustment, and teacher well-being: A synthesis of 40 years of research. *Review of Educational Research* 86, 4 (2016), 981–1015.

[29] N Zhou, H Nguyen, C Fischer, D Richardson, and M Warschauer. 2020. High School Teachers' Self-efficacy in Teaching Computer Science. *ACM Transactions on Computing Education (TOCE)* 20, 3 (2020), 1–18.

[30] CSforAll. 2021. SCRIPT Program. Retrieved from: https://www.csforall.org/projects_and_programs/script/

[31] CSforAll. 2021. CS Visions Toolkit. Retrieved from: https://www.csforall.org/visions/

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Finding Balance: The Tradeoffs in Ambition and Specificity When Creating an Inclusive Computing Pathway

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ABSTRACT

Over the last three years, we have worked in a research practice partnership (RPP) between a research non-profit and three school districts to establish system-wide K-12 pathways that support equitable participation in computational thinking (CT) that is consistent across classrooms, cumulative from year to year, and competency-based. Reflecting on the work done over the last three years, we have identified tensions related to ambition and specificity within our RPP and the development, implementation, and spread of inclusive computing pathways. Ambitions can waver between grandiose upheaval in curriculum and classes and the identification of CT solely in what is already happening. While it is relatively easy to adopt and spread programs that propose modest change, these programs are not necessarily worth an investment nor do they produce CT skills in alignment with the district's overall vision. Similarly, the specificity in which computational thinking is operationalized can teeter between prescriptive lesson plans and broadly-stated curricular standards. Vague initiatives are difficult to implement, but teachers are also resistant to overly prescriptive programs. In this paper, we explore these tensions balancing ambition and specificity using examples from our partner districts. Drawing on our experiences co-designing the inclusive computing pathways as well as interviews with and open-ended questionnaire responses from our district partners, we discuss implications related to these issues and the ongoing tensions around ambition and specificity that need to be considered and overcome in order to meet the national call to develop more inclusive computing pathways for schools and districts.

CCS CONCEPTS

• Social and professional topics ~ Professional topics ~ Computing education ~ Computational thinking • Social and professional topics ~ Professional topics ~ Computing education ~ K-12 education • Social and professional topics ~ Professional topics ~ Computing education ~ Computing education programs ~ Computer science education

KEYWORDS

Computational thinking, computing pathway, ambition, specificity, computer science education

1 Introduction

Over the last decade, computer science (CS) and computational thinking (CT) education has increased its presence within schools internationally. As both CS and CT have become requirements within school systems globally (e.g., New Zealand [3], England [4], Israel [1], United States [8]), CT has been identified as a means to integrate computing into disciplinary subjects to both provide a greater number of students with computing skills as well as to enhance disciplinary learning [13,14,19,30]. As careers increasingly include elements of computing and motivations for CT integration expand to focus on how students can use computing to express their creativity, advocate for a more just and equitable world, and develop a more innovative society [25,27], CT is becoming increasingly important in education. As such, CT curriculum and initiatives exist that provide learning opportunities for youth both in formal and informal learning environments.

Despite the increasing prevalence of CS and CT opportunities for students, inequities remain around who participates in these opportunities and their experiences. Physical, social, and psychological barriers exclude Black, Indigenous, and Latinx students, students who identify as a women or non-binary, and students with disabilities from computing opportunities [17,18,28]. In our work, we are focused on decreasing these barriers and creating equitable and inclusive computing opportunities for students across the K-12 spectrum. In a research practice partnership (RPP) [7] between three school districts and a research non-profit, we have worked to develop inclusive computing pathways that will provide all students within the school districts, particularly those excluded from computing, with opportunities to learn CT and CS. Looking at the inequities in who participates in elective high school CS offerings, our districts have come to the conclusion that their existing patchwork of opportunities to learn computing is at fault and instead a cumulative, consistent, and competency-based pathway is necessary to provide computing opportunities for students from kindergarten through 12th grade (the span of compulsory education in the United States).

As our RPP concludes its third year of working together, in this paper we look back at the individual processes the districts went through as well as trends across the districts to provide insights for new districts seeking to design, develop, and implement an inclusive computing pathway. Across our three partner districts, researchers and district leaders observed tensions related to how ambitions and specific a pathway needs to be to be successful given unique characteristics of the districts. Given the importance of providing comprehensive and inclusive computing pathways for all students K-12, in this paper we examine the tensions felt by the districts relating to ambition and specificity. We present data from the district leaders regarding how these tensions were felt within their district and strategies they used to overcome the tensions. We aim to answer the research questions:

1. How do school districts experience and alleviate tensions related to the ambitiousness of a novel inclusive computing pathway?
2. How do school districts experience and alleviate tensions related to the specificity of a novel inclusive computing pathway?

This paper contributes to the growing knowledge of how districts can develop an inclusive computing pathway and aims to support researchers and practitioners working in partnership to anticipate, plan for, and overcome the tensions they experience related to ambition and specificity.

In section 2 we review prior literature on CT in K-12 spaces, tensions when scaling educational programs, and measuring scale up. Through this literature, we define specificity and ambition. Next, in section 3, we detail our methods for completing this work including providing descriptions of each of our partner districts. In section 4, we present the findings of our work using illustrative cases from our partner districts to highlight facets of the tensions of specificity and ambition. Finally, in section 5, we discuss these findings and implications for work broadly within CS and CT education and the creation of inclusive computing pathways.

2 Literature Review

This work is grounded in literature regarding the integration of CT within K-12 education and evaluation literature on tensions in scaling educational programs and measuring scale up. In the following section we provide a brief review of these literatures as they relate to the present work and define the concepts of ambition and specificity.

2.1 Integrating Computational Thinking

Adding opportunities for all students to learn computer science to the K-12 curriculum is not easy because requirements already fill the curriculum [12]. Further, many of these requirements have mandated accountability via statewide assessments, and thus it is not an option to reduce the time dedicated to the existing core subjects to make room to add a new core subject. Consequently, computer science is often first added to the curriculum as an elective, summer, or afterschool activity [e.g., 15,29,32]. Unfortunately, confining CS to electives or extracurriculars tends to maintain inequities; this strategy does not broaden participation [8].

As an alternative, researchers have called for *integration* of computational thinking into existing core curriculum [13]. For example, projects have developed materials that integrate computational thinking with coursework in science [30], English [5,20], and more [16]. Through such integration, students are not only exposed to computing, they also learn to use CT skills and practices to enhance their disciplinary learning [13,19,30]. The term “computational thinking” encompasses competencies with topics such as algorithms, data, and simulations, as well as practices like debugging and abstraction. [2,10,31]. Integrating CT into compulsory education has been proposed as a viable strategy to broaden participation in computing, particularly for students who experience marginalization and are disproportionately enrolled in elective coursework [31].

In practice, many school districts provide all three possibilities: elective courses (e.g., AP Computer Science), extracurricular activities (such as robotics clubs), and integration of CT into existing curricular requirements. Through a combination of these three opportunities to learn computing, districts focus on creating a pathway for students to learn CT beginning in early elementary school and continuing through high school [22]. These pathways aim to not only provide computing experiences for all students, but to do so in ways that are purposefully equitable and inclusive and that work to counter the effect of exclusion in computing spaces.

2.2 Tensions in Scaling Educational Programs

The goal of increasing CT integration to reach all students implies scaling up. Scaling up has long been a topic in educational research and evaluation, and much is known about the challenges that arise as educational institutions take programs that were initially developed and tested at small scale and now will be implemented in many more districts, schools, and classrooms [9]. Evaluators have observed that scaling a program involves going from an *intended* curriculum (what the program developers plan and envision) to an *enacted* curriculum (what teachers and students do) [21]. Gaps between an intended and enacted curriculum can arise at scale for many reasons, two of which have been found to be important in program evaluation [23] are applied in the analysis that follows.

Ambition refers to distance between existing classroom practice and what a new curricular program asks teachers and students to do. When the distance is large, fewer teachers and students can easily enact the new program. They may stop using materials or enact them for a short time or in shallow ways. Conversely, when the distance is small (for example, using new worksheets to replace existing worksheets in a math course), a curricular change can be easier to scale with fidelity to intentions. Ambition is a tension in designing and implementing curricular change. Too much ambition will be unrealizable, too little is not worth doing.

Specificity refers to a continuum from highly prescribed teaching and learning activities to merely suggestive teaching and learning activities. When a new curricular program is at least somewhat ambitious, teachers and students will not know what to do. On one extreme, materials may tell them exactly what to do in a step-by-step fashion. On the other extreme, materials may give broad guidance that requires much local elaboration by teachers and students into activities they can do. Highly scripted materials are hard to adapt to local needs and may undermine teacher expertise. Yet if the expectations of what teachers and students can elaborate on their own are too high, they might not be able to figure out what to do or may elaborate in ways that result in enactment that drifts far from intended learning goals. Thus, both ambition and specificity are tensions that must be resolved as local school participants figure out how to go from an intended to an enacted curriculum.

2.3 Measuring Scale Up

The easy definition of scale up as achieving a large number of users for a new curricular program may be easy to measure in terms of exposure and access, but it can also fail to measure what is important in terms of continued engagement and changes in actual practice. Educational researchers today define scale up in terms of depth, spread, shift of ownership, sustainability and evolution [6,11]. *Depth* means that curricular enactment provides opportunities for students to progress to advanced proficiency in the intended curriculum, in contrast to experiencing a watered-down, light coverage only. *Spread* incorporates equity by considering which populations a new curriculum program reaches and for whom it provides intended growth in competencies. *Shift of ownership* considers the extent of the transition from the original provider to local schools, teachers, parents, and students, and to what degree such parties continue a program because they adopt it as their own desired approach rather than based on top-down compliance measures. Though *sustainability* and *evolution* are likewise key elements, this research herein will not use these additional two elements because the timescale is too short for sustainability and evolution of programs to come into play.

3 Methods

We worked in an RPP [7] between an educational research non-profit (Digital Promise) and three school districts (Indian Prairie School District (Illinois), Iowa City Community School District (Iowa), Talladega County Schools (Alabama)) to develop inclusive computing pathways in each of the three districts as part of a three-year project. While the three districts and research team co-designed a general structure for the pathway development process together, each district adapted the structures to fit the unique attributes and specific ambitions of their schools and communities. Each district identified a district lead for the work. In the following section we first introduce each of the school districts. Then, we detail data collection and analysis used within the present work.

3.1 Partnering School Districts

The three partnering school districts were selected to purposefully represent a diversity of contexts. All three districts had some computing offerings within their schools before working in the RPP, but these opportunities often varied by school or grade level and data from the districts demonstrated inequities in offerings and course registration across student demographics. Prior to beginning the work, each district identified an equity goal, typically a population or set of schools within the district who were excluded from or did not offer computing courses, on which they focused throughout the work. Details about each district and their equity goals are provided below.

3.1.1 Indian Prairie School District

Indian Prairie School District (IPSD) is a suburban district located outside of Chicago in Illinois. IPSD has a student enrollment of around 28,000 students across 31 schools (21 elementary, 7 middle, 3 high). Within IPSD, about 12% of students identify as Latinx and 9% of students identify as Black. Seventeen percent of students have been identified by the district as low-income. IPSD set the equity goal of focusing on a cluster of five Title I elementary schools within the district and increasing computing opportunities within these schools. This goal sought to ensure that computing was occurring in all parts of the district rather than only in specific schools. Prior to developing their inclusive computing pathway, IPSD offered robotics K-12 and had specific computing-integrated technology courses for middle school students (grades 6-8) and CS courses offered at the high school level (grades 9-12). Additionally, the elementary school and middle schools had makerspaces, often within their library media centers.

3.1.2 Iowa City Community School District

Iowa City Community School District (ICCSD) is an urban school district located in Iowa City, Iowa. The district serves around 14,500 students across 28 schools (21 elementary, 3 junior high, 4 high school). Across the district, 12% of students identify as Latinx, 19% identify as Black, and 37% have been identified as low income. ICCSD identified the equity goal of focusing on improving access to computing for their Black and Latinx students, including students who have been designated as English language learners. Prior to building their inclusive computing pathway, ICCSD offered robotics clubs at the elementary, middle, and high school levels and CS courses for high school students.

3.1.1 Talladega County Schools

Talladega County Schools (TCS) is a rural school district in Talladega County, Alabama. The district enrolls 7,500 students and has 17 schools (7 elementary, 3 junior high, 7 high school). Two percent of TCS students identify as Latinx, 33% identify as Black, and 71% have been identified as low income. TCS set an equity goal of increasing computing offerings for students from low socio-economic households as well as students who identify as girls. The district is a leader in STEAM (science, technology, engineering, art, and math) education and prior to implementing their inclusive computing pathway, TCS had CS and CT materials available to teachers such as robotics and maker kits and materials for using Scratch and simulations, but these materials were not used consistently.

3.2 Data Collection

Two data sources are reported upon within the present work: (1) an open-ended questionnaire and (2) follow-up interviews with district leaders. We collected these data at the close of the three-year project. While other data were collected during the project (i.e., exit tickets, field notes, focus groups, lesson plans), this paper reports upon the opportunity for district leads to reflect individually and together on the inclusive computing pathway development process and the tensions within ambition and specificity.

First, the three district leads were asked to complete a questionnaire about ambition and specificity within their district pathway and the process they used to develop pathway. The questionnaire included nine questions, four about ambition and five about specificity. The questions were purposefully open-ended and were given in a questionnaire format to provide the district leaders the time to think through their responses rather than answering immediately. Questions included “We are interested in ‘ambitiousness’ of a CT Pathway as a tension. Describe how your district experienced the tension of being ‘too ambitious’ (asking teachers to change too much) and ‘not ambitious enough’ (allowing teachers to avoid change)” and “What characteristics of your district play a role in how specific your CT pathway and the related changes could be?”

After completing the questionnaire, the district leaders participated in interviews with the research team to learn more about their answers and ask follow-up questions. The semi-structured interview protocol was developed based on responses to the initial questionnaire. One or two districts participated in each interview and interviews lasted 30 minutes. The interviews were audio recorded and transcribed.

3.3 Data Analysis

Once all of the districts had completed the questionnaire, one researcher read through all responses and inductively open coded the responses using descriptive coding [24]. These codes were discussed with the entire research team and were used to develop a set of inductive codes (Table 1). Then, two researchers separately coded all questionnaire responses using the codes. Following coding, the two researchers met and discussed any coding discrepancies to reach 100% agreement on the coding.

This coding was used to develop the follow-up and clarifying questions used during the interviews. Following the interview, the interview transcripts were coded using the same inductive codes by the same two researchers. The researchers again met to discuss any differences in their coding and discussed the coding to reach 100% agreement.

Code	Code Definition	Example
Ambition		
Speed	This code describes the speed at which the CT initiative took place. This includes discussion of the initiative moving slowly or quickly, opinions about the speed of the initiative, and the overall timeline for the initiative. This also includes discussion of specific phases of the initiative if it relates to timing.	"Again, this takes time, but allows teachers to onboard when ready and with support at the building level."
Scale	This code describes the overall scale of the initiative including how many teachers or schools are involved. This includes descriptions of how the initiative was rolled out if they relate to the specific teachers or buildings involved, the use of small groups, and the requirements on individual teachers.	"We decided early on to frame our CT Pathways work as a district-wide initiative."
Scope	This code describes the types of changes that were necessary to implement the CT Pathway. This includes discussion on introducing novel elements to the curriculum/school system, discussion of foundations on which the CT initiative is built and ways those foundations have been utilized, and the specific changes made to enact the CT Pathway.	"We've really tackled this by trying to provide the best of both worlds. On one hand, highly-specified curriculum (PLTW), while on the other, an opt-in (so far) model that provides teachers with the skills and resources necessary to incorporate CT into their existing curriculum."
Specificity		
Competencies	This code includes the use of definitions, specific competencies, and describing a shared vision in order to clarify/specify what computational thinking is. This includes description of instructional strategies for integrating competencies and using these competencies within the classroom and in teacher professional development. It also includes creating shared understanding through the use of competencies, visioning, and definitions and discussion of creating, editing, or using the district competency map.	"…spend time in the beginning describing both the "why" of the work and develop a common vocabulary for our work."
Curriculum	This code includes all discussion of curriculum, teaching materials, lessons, and resources. This includes discussion of specific curriculum used, assessments, and reasons for choosing those curricula. This also includes discussion of integration of computational thinking within disciplinary subjects and the level of innovation within these integrations.	"We need to be able to ensure that all students, in all schools, have access to high-quality curriculum that addresses CT competencies and the CSTA standards."
Collaborative Professional Development	This code includes all mentions of professional development, teacher support, and professional learning related to the inclusive computing pathway.	"Our best learning has happened when we provide opportunities for our staff to experience CT in action in relation to their curriculum and instruction."
Choice	This code includes discussion of teachers having autonomy and making decisions related to the enactment of the inclusive computing pathway.	"This ensured that teachers had choices and options to use when planning."

Table 1: Analysis codes, definitions, and examples

4 Findings

We examined the facets of the tensions of ambition and specificity faced by our district partners when developing and implementing inclusive computing pathways. We found that ambition needed balancing in three areas: speed, scale, and scope. Likewise, we found four areas where districts needed to balance specificity: competencies, curriculum, collaborative professional development, and choice. Answering our research questions, we define each of these seven areas and provide an example of how the area manifested in one of our partner districts. The examples describe both how the district experienced the tension and their actions toward alleviating it. In some cases, we compare and contrast district experiences across the designated area; however, in what follows, for the sake of space, these illustrations are usually singular examples and highlight the tension in one particular district, even though similar tensions may have existed in the other two districts as well.

4.1 Ambition: Speed

District leaders discussed needing to find a balance with the speed of their pathway rollout. All three districts began with three- to five-year timelines for the rollout of the new initiative and aligned these timelines to the speed at which past initiatives had been implemented. This included a year for research and development, one or more years for piloting, and a final stage of scaling and growth within the district. Yet, these timelines shifted depending on the needs of the district and external factors. One external factor that greatly affected the speed at which districts could rollout their timelines was the COVID-19 pandemic, which began in the middle of the second year of the project.

In Iowa City, district leaders needed to balance the speed at which teachers who were part of the early initiative and pilot wanted to move with how fast something could be implemented across the district. When the project began, the district expected the project "to be a multi-year project and more than the three years" of the grant. The district planned to spend the first year defining and refining the pathway, the second year testing and piloting the pathway, and the third year scaling up, although not to the full scale of the district. In total, the district leadership planned a five-year timeline where by the end of the fifth year the entire district was using the pathway. According to the district leader, the slower timeline in the first years where only certain schools or teachers were targeted was "obviously non-ideal in terms of meeting the demands of the more ambitious faculty who would like to see us scale this initiative more rapidly, but is a necessary approach at this time." As a medium sized school district (and a large school district for their state), it was important for Iowa City to have a gradual rollout that allowed them to show success as a proof of concept when growing and making larger-scale changes than just implementing in a few schools, as they did in the pilot. The slower speed of their initiative along with the longer five-year timeframe allowed opportunities for early adoption and successes before larger spread.

4.2 Ambition: Scale

The ambitiousness of district scaling varied across our three partner districts. For each, the rate at which they could increase the number of teachers or schools involved in the initiative varied. This rate of scaling was influenced by both the size of the district and existing systems in place to roll out initiatives.

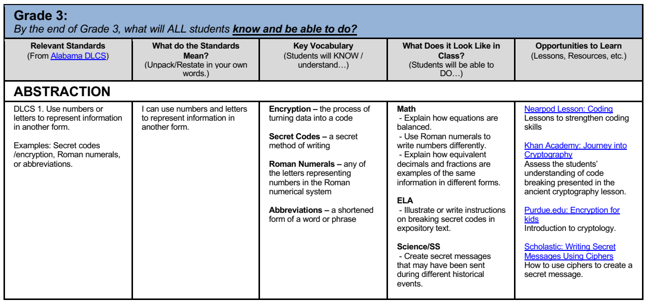
From early in the pathway development process, Talladega decided "to frame our CT Pathways work as a district-wide initiative." After three years, all 17 schools in Talladega are involved in the pathway work, reaching over 7,000 students. Teachers "are able to collaborate with teachers from other schools" and the project has been successful because of "teacher leaders because they do have to have the buy in and when they are excited about something it kind of spreads in their building." According to the district leads, the inclusive computing pathways initiative was successful because "all 17 schools had been involved in PBL [project-based learning] and STEAM, we just keep them all involved in the computational thinking as well." One reason this large-scale effort was important to the district was ensuring equity for all students. They wanted "to make sure that, that no matter where they [students] go to school or what grade band they were going to get exposed to this [CT]." Leveraging their small size and these existing structures, Talladega was able to reach a large scale in a short period of time—within eight months.

For Indian Prairie, reaching the full size of the district means expanding to 31 schools and 28,000 students. According to the district leader, "to get every, every building and every grade level moving in the same direction is sometimes difficult because we have a lot of initiatives." Due to their size, the "district has a long-standing practice of allowing many instructional shifts to happen organically. The early adopters engage in professional learning and introduce the concepts to students. Through the evolution of the change additional teachers join in the work." By getting a few teachers who "have a natural connection to it, have shown an ambition toward this, who are ready to go and adapt" and then using their success to get a classroom neighbor or grade level colleague involved, Indian Prairie is able to have initiatives "trickle" into buildings and develop a stronghold in the district. Within Indian Prairie, the most effective professional development has been small scale, having teachers participate in several meetings over a period of time. But, this does not allow the district to reach all teachers or buildings quickly. Using professional development, all school buildings within Indian Prairie have been exposed to computational thinking, but not all teachers in those buildings have received the professional development and using the pathway.

4.3 Ambition: Scope

The third area in which districts needed to balance ambition was the scope of the changes they sought to make. The exact scope of the inclusive computing pathway was different for each district, but all three districts worked to build their CT initiative on existing district programs and curricula through strategic alignments. Within the scope of changes, districts considered the degree to which they integrated computational thinking into courses verses the development of new CS or CT specific courses, using a prescribed or flexible curriculum and who developed that curriculum, and how CT was aligned with and expanded existing programs.

Talladega has been able to take on a more ambitious scope because they had an “established framework of teacher leaders who would advocate for positive, innovative change” and they followed a process that had been successful in other initiatives. The teacher leaders included “experts down the hall”, school-level technology coaches, and the math and science leadership teams who participated both in the development of the pathway as well as supporting their fellow teachers as the pathway was implemented. According to district leaders, “the key was to connect computational thinking to previous learning.” In order to do this, the district focused on first “describing both the ‘why’ of the wok and develop[ing] a common vocabulary for [the] work” before turning to the competencies and, finally, to integrated CT within the curriculum. This allowed for a strong foundation on which to build out a larger program.



Grade 3:
By the end of Grade 3, what will ALL students ***know and be able to do?***

Relevant Standards (From Alabama DLCS)	**What do the Standards Mean?** (Unpack/Restate in your own words.)	**Key Vocabulary** (Students will KNOW / understand…)	**What Does it Look Like in Class?** (Students will be able to DO…)	**Opportunities to Learn** (Lessons, Resources, etc.)
ABSTRACTION				
DLCS 1. Use numbers or letters to represent information in another form. Examples: Secret codes /encryption, Roman numerals, or abbreviations.	I can use numbers and letters to represent information in another form.	**Encryption –** the process of turning data into a code **Secret Codes –** a secret method of writing **Roman Numerals –** any of the letters representing numbers in the Roman numerical system **Abbreviations –** a shortened form of a word or phrase	**Math** - Explain how equations are balanced. - Use Roman numerals to write numbers differently. - Explain how equivalent decimals and fractions are examples of the same information in different forms. **ELA** - Illustrate or write instructions on breaking secret codes in expository text. **Science/SS** - Create secret messages that may have been sent during different historical events.	Nearpod Lesson: Coding Lessons to strengthen coding skills Khan Academy: Journey into Cryptography Assess the students’ understanding of code breaking presented in the ancient cryptography lesson. Purdue.edu: Encryption for kids Introduction to cryptology. Scholastic: Writing Secret Messages Using Ciphers How to use ciphers to create a secret message.

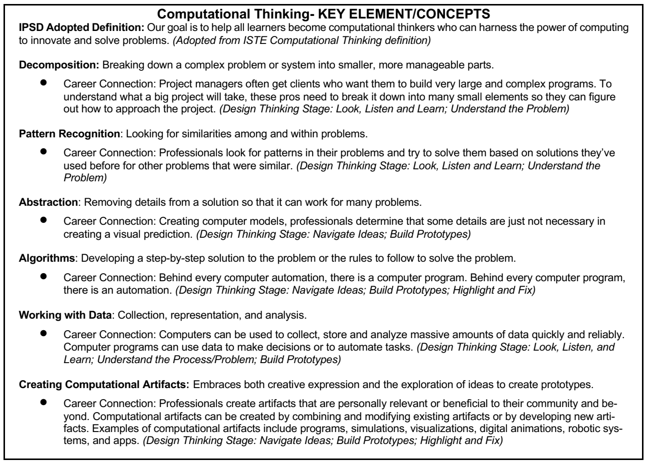
Table 2: Talladega County School District Competency Map for Grade 3, Abstraction

Talladega elected to focus the scope of their inclusive computing pathway on integration within existing curricula across disciplines. Discussing this integration, the district leaders noted, “it was important for us to make sure teachers could see the connection with what they were already doing in their classrooms.” Talladega focused on having a group of teachers develop their competency map with connections to standards, objectives, vocabulary, disciplinary subjects, and example lessons and resources for each grade level (Table 2). Having a homegrown program developed by Talladega teachers was, according to district leaders, “the reason our initiative was successful…teachers actually did the work of learning and creating.” While Talladega’s competency map and inclusive computing pathway is very ambitious, this ambition was made possible by their combination of building on past successes, programs with support in schools, and building the new initiative within the district.

4.4 Specificity: Competencies

In order to guide the new CT initiatives, each school developed a competency map. Similar to that of Talladega described above, each competency map identified four to six computational thinking competencies that cumulatively build across grades or grade-bands. Given the varied definitions of computational thinking [26], the identification of competencies was important for each district to develop their own definition that aligns to state or national standards. This gives each district a shared vocabulary and pacing that is specific to their district and needs.

Indian Prairie identified six competencies: decomposition, pattern recognition, abstraction, algorithms, working with data, and creating computational artifacts. Since the state of Illinois did not have computer science standards when they created their map, Indian Prairie developed these competencies based on definitions of computational thinking by leading computer science education organizations (e.g., International Society for Technology in Education, Computer Science Teachers Association). In order to ensure that all teachers within their district defined their competencies similarly, IPSD created a definition page at the beginning of their competency map (Table 3). This page not only defines each competency, but also makes connections to other initiatives within the district: World of Work (career connections) and design thinking. The combination of the shared definitions as well as the competency map as a whole “provided defined learning outcomes for all grade levels and subjects that are developed in collaboration with teachers and [the] district curriculum and instruction team.” Over the last three years, Indian Prairie has worked to help teacher see how their instructional approaches already had and could be enhanced by CT. According to district leadership, “they [teachers] just needed to highlight when it was happening and the vocabulary.” After a few years of learning about and using CT, a visitor to an IPSD classroom would see teachers “highlighting and leveraging these competencies in their classroom.” While IPSD has focused on providing examples and strategies for integration for their teachers, competencies have been at the core of their efforts and they have used these competencies to provide specificity for their initiative without removing teacher autonomy.



Computational Thinking- KEY ELEMENT/CONCEPTS

IPSD Adopted Definition: Our goal is to help all learners become computational thinkers who can harness the power of computing to innovate and solve problems. *(Adopted from ISTE Computational Thinking definition)*

Decomposition: Breaking down a complex problem or system into smaller, more manageable parts.

- Career Connection: Project managers often get clients who want them to build very large and complex programs. To understand what a big project will take, these pros need to break it down into many small elements so they can figure out how to approach the project. *(Design Thinking Stage: Look, Listen and Learn; Understand the Problem)*

Pattern Recognition: Looking for similarities among and within problems.

- Career Connection: Professionals look for patterns in their problems and try to solve them based on solutions they’ve used before for other problems that were similar. *(Design Thinking Stage: Look, Listen and Learn; Understand the Problem)*

Abstraction: Removing details from a solution so that it can work for many problems.

- Career Connection: Creating computer models, professionals determine that some details are just not necessary in creating a visual prediction. *(Design Thinking Stage: Navigate Ideas; Build Prototypes)*

Algorithms: Developing a step-by-step solution to the problem or the rules to follow to solve the problem.

- Career Connection: Behind every computer automation, there is a computer program. Behind every computer program, there is an automation. *(Design Thinking Stage: Navigate Ideas; Build Prototypes; Highlight and Fix)*

Working with Data: Collection, representation, and analysis.

- Career Connection: Computers can be used to collect, store and analyze massive amounts of data quickly and reliably. Computer programs can use data to make decisions or to automate tasks. *(Design Thinking Stage: Look, Listen, and Learn; Understand the Process/Problem; Build Prototypes)*

Creating Computational Artifacts: Embraces both creative expression and the exploration of ideas to create prototypes.

- Career Connection: Professionals create artifacts that are personally relevant or beneficial to their community and beyond. Computational artifacts can be created by combining and modifying existing artifacts or by developing new artifacts. Examples of computational artifacts include programs, simulations, visualizations, digital animations, robotic systems, and apps. *(Design Thinking Stage: Navigate Ideas; Build Prototypes; Highlight and Fix)*

Table 3: Indian Prairie School Competency Map front page

4.5 Specificity: Curriculum

All three partner districts provided curricular supports to their teachers, particularly to teachers who were new to incorporating CT in their classrooms. Yet, this looked very different in each district based on the needs, norms, and affordances of the districts. Below we present the curriculum solution of each district partner to demonstrate the variety of curriculum specificity provided within their CT initiatives. For all three districts, embedding within existing curriculum features was important for specificity and districts had to help teachers balance between simply identifying that CT exists in lessons they already do and enhancing disciplinary learning by adding and highlighting computational thinking.

In Indian Prairie, the district has focused significantly on the competencies, as described above, particularly in the lower grades where the district does not have designated technology or computer science courses. As such, they have developed examples and strategies for integration to provide to teachers rather than a set curriculum they need to follow. According to district leaders, "it is difficult to provide a prescribed scope and sequence for computational thinking because we wanted to embed the competencies into all instructional areas." Yet, the district leaders have noted that examples only go so far. Although they "developed example lesson plans for teachers at the K-5 grade level…the difficult part with this approach is that unless you are teaching the specific grade level and subject you cannot utilize the lesson with students." While the teachers asked for these examples, "they were not used as much as we [district leaders] hoped." Instead, the district is shifting to highlighting integration strategies (e.g., creating a story timeline, data-driven science experiments, creating infographics) that can be used within any context and they continue to balance curricular specificity.

In Iowa City, the district elected to use a pre-packaged curriculum as a feature supporting teachers and creating clear expectations. The district has adopted Project Lead the Way (PLTW) classes both for technology and science courses. The courses integrate CT and provide teachers with a prescribed curriculum and professional development. This approach has not been without pushback. According to district leadership, "we've had some pushback from our science program coordinator about a perception that our approach of tying CT instruction into science curriculum is limiting science curriculum." Despite this pushback, overall, the district leader feels that the "PLTW programming has been well-received" and while, PLTW "offers a great deal more specificity than most curriculum in the district," this specificity has led to success because it can be implemented with fidelity and provides support for teachers who are not familiar with CT. Although the prescribed curriculum has been successful to date, the district continues to "engage in active evaluation of whether PLTW continues to be our best option going forward." The specificity of the curriculum, particularly with such a defined curricular solution, is an ongoing tension that was not, and cannot be expected to be, balanced within the three initial years of the project. It will continue to be an ongoing balance.

Talladega created their own specified curriculum because they felt that using a pre-packaged solution would cause more specificity tension due to the norms and needs of the district. According to the district leader, the "goal with our CT Pathways was to embed those opportunities in every class, no matter the content area." Creating their own curriculum not only allowed Talladega to meet their goal, but specificity "wasn't an issue for [them] since [they] didn't buy a prepackaged solution." Beginning with their middle school science teachers, Talladega brought together their teachers "to work together to plan lessons, teach lessons, [and] reflect on them together." It was "so successful that we see the value in doing that with other groups as well." Their final curriculum map (Table 2) uses detailed lessons and resources along with a grade-by-grade map to provide teachers with structure and support regarding what they need to do to integrate CT within their classroom.

4.4 Specificity: Collaborative Professional Development

Professional learning opportunities played an important role in balancing ambition and specificity and the successful spread of the district CT initiatives. All three districts began with small, collaborative groups who helped to build the competency maps, examples, and other resources to support the CT initiative. Often, these groups were also pilot teachers. In this way, the inclusive computing pathway planning time was also collaborative professional development that allowed teachers to discuss and learn from one another. According to the district leader of Indian Prairie, these small, collaborative groups were the most effective professional learning opportunities for teachers. How these small, collaborative groups grew into larger district professional development initiatives differed depending on the district, and in some cases is still something that is being balanced, particularly due to the disruption in implementation caused by the COVID-19 pandemic. This growth included utilizing building teacher leaders to educate each other, on-demand professional development as requested by building administrators, teachers attending curriculum professional learning sessions, and a combination of these (and other) options.

In Iowa City, where expansion of the inclusive computing pathway has been slower, the district has "had to mete out training opportunities, and target specific groups for training and program expansion." They have done this through the use of PLTW and having teachers attend the PLTW trainings each summer as well as developing their own district "professional learning-focused approach to integrate computational thinking into [their] existing curriculum." This is viewed as a complementary approach. According to the district leader, by utilizing the established and highly specified PLTW training, the district can "be pretty confident, because we are providing them [teachers] with all the specific materials, that what they teach will be exactly what they're supposed to teach." This is especially supportive for teachers who might not have a strong background or inclination toward science, the main subject in which the district is integrating CT, or CT itself. Yet, the district leaders do not want to limit teachers. As such, they are providing district professional development over the summer and the district is working to launch a micro-credential program using the credentials available through Digital Promise. The district will "incentivize teachers to earn, in this case CT focused micro-credentials, which are geared largely towards adapting their existing curriculum." In this way, teachers will be able to integrate not only in science using the PLTW content, but also in other subjects using lessons they develop on their own.

4.4 Specificity: Choice

The level of choice teachers had about how they taught CT and what lessons they used varied by district and even within districts. Districts needed to balance the amount of choice provided to teachers with the complexity and novelty of CT concepts. This balance meant providing teachers materials that were specific enough that they could accurately and confidently write and implement lessons focused on CT, but not so specific that teachers lost their autonomy and felt their expertise was in jeopardy.

The tension of specificity with regards to teacher choice was especially salient in Indian Prairie where there is "a long-standing practice of allowing many instructional shifts to happen organically" and "teachers have the autonomy to adjust as needed to meet the needs of students in their classrooms." Because of this, Indian Prairie has adopted a less specific inclusive computing pathway than the other districts and is relying on examples and suggested implementation strategies rather than a scripted or district-wide curriculum. In this way, they "trust the professional in the room to provide student learning experiences that will benefit the students in front of them." While this is not without its own challenges related to other areas of the tension of specificity, this teacher choice centered approach fits with both the norms and needs of Indian Prairie and is aimed at promoting teacher buy-in, rather than leading to push-back against new ways of doing things along with the new content.

5 Discussion

The tensions of ambition and specificity will come up in the development of any new innovation, including the development of an inclusive computing pathway. Being intentional about choices as they relate to ambition and specificity can help districts make computing initiatives more relevant to their schools and communities and, ultimately, more successful. In this paper, we aimed to examine how our partner school districts experience and alleviate tensions related to ambitiousness and specificity when implementing a novel inclusive computing pathway. We found that districts needed to balance the tensions of ambition with regards to speed, scale, and scope and the tensions of specificity with regards to competencies, curriculum, collaborative professional development, and choice. Districts learned that in order to balance these tensions, they needed to make trade-offs. For example, specificity in curriculum supports can provide greater speed in terms of more immediate classroom implementation, but can hinder having an ambitious scope across disciplines and these supports can take a narrower view of the competencies. Each of the districts balanced ambition and specificity in unique ways, demonstrating that there is no one way to successfully scale an initiative and the importance of customizing scaling to the needs and norms of a district. Yet, certain strategies were especially successful across the districts despite their differences in size and location. For example, grounding the inclusive computing pathways in existing initiatives to strategically align to what was happening not only created opportunities for scaling and a clearer scope of where to implement CT, but also provided springboards on which teachers and district personnel could build successfully. Additionally, the use of teacher leaders as experts within and across schools provided opportunities for collaboration that led to not only professional learning for the collaborating teachers, but also to successful identification of competencies and development of curricula that allowed the districts to implement their inclusive computing pathways.

The three areas of ambition which require consideration (speed, scale, and scope) aligned with previously identified dimensions of scaling [6,11], particularly those visible and present within the shorter timeframe in which this work has been executed. Coburn [6] identified the dimensions of *depth*, *spread*, and *shift in reform ownership*. Within the present work and the defined areas of ambition, depth relates to the scope of the work. Work that has a narrow scope and does not ambitiously make change likely also has a shallow depth, leading to change in only "surface structures or procedures" rather than "alter[ing] teachers' beliefs, norms of social interaction, and pedagogical principles" (p. 4) as is the goal according to Coburn [6]. Additionally, spread relates to the scale and speed at which an initiative is implemented. The present work highlights Coburn's definition of spread focused on not only having a greater number of schools or classroom involved, but also spreading norms and pedagogical principles. Using the careful tactics of scale and speed employed by each of our partner districts, spread includes not only having more students gain exposure to CT, but also ensuring that they receive equitable and rich learning experiences. While not described in this paper, we have also explored the shift of reform ownership within the districts. As initiatives spread, sharing leadership has emerged as a key aspect of this shift (see [22] for further details).

Despite the identification of inductive categories and distinct trends when balancing specificity and ambition, we identified significant overlap between these two tensions. While balancing ambition requires attention to speed, scale, and scope, a major part of scope is thinking about elements of specificity. In order to decide on the scope of changes to be made and how ambitious those changes can be, district leaders need to consider the curriculum, professional learning, and understandings that teachers currently have and will need. The tensions related to specificity are actually embedded within the tension of ambition and are, at least in part, the building blocks of scope. That is, the specificity of an initiative is tied to the level of ambitiousness and part of negotiating the level of ambition within an initiative is defining the specificity within it. This is not to say that specificity cannot be considered on its own or that elements of specificity and finding balance within specificity does not also require taking into consideration the ambitiousness of the initiative. When balancing competencies, curriculum, collaborative professional development, and choice as part of the specificity of the initiative, the scale and speed of the rollout must also be considered. Different levels of specificity can be reached at different speeds and scales. As such, districts must consider not only how ambitious their inclusive computing pathway or other initiative is, but also how specific it will be and the balance not only within ambition and within specificity, but between the two concepts as well. Although a challenge that arises could pertain only to ambition or specificity, it is likely that challenge will interplay with both tensions and a balance will be required across the two concepts.

When implementing a new district initiative, these data suggest a small beginning that builds upon current district initiatives and work will help to balance ambition and specificity from the start. Yet, it is important to keep these facets of scaling under consideration from the beginning of the development process. A limitation of this work is the current three-year timeline does not allow for the elements of sustainability and evolution to be thoroughly examined. Going forward, there is a need to examine how ownership connects to sustainability and have our district leads make predictions about what they see as the potential evolution of their current inclusive computing pathways. Additionally, future work should continue to follow scaling within these districts to examine the sustainability and evolution of their inclusive computing pathways and how the tensions of ambition and sustainability continue to play a role in the pathway development.

As demonstrated by the district cases on curriculum, ambition and specificity will require continuous balancing as both the initiative progresses and new considerations arise. While there is no “sweet spot” that is perfect for every district, each district can find their spot through consideration of the factors that will influence each tension and ways to alleviate them. While this work centers around the development of inclusive computing pathways within an RPP that includes three districts, these tensions are likely to exist no matter the subject of the initiative that is being developed, implemented and scaled. This is supported by the alignment between our findings and past work on scaling. Ambition and specificity will be ever-present tensions within any implementation, consideration of the areas that require balancing and planning as well as purposeful examination of the district will support successful scaling of new initiatives within districts and beyond.

6 Conclusion

When working in an RPP to improve CS in K-12, there are many things on which to focus. Here we have found it useful to examine higher level tensions that permeate all the work. While making choices about curriculum and professional learning, district leaders and researchers are not only making those choices, but also asking, “how specific should we be?” and “how ambitious can we be?” By paying attention to, and being intentional about these two essential dimensions, RPPs can make their work more coherent and promote greater success from the beginning of their work. The tensions of ambition and specificity will continue to exist, considering the speed, scale, and scope will help to balance ambition. Further considering the competencies, curriculum, cooperative professional development, and choice will help in this balancing and provide the correct level of specificity for a district.

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REFERENCES

[1] Iris Zur Bargury, Orna Muller, Bruria Haberman, Doron Zohar, Avi Cohen, Dalit Levy, and Reuven Hotoveli. 2012. Implementing a new Computer Science Curriculum for middle school in Israel. In *Frontiers in Education Conference (FIE)*, IEEE. DOI:https://doi.org/10.1109/FIE.2012.6462365

[2] Valerie Barr and Chris Stephenson. 2011. Bringing computational thinking to K-12: What is involved and what is the role of the computer science education community? *ACM Inroads* 2, 1 (2011), 48–54.

[3] Tim Bell. 2014. Establishing a nationwide CS curriculum in New Zealand high schools. *Commun. ACM* 57, 2 (2014), 28–30. DOI:https://doi.org/10.1145/2556937

[4] Neil C. C. Brown, Sue Sentance, Tom Crick, and Simon Humphreys. 2014. Restart: The resurgence of computer science in UK schools. *ACM Trans. Comput. Educ.* 14, 2 (2014), 9: 1-22. DOI:https://doi.org/10.1145/2602484

[5] Quinn Burke. 2012. The markings of a new pencil: Introducing programming-as-writing in the middle school classroom. *J. Media Lit. Educ.* 4, 2 (2012), 121–135. Retrieved from http://altechconsultants.netfirms.com/jmle1/index.php/JMLE/article/view/189

[6] Cynthia E Coburn. 2003. Rethinking scale: Moving beyond numbers to deep and lasting change. *Educ. Res.* 32, 6 (2003), 3–12. Retrieved from http://journals.sagepub.com/doi/10.3102/0013189X032006003

[7] Cynthia Coburn, William R. Penuel, and Kimberly Geil. 2013. *Research-practice partnerships: A strategy for leveraging research for educational improvement in school districts*.

[8] Code.org, CSTA, and ECEP Alliance. 2020. *2020 State of computer science education: Illuminating disparities*. Retrieved from https://advocacy.code.org/stateofcs

[9] David K. Cohen, Stephen W. Raudenbush, and Deborah Loewenberg Ball. 2003. Resources, instruction, and research. *Educ. Eval. Policy Anal.* 25, 2 (2003), 119–142. DOI:https://doi.org/https://doi.org/10.3102/01623737025002119

[10] Computer Science Teachers Association (CSTA) and International Society for Technology Education (ISTE). 2011. *Operational definition of computational thinking for K-12 education*.

[11] Chris Dede. 2005. Scaling up: Evolving innovations beyond ideal settings to challenging contexts of practice. In *Cambridge handbook of the learning sciences*, R. Keith Sawyer (ed.). Cambridge University Press, Cambridge. DOI:https://doi.org/10.1017/CBO9780511816833.034

[12] Maya Israel, Jamie N. Pearson, Tanya Tapia, Quentin M. Wherfel, and George Reese. 2015. Supporting all learners in school-wide computational thinking: A cross-case qualitative analysis. *Comput. Educ.* 82, (2015), 263–279. DOI:https://doi.org/10.1016/j.compedu.2014.11.022

[13] Irene Lee, Shuchi Grover, Fred Martin, Sarita Pillai, and Joyce Malyn-Smith. 2020. Computational thinking from a disciplinary perspective: Integrating computational thinking in K-12 science, technology, engineering, and mathematics education. *J. Sci. Educ. Technol.* 29, 1 (2020), 1–8. DOI:https://doi.org/10.1007/s10956-019-09803-w

[14] Irene Lee, Fred Martin, and Katie Apone. 2014. Integrating computational thinking across the K – 8 curriculum. *ACM Inroads* 5, 4 (2014), 64–71.

[15] Jacqueline Leonard, Adrienne Unertl, Alan Buss, and Monica Mitchell. 2016. Using robotics and game design to promote pathways to STEM. In *Proceedings of the 38th annual meeting of the North American Chapter of the International Group for the Psychology of Mathematics Education.*, Tuscon, AZ, 1487–1495.

[16] James Lockwood and Aidan Mooney. 2017. Computational thinking in education: Where does it fit? A systematic literary review. (2017), 1–58. Retrieved from http://arxiv.org/abs/1703.07659

[17] Jane Margolis, Rachel Estrella, Joanna Goode, Jennifer Jellison Holme, and Kimberly Nao. 2008. *Stuck in the shallow end: Education, race, and computing*. MIT Press, Cambridge, MA.

[18] Jane Margolis and Allan Fisher. 2002. *Unlocking the clubhouse: Women in computing*. MIT Press, United States of America.

[19] Fred Martin. 2018. Rethinking computational thinking. *The CSTA Advocate Blog*. Retrieved from http://advocate.csteachers.org/2018/02/17/rethinking-computational-thinking/

[20] Natasha Nesiba, Enrico Pontelli, and Timothy Staley. 2015. DISSECT: Exploring the relationship between computational thinking and English literature in K-12 curricula. In *2015 IEEE Frontiers in Education Conference (FIE)*, El Paso, Texas, 1–8.

[21] Andrew C Porter and John L Smithson. 2001. *Defining, developing, and using curriculum indicators*. Retrieved from http://repository.upenn.edu/cpre_researchreportshttp://repository.upenn.edu/cpre_researchreports/69

[22] Jeremy Roschelle, Quinn Burke, Rafi Santo, and Pati Ruiz. 2021. Towards CS/CT pathways: Creating guidance documents as district leadership development. Manuscript submitted for publication. (2021).

[23] Jeremy Roschelle, C. Mazziotti, and Barbara M. Means. 2021. Scaling up design of inquiry environments. In *International Handbook on Learning and Inquiry*, C. Chinn and R.G. Duncan (eds.). Routledge.

[24] Johnny Saldaña. 2015. *The coding manual for qualitative researchers* (3rd Editio ed.). Sage, Thousand Oaks, CA.

[25] Rafi Santo, Sara Vogel, and Dixie Ching. 2019. *CS for what?: Diverse visions of computer science education in practice*. New York, NY. Retrieved from https://www.csforall.org/visions/

[26] Matti Tedre and Peter Denning. 2016. The long quest for computational thinking. In *Proceedings of the 16th Koli Calling Conference on Computing Education Research*, Koli, Finland, 120–129.

[27] Mike Tissenbaum, David Weintrop, Nathan Holbert, and Tamara Clegg. 2021. The case for alternative endpoints in computing education. *Br. J. Educ. Technol.* 52, 3 (2021), 1164–1177. DOI:https://doi.org/10.1111/bjet.13072

[28] Jennifer Wang and Sepehr Hejazi Moghadam. 2017. Diversity Barriers in K–12 Computer Science Education: Structural and Social. In *Proceedings of the 2017 ACM SIGCSE Technical Symposium on Computer Science Education*, 615–620. DOI:https://doi.org/10.1145/3017680.3017734

[29] Gloria Washington, Marlon Mejias, and Legand Burge. 2020. Understanding how to engage Black HS boys in computer science through tech innovation and entrepreneurship. *Comput. Sci. Eng.* 22, 5 (2020), 20–28. DOI:https://doi.org/10.1109/MCSE.2019.2950408

[30] Kevin P. Waterman, Lynn Goldsmith, and Marian Pasquale. 2020. Integrating computational thinking into elementary science curriculum: An examination of activities that support students' computational thinking in the service of disciplinary learning. *J. Sci. Educ. Technol.* 29, 1 (2020), 53–64. DOI:https://doi.org/10.1007/s10956-019-09801-y

[31] David Weintrop, Elham Beheshti, Michael Horn, Kai Orton, Kemi Jona, Laura Trouille, and Uri Wilensky. 2016. Defining computational thinking for mathematics and science classrooms. *J. Sci. Educ. Technol.* 25, 1 (2016), 127–147.

[32] Marla Weston and Dianne Biin. 2013. The ancestor project: Aboriginal computer education through storytelling. *IADIS Int. Conf. Cogn. Explor. Learn. Digit. Age, CELDA 2013* Celda (2013), 85–92. DOI:https://doi.org/10.1007/978-3-319-05825-2_20

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One-on-one meetings as Boundary Practices: Managing RPP Computer Science Curriculum Co-design

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ABSTRACT

Research-practitioner partnership (RPP) projects using approaches such as design-based implementation research (DBIR), seek to build organizational infrastructure to develop, implement, and sustain educational innovation [19]. Infrastructure consists of the practices and objects that support educational practice. Infrastructure constitutes human and material resources and structures that support joint work [18,29]. Although RPP literature has identified co-design as an infrastructure-building approach, to the best of our knowledge, specific techniques for managing co-design and other infrastructure building practices are still lacking [9,18,23]. Without such tools, RPP partners' varied backgrounds, workplace norms, and priorities can produce behaviors that may be normal in the context of a single organization but can impede communication, resource access, and innovation implementation in a collaborative context. The NSF-funded Computer Science Pathways RPP (CS Pathways) project's DBIR approach uses co-design of a culturally responsive middle school CS curriculum to develop infrastructure for providing high-quality CS education across three urban school districts. The curriculum focuses on developing mobile apps for social good and will be taught by teachers with varied CS experience in varied classroom contexts (e.g., civics, science). The purpose of this workshop paper is to demonstrate a technique, namely Manager Tools One-on-one meetings [15], adapted by CS Pathways partners to manage the co-design process. O3s have six features: they are frequent; scheduled; 15 to 30 minutes in duration; held with all participants working on a specified project; semi-structured; and documented by the manager or researcher. This workshop paper describes how to use O3s to engage teachers and researchers in developing collaborative infrastructure to promote shared exploration of feedback and build and sustain partnerships.

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Keywords

research-practice partnership, design-based implementation research, co-design, infrastructure, one-on-ones, joint work, boundary, boundary object, boundary practice, boundary spanner,

1. INTRODUCTION

Researcher-practitioner or research-practice partnerships (RPP) and associated collaborative research approaches, such as DBIR, have become a popular means for leveraging research to promote educational improvement and transformation through a mutualistic, bi-directional collaborative strategy instead of using a uni-directional research to practice knowledge transfer approach [7,9,13]. CS Pathways researchers and teachers representing two universities and three urban school districts engaged in collaborative curriculum design (co-design) as part of a design-based implementation research (DBIR) approach to develop, establish, and sustain culturally responsive middle school CS programming within partnership districts. CS Pathways' curriculum co-design involved adapting a previously developed curriculum to new contexts and for use with new instructional media (i.e., switching from MIT App Inventor to App Lab from Code.org). DBIR proponents identify co-design as a means to collaboratively develop practices and objects that support educational program development, implementation, sustainability, and study [18–20,22]. These objects and practices are called infrastructure [17,29]. While RPP research has acknowledged infrastructure's importance to RPP work and identified some of its characteristics and functions, it currently calls for research to identify techniques to address RPP infrastructure development [7].

Infrastructure includes not only objects and practices resulting from collaboration between practitioners and researchers, such as a curriculum, a professional learning community, and professional development sessions [18,19,22], but also objects and practices that *facilitate* effective collaborative work among members of these two distinct professional communities [5,17,29]. Research has conceptualized *boundaries* as the cultural differences between members of research and practice communities that challenge collaboration. Collaborating partners use "boundary infrastructure"

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[17], or boundary practices, boundary objects, and the actions of boundary spanners to facilitate RPP partners' joint work "to define, create, implement, and study strategies for improvement" [21:183]. RPP proponents argue that joint work at boundaries supports RPP partners' mutual learning and effective RPP functioning [9].

As RPP research has begun to identify RPP benefits and outcomes, dimensions for effective RPP functioning, and principles for conducting collaborative research that boundary infrastructure supports [7,12,13,23], it has also identified a need to identify and develop techniques to manage and investigate the infrastructuring process [9,18,23]. Similarly, research has identified common challenges and dilemmas faced by RPPs and a corresponding need to address and manage them. While the literature recommends general strategies for developing such methods, it also calls for research about "processes and structures through which RPPs operate" [9:2520].

To manage infrastructuring and address these challenges, CS Pathways researchers and teachers adapted a specific business management technique called One-on-ones (O3), developed by the management consulting and training firm called Manager Tools [34]. CS Pathways partners used and adapted O3s as a boundary practice to develop boundary objects and support boundary spanning in their co-design of the adapted CS Pathways curriculum. Manager Tools O3s and CS Pathways adapted O3 will be described in the literature review and methods section, respectively.

The co-design project sought addressed the following CS Pathways partner requirements:

1. Teachers, researchers, and district leaders determined that the existing CS Pathways model curriculum had to be adapted for remote teaching in response to COVID-19 remote teaching requirements.
2. Additionally, some district leaders and some teachers desired curriculum lesson plans that provided more detailed instructional guidance than the original curriculum.
3. The co-designed curriculum's learning goals and content should align with state digital literacy and computer science standards.
4. The co-designed curriculum should be general enough to apply to the three partner districts but also supply sufficient resources to support distinct district strategies.
5. Curriculum modules should address culturally responsive pedagogy, specifically culturally responsive computing.
6. The curriculum materials should be hosted in a central repository that allows for shared viewing and collaborative development.

The purpose of this paper is to describe and demonstrate how CS Pathways O3s functioned as a boundary practice and infrastructuring technique that supported teachers' and researchers' joint work to co-design curriculum. O3s addressed three orders of infrastructure development issues:

1. They provided human, material, and information resources to support researchers' and teachers' co-design.
2. They provided a forum for teachers and researchers to develop objects and practices that afforded resource use.
3. They provided a forum for teachers and researchers to resolve or manage conflicting agendas and understandings regarding co-design.

By addressing these challenges, O3s supported the RPP partners' curriculum co-design efforts, increased teachers' and researchers' co-design capacity, and built and sustained their partnership.

2. LITERATURE REVIEW

The RPP strategy developed from researchers', practitioners', and policy-makers' efforts to develop a more effective paradigm for leveraging research to inform practice than a "pipe-line" model or push model. Critics of the "pipe-line" model argue that the paradigm has not worked as well as expected to engage research to inform or support educational practitioners' missions to improve schools, [4,14,32] . Instead, some policymakers, researchers, and practitioners developed RPPs. RPPs are partnerships between practitioners and researchers that

1. Are long-term,
2. Focus on problems of practice,
3. Are committed to mutualism,
4. Use intentional strategies to foster partnership, and
5. Produce original analyses. [4]

Research approaches that support these principles have been organized into three categories: research alliances, design research, and networked improvement communities. DBIR is a kind of design research.

Consistent with the RPP strategy, the DBIR approach places a strong emphasis on developing collaborative relationships between practitioners and researchers [11]. DBIR's four principles are listed below [11:393].

1. A focus on persistent problems of practice from multiple stakeholders' perspectives
2. A commitment to iterative, collaborative design
3. Developing theory and knowledge related to both classroom learning and implementation through systematic inquiry
4. Developing capacity for sustaining change in systems

As an approach that endorses adaptation as part of an iterative process, CS Pathways used DBIR to co-design and adapt a previously developed curriculum in which students developed apps to serve their communities. Co-design is a collaborative process in which a group of teachers, researchers and developers engage in iterative cycles of design, implementation, testing, and re-design to develop curriculum materials [23].

In CS Pathways' co-design, teachers and researchers collaborated as developers. Teachers developed, implemented, and tested materials. Researchers shared concepts from research, discussed implementation, provided feedback, and managed and collected data on the process and the materials developed.

Using RPP strategy and associated research approaches, researchers and practitioners develop and use practices and objects that facilitate work among partners from different professional communities. The objects and practices that result from and support the collaborative approaches of RPP and DBIR are called infrastructure. Star and Ruhleder characterize infrastructure as a phenomenon that

> ...occurs when the tension between local and global is resolved. That is, an infrastructure occurs when local practices are afforded by a larger-scale technology, which can then be used in a natural, ready-to-hand fashion [29].

Thus, infrastructures are objects and practices that allow individuals representing one professional locale to use knowledge, tools, and work developed in other (global) locales; they allow researchers to leverage practitioners’ knowledge and vice versa.

According to Star and Ruhleder, infrastructure has the following dimensions: embeddedness, transparency, learned as part of membership, links with conventions of practice, embodiment of standards, built on an installed base, becomes visible upon breakdown [29]. In a collaborative and educational context, these dimensions describe the extent to which objects and practices are familiar, meaningful, and useful to *all* collaborating partners within their local or home professional communities. Researchers and practitioners in RPPs seek to build infrastructure that serves both researcher and practitioner partners.

As RPP’s and collaborative research approaches have grown in popularity as an improvement strategy, the body of research on their impact in education has also grown [9,10,12,25,26,33]. RPP scholars have identified dimensions of RPP effectiveness [13].

1. Building trust and cultivating partnership relationships
2. Conducting rigorous research to inform action
3. Supporting the partner practice organization in achieving its goals
4. Producing knowledge that can inform educational improvement efforts more broadly.
5. Building the capacity of participating researchers, practitioners, practice organizations, and research organizations to engage in partnership work

These dimensions describe characteristics of effective RPP. To achieve these descriptions of effectiveness, co-design has been used an as infrastructure building strategy to both promote professional development, as well as educational innovation [18,25]. However, research reports that RPPs can continue face challenges that stem from differences in their professional cultures [7,9]**.**

To describe and address effective RPP infrastructure development, recent RPP research has replaced metaphors of translating knowledge between professional communities with a conceptualization of RPP members from partner communities doing “joint work at boundaries” [21] .

2.1 Joint work and Boundary Infrastructure

Recent RPP literature proposes a joint work at boundaries conceptual framework to capture the bi-directional nature of collaboration within effective RPPs [9,21,23]. Penuel et al. argue translational metaphors imply that knowledge is transferred from researchers to practitioners, that knowledge or interventions developed from research are enacted identically or very similarly in all contexts, and that practitioners play a passive role in developing the research agenda [21].

The joint work at boundaries conceptual framework draws on cultural-historical activity theory and organizational theory to understand collaboration. The theories and framework recognize the role of cultural and historical circumstances in creating the different missions, resources, and systems developed by collaborating researcher and practitioner communities. They further recognize that the missions, resources, and systems present and valued in one community, may not be present or hold the same value in others [9,21]. Therefore, when members of researcher and practitioner communities seek to collaborate on a project that both communities value, they may value or understand the collaborative project differently and seek to apply different knowledge, resources, and approaches to the project. These differences in cultural professional cultures can interrupt partners’ work on the valued project [1,9].

To continue collaborative work when cultural differences make collaboration difficult, the joint work at boundaries framework argues that effective RPP partners engage in “mutual learning” [9:2515], adhering to a social constructionist paradigm that recognizes that knowledge is not transferred from a source to a receptacle but constructed by each individual according to their understanding of prior knowledge and social experiences [17]. Therefore, within a joint work at boundaries framework, when collaborating individuals encounter boundaries, they develop and construct knowledge in order to advance the project according to each partner’s developing sense of project mission, resources, and systems [9,17,21]. They construct this knowledge through their mutual interactions using boundary practices and boundary objects and with the help of boundary spanners.

Boundary practices are partnership activities that provide forums in which partners representing research and practice communities interact and engage with each other’s ideas, resources, norms, and systems and construct knowledge that they can use within their respective professional communities [9]. Examples from the literature include co-design meetings and Plan-Do-Study-Act cycles [6]. Other examples are planning sessions for professional development when they include researchers and teachers, and the O3s that are the subject of this paper.

Boundary objects are tools, like standards, templates, rubrics, or curriculum formats, that research and practitioner partners use to coordinate and mediate joint work at boundaries [9,17]. They coordinate work as an object that both researchers and practitioners use. They mediate work by serving members’ particular research or practical purposes as determined by their developing, socially constructed knowledge. As social constructions, “Boundary objects can also serve to make aspects of partners’ practices and expertise visible, and it can carry some of the meaning of other settings within a partnership” [9:2517].

The joint work at boundaries framework makes it clear that boundary practices and objects allow researchers and practitioners to work within and perhaps expand their professional communities’ boundaries. However, the joint work at boundaries framework includes the concept of boundary spanners, individuals that can inhabit multiple communities and facilitate these processes. Farrell et. al, argue that by promoting mutual learning, joint work at boundaries coordinated and mediated by boundary practices, objects, and spanners promotes RPP effectiveness.

The joint work at boundaries framework also describes organizational conditions that influence effective boundary object, practice, and spanner development and employment. These conditions have been described as human, material, and structural aspects of infrastructure [18,29] that address three orders of issues faced at professional community boundaries.

First order issues involve material and information resource availability to partners (e.g., knowledge, software). Second order issues involve contextual effects on first order issues (e.g., knowledge or software is available but institutional support or expertise is lacking). Third order issues involve political, cultural, or permanent conflicts among partners (e.g., partners disagree about whether software or knowledge is appropriate) [29]. The literature calls for the development and study of specific methods and tools to manage infrastructuring activity in RPPs partners or in other words specific techniques or boundary practices to build boundary infrastructure [7,18].

2.2 Boundary practice for managing joint work

To coordinate and study the CS Pathways infrastructure-building DBIR approach, we borrowed a technique developed from business management. Specifically, we borrowed and adapted the One-on-one (O3) meeting technique developed by the management consulting and training company Manager Tools (https://manager-tools.com/) [34]. We argue that O3s adapted to CS Pathways functioned as a boundary practice to support curriculum co-design and partnership.

Manager Tools developed O3s as one of four reproducible techniques to promote four critical managerial behaviors: 1) developing a critical and holistic knowledge of employees, 2) giving feedback about employee performance, 3) asking employees to improve performance, and 4) delegating work to employees. The company argues that promoting these behaviors in managers improves company productivity and employee retention [15]. While O3s were specifically designed to develop a trusting, critical, and holistic relationship between managers and employees, the firm attributes 40% of value added to its client organizations to this single technique[15].

Manager Tools O3s are half-hour long, weekly or bi-weekly, semi-structured business meetings between a manager and all of their directs (i.e., employees that directly report to them) O3s are scheduled and rarely missed but may be rescheduled. They have a set time limit of usually 30 minutes. They are semi-structured, consisting of three parts. Meetings start with the manager inviting the direct to share their agenda. Next, the pair discuss the manager’s project agenda, including expectations and performance feedback. In the last third of the meeting, manager and direct may discuss next steps or future projects. During the direct’s agenda-sharing portion, they can share whatever information they deem relevant to their work. Throughout the meeting, the manager takes notes [15].

Each aspect of O3s--their regularity, frequency, universality, duration, structure, and documentation--serves to build trust between manager and directs. Regularly scheduling meetings indicates that the manager-direct relationship is operationally important and allows time to prepare for meetings, including follow-up material from a previous O3. Meeting on a weekly to biweekly basis assures that participants can discuss a feasible number of important issues in a timely fashion. Having meetings with all directs creates project team unity by communicating that each is important as another. Thirty-minute O3s held weekly were found by Manager Tools research to be long enough to produce desired benefits and short enough to support compliance. Starting the meetings with the direct’s agenda recognizes the manager-direct power differential and ensures that the direct’s voice is heard. Manager documentation of O3s communicates the importance of the information shared in the meeting and supports accountability for both participants acting on shared information. These O3 characteristics build trust by communicating to the participant with lesser structural power within the organization-- the direct--that they are valued and what they have to say is meaningful to the organization [15]. O3s also support the three other Manage Tools critical behaviors: giving feedback about performance, asking for improvement, and delegating work by providing a forum for exchanging information.

Just as O3 structure and function support Manager Tools critical managerial behaviors, aspects of O3 structure support teachers’ and researchers’ joint work at boundaries of their respective professional cultures. For example, O3 ordered agenda sharing assures that researchers hear from teachers about the classroom realities of adapting and implementing curriculum, while teachers are exposed to and made aware of the wider scope and purposes of the project, such as developing program sustainability.

Table 1 show how aspects of O3s align with RPP effectiveness and DBIR principles

Table 1. Alignment of O3 structural aspect, RPP Effectiveness, and DBIR Principles

O3 aspect	RPP Effectiveness	DBIR Principle
Regular meetings	Building trust and relationships Supporting practice goals Building capacity	A commitment to iterative, collaborative design Developing capacity for sustained systemic change
Frequency		
Duration		
Universality		
Agenda Discussion 1. Teacher (manager) 2. Researcher (teacher) 3. Next steps	Building trust and relationships Supporting practice goals Building capacity Conducting rigorous research to inform action	A focus on persistent problems of practice from multiple stakeholders’ perspectives Developing theory and knowledge related to both classroom learning and implementation through systematic inquiry
Researcher documentation	Conducting rigorous research to inform action	Developing capacity for sustaining change in systems. Developing theory and knowledge related to both classroom learning

		and implementation through systematic inquiry

O3s are structured to perform functions similar to boundary practices cited in the literature: they "elicit and make use of relevant perspectives and knowledge of participants" and "develop and establish roles, responsibilities, and expectations" [9:2517] for both practitioner and researcher when they discussed agendas. They recognize and address differences in social power and structural power by starting with the teacher's agenda first, ensuring that their voices are heard. They can create conditions for partners to construct useful knowledge from "relevant perspectives and knowledge of [practice] participants" [9:2517]. O3s can build partner capacity through regular scheduling and documentation, which contribute to routinization, data collection and use.

Research Questions:

RQ1: As a boundary practice, what CS Pathways co-design infrastructural issues did O3s identify?

RQ2: How did teachers and researchers address collaborative design issues through O3s?

3. METHODS

3.1 Methodological Approach

In alignment with DBIR, to study O3s we used a collaborative inquiry methodology, which seeks "to understand and transform practices in order to understand and improve them" [28:269] (Savin-Baden & Major, 2013, p. 269). Collaborative inquiry places the researcher in the study as an active participant who used O3s with teachers as a boundary practice to manage and study the curriculum co-design process, both identifying challenges and investigating how O3s helped us to address them. In collaborative inquiry, the researcher attends to four types of conversations in the data: *framing conversations* that identify assumptions underlying participants' experiences of phenomena; *advocacy conversations* that capture partners' suggestions for courses of action; *illustration conversations* that describe courses of action; and *inquiry conversations* that capture responses to conversations [30,31]. O3s themselves provide opportunities for these conversations.

To identify themes, concepts, and generate knowledge from O3 analysis, we used a modified grounded theory approach to code the data using Star and Ruhleder's three orders of infrastructure development issues, as well as dimensions of RPP effectiveness and DBIR principles [6,29]. We used open coding to identify specific co-design issues identified by teachers and researchers. By interpreting and connecting themes and concepts from data generated by O3s we developed "conceptions about what is taking place" [28:184] to describe how O3s are used to coordinate, mediate, and study curriculum co-design.

3.2 Theoretical Framework

The joint work at boundaries conceptual framework and three orders of infrastructure development are consistent with a social constructionist theoretical framework, which maintains that individuals construct knowledge and meaning and express them through social artifacts, such as curricula, and language. Individuals interpret social artifacts to construct their own knowledge and meaning [28]. Using a social constructionist theoretical framework, researchers and practitioners can develop and study "shared and co-constructed realities" [28:62] through boundary practices, boundary objects, and facilitation by boundary spanners.

3.3 Participants and Sites

Six teachers participated in co-design. Four were from State 1-- , Teachers A, D, E, and F-- and two were from State 2—Teachers B and C. The four State 1 teachers had experience teaching computer science or technology classes to middle school students and had previous experience with App Lab. Teachers A and E had attended a Code.org professional development during the previous summer that included App Lab. instruction The State 2 teachers had not had previous computer science teaching experience but had received professional development on developing apps through the CS Pathways program. Teacher B taught a middle school engineering technology class and Teacher C taught science. Teachers B. E, and F had participated in co-design activities with a team of researchers and other teachers over the previous summer. Teachers A, C, and D joined co-design efforts as part of implementing, testing, and adjusting curriculum iterations. Despite school district staffing disruptions due to the COVID-19 pandemic, these six teachers chose to participate in co-design, with Teachers A, B, C, D, and E implementing the developing curriculum in their classrooms.

Initially, two members of the CS Pathways leadership and research team filled the manager role. The teachers were assigned to researchers according to the state they taught in. One research team member worked with five teachers in State 1 and another worked with one teacher in State 2.

The State 1 researcher was a research assistant on the project and a PhD student in a Research and Evaluation in Education program. He had a master's degree in school leadership and experience teaching and working with schools, non-profits, and small businesses, including implementing O3s. The State 2 research team member was an experienced college and high school CS teacher, with an MS in computer science and a Master of Arts, in Teaching for Technology. She had extensive experience with experience using and developing CS curricula, as well as developing state computer science and digital fluency standards. She was also the project coordinator for State 2 teachers. A third researcher and PhD student in Educational Theory and Practice often assisted in observing meetings, taking notes, and contributing appropriate questions and comments. The State 1 researcher is also the lead author of this paper, and the other researchers are co-authors.

3.4 Data Collection & Analysis

The data collected and analyzed are from selected notes and transcriptions from 100 O3s carried out from October 2020 to June 2021. The selection of O3s and notes contains meetings involving all co-designing teachers from different times in the school year and are intended to describe and demonstrate O3s' function as a boundary practice. In addition, in the last O3 for three teachers, the researcher's agenda included the following questions:

> What were the challenges in co-development?
>
> How did O3s help to address challenges, if at all?
>
> What would you change about O3s?

O3s were designated as research instruments. They were designed as 15-minute, semi-structured, weekly quick check interviews for the purpose of supporting teachers and collecting data on practice as they collaborated with researchers and other teachers in curriculum “co-construction” (co-design). The researcher was designated as the interviewer and the teacher as the interviewee. Although 15 minutes were allocated for O3s, meetings could run longer with the consent of both parties.

In the analysis, both structural and open coding methods and constant comparison were used to derive themes and patterns in the data regarding O3 aspects and their function as boundary practices that supported co-design [27,28]. We used five dimensions of RPP effectiveness and DBIR principles as structural codes. We used open coding to construct sub-codes for a priori data and to code data that seem significant to issues of curriculum co-design and collaboration but were not addressed by a priori codes. We used the three orders of issues addressed by infrastructure as axial codes for O3 infrastructural function. We will use a constant comparison approach to derive themes and develop interpretations that answer the research questions.

4. RESULTS

4.1 Implementation Overview

CS Pathways partners adapted O3s in three ways. First, we established developing and producing adapted curriculum materials and an on-line repository as an analog for external or internal business goods, services, and purposes. Although as a collaboration of public agencies seeking to produce a public good, CS Pathways’ definition of organizational productivity is more complex than that of a business, we were able to focus O3 purposes on producing adapted computer science curriculum materials and an online platform to make them available to teachers.

During the previous summer, a team of teachers and researchers, which included Teachers B, E, and F and the O3 researchers, had developed a five-unit framework for adapting the original CS Pathways curriculum for use with App Lab. The framework included lesson and curriculum goals mapped to State 1 and State 2 standards, as well as listing of related activities. While the units presented a framework for approaching the curriculum material, it did not include a sequence of specific lessons. The co-design team sought to develop an online platform presenting a sequence of lessons and supporting materials for teachers to implement the five-unit curriculum framework. We adapted O3s to manage and study this process.

Second, we assigned the role of manager to the researcher and the role of direct to teachers, acknowledging structural and cultural power dynamics in the project. Although the hierarchical manager-direct relationship is built into business structures, RPP and DBIR principles which promote bi-directionality and democratized relationships between practitioners and researchers problematize assuming the same relationship in an RPP. However, the CS Pathways grant structure, differences in computer science expertise and familiarity with the previous curriculum, and cultural attitudes within education that give rise to statements from teachers, such as “us lowly teachers,” placed researchers in the position of managing CS Pathways curriculum co-design. Similar situations appear in RPP literature [3,8,9,16,21,22,24]. Acknowledging this situation within the context of a technique meant to build trust between partners with unequal situational power allowed the technique to serve a democratizing function.

Third, O3 collaborating researchers, teachers, and districts negotiated the O3 structure, specifically meeting frequency and duration. Because governmental and non-governmental agencies seek to produce distinct public goods and have distinct means for producing them, when they collaborate they must negotiate and align collaborative or boundary practices, rather than relying on the hierarchical structure of a single organization [2] This is not to say that negotiating policies and procedures of single businesses, governmental, and non-governmental organizations is simple but only that negotiating processes among collaborating organizations is more complex because of professional community boundaries.

Designating the O3s as part of research facilitated negotiating the allocation of teachers’ time and remuneration to take part in O3s as part of the co-design process. One district leader negotiated for 15-minute meetings on a bi-weekly schedule basis. Three teacher co-designers followed this model. Two teachers from two different districts opted to meet weekly, one for 15 minutes, the other for 30 minutes. Later in the school year a sixth co-designer joined and met with a researcher on bi-weekly basis. The initial five co-designers were paid stipends for their work, supplemented by professional development funding to cover cost overruns when meetings ran long. The sixth teacher co-designer was paid through professional development funding.

After negotiation, the following aspects applied to all CS Pathways O3s: 1) they were regularly scheduled, rarely missed, and rescheduled when necessary; 2) they were held on at least a bi-weekly basis; 3) all co-designing teachers participated; 4) meetings opened with teachers invited to share their agendas; and 5) researchers took meeting notes. Most meetings were recorded and transcribed, as well. Between O3s, teachers continued to adapt and implement curriculum, while researchers organized teacher-developed teacher materials, developed the Google Classroom to host curriculum materials, and researched, developed, and collected resources to support curriculum co-design and implementation.

Teachers and researchers began running O3s starting in October of 2020 and continued until June 2021. One of the six teachers who participated in co-design had to discontinue participation in the project in March for personal reasons, although they did continue adapting and implementing the curriculum in their classroom. All teacher co-designers participated in O3s for as long as they were co-designing. Teacher meetings ranged from 15 minutes to an hour, depending on the topics discussed, teachers’ needs, and schedules.

The State 1 researcher participated in 85 O3s with all six teachers, and the State 2 researcher participated in 15 O3s with one teacher. Seventy-nine total meetings were recorded and transcribed. In early April, both researchers and the State 2 teacher agreed that the teacher should switch to meeting with the State 1 researcher to better connect with the overall co-design project. The State 1 researcher was more heavily involved in coordinating the curriculum co-design than the State 2 researcher.

CS Pathways O3s had the following structure:

1. The researcher takes notes, and when possible, records the meeting for later transcription.
2. The researcher invites the teacher to start the meeting with their agenda, sharing and discussing their thoughts, feelings, plans about co-design work and project-related work in general with an opening statement, such as “What’s going on?”
3. For at least five minutes in 15-minute O3s and for 10 minutes in 30-minute O3s, the teacher shares their agenda, and the researcher responds as required by the teacher.

4. The next third of the meeting is for the researcher's agenda, to discuss project issues, follow-up on old business, and to gather any additional feedback.
5. The final third is used to determine what should be done for the next meeting. Sometimes this portion is truncated if teacher and researcher take longer than one third of the time allotted. Time on each agenda should be roughly equal.

4.2 Findings

Researchers and teacher used this O3 structure to manage the CS Pathways co-design process and to answer the following research questions:

RQ1: As a boundary practice, what CS Pathways co-design infrastructural issues did O3s identify?

RQ2: How did teachers and researchers address collaborative design issues through O3s?

4.2.1 As a boundary practice, what CS Pathways co-design infrastructural issues did O3s identify?

As a boundary practice, each aspect and stage of the O3 provided opportunities for the teacher and researcher to express and/or engage their knowledge regarding the co-design project with the other.

Four teachers, Teachers A and F from State 1 and Teachers B and C from State 2, were able to participate in O3s at the end of the school year in which the researcher asked about co-design challenges and what role, if any, O3s had in addressing them.

The three teachers noted that O3s addressed the following challenges: finding resources, preparing for group meetings, getting organized as a group ("we were all over the place"), and being connected to the project. All three found O3s helpful, at times contrasting their utility with group meetings. Teacher A said, "We didn't need a [group] meeting every other week, or I should say what I found more helpful were these one on ones." Teacher C said "O3 has been. that's been singularly the most useful thing [from] this whole computer science grant thing."

The four teachers commented on the regularity, universality, and agenda sharing structure of the technique as addressing other challenges. They noted that regular scheduling allowed them to know that they had a regular forum for their questions and finding project information and resources. Teacher A said,

> I would have my handy dandy notebook as I was working in those two weeks. I had a question … write that down because when I talked to Researcher, I can ask him about that.

During O3s other teachers also referred to notebooks and sticky notes on which they would accumulate questions for their agendas. Regular meeting O3s also provided a connection to the larger project. Teacher F said he thought they made people feel valued and that through O3s, he got to "learn more about the program" than through larger meetings, although he thought larger meetings helped to bring everything together.

Having all co-designing teachers participate in O3s allowed the researcher to broker connections between teachers as well. Because the researcher had developed knowledge about other teachers' approaches, they were able to make referrals about specific topics. Teacher C said about the importance of specificity,

> The questions that I had were very specific and you guys were like Teacher B did things along this this and this line, you should ask her, I was like perfect … that gave me a specific reason to contact Teacher B and trust that she was going to have the information that I needed if you guys did.

When commenting about agenda sharing, while all four teachers appreciated having their voices heard and questions addressed, three also said that they valued hearing the researcher's agenda. Teachers B, C, and F noted that questions asked or statements asked by the researcher caused them to think about a concept differently. Teacher C said sharing agendas

> helped me understand the different roles and therefore helps me understand what kind of support I can get from you and also what support I can offer you, and vice versa.

The four teachers' comments touch on three orders of issues involved in building infrastructure that O3s address. They valued O3s for providing resources that they need (first order) and in ways that they found useful (second order). They also recognized that O3s engaged them as teachers with ideas from a researcher community that understood reality differently. This last is an example of a third order issue, potential conflict between teacher and research cultures, being resolved.

The selection of analyzed O3 data demonstrates other similar examples of how aspects of O3s addressed first, second, and third order collaborative issues in the co-design project.

4.2.2 O3s and CS Pathways Co-design

First order issues were relatively easy to address through O3 structure. O3s facilitate timely information and resource passing back and forth between teachers and researchers, as long as both teacher and researcher communities recognize the information and resources as meaningful. Researchers were able to answer CS questions and organizational questions. Teachers were able to report on classroom events and student reception of curriculum, providing data to researchers. However, when some aspect of one or the other community does not value the information or resource, then access to information or resources becomes a second order issue.

Although O3 records show that second order co-design issues are persistent because they involve embedded infrastructures for a particular professional community, O3 can be used to manage the issues they pose. For example, seem especially researchers designed a template that aligned lesson learning goals with state standards for teachers to document their lesson plans in a uniform manner. The researcher's portion of the O3 provided time to introduce the template and work on revisions with teachers. O3 frequency, universality, and invitation for teacher feedback allowed teachers and researchers to abandon the cumbersome template before it halted production of curriculum materials altogether. Instead, the task of documenting standards alignment was delegated to a research assistant. O3 aspects afforded management of this messy process, study of this dilemma, and most importantly continued production of curricular materials to test in classrooms.

Another second order issue involved giving teachers' school accounts access to the Google Classroom hosting our curriculum. Because the project spans three districts and three IT departments, allowing desired access is difficult. O3 frequency, universality, duration, agenda sharing, and documentation provided the collaborating teachers and researchers the time and expertise to develop workarounds but also to develop the Google Classroom into a boundary object used by project researcher and teachers. The difficulty exists because the value perceived by researchers and teachers is outweighed in the eyes of school IT administrators by concerns about security, control, and managing organizational complexity. Although developing agreements between districts is a continuing struggle, O3s provide a means to develop curriculum concurrently and collaboratively on a platform widely used by schools and teachers.

In CS Pathways, O3s surfaced third order issues involving potential conflict or simply confusion leading to interrupted collaboration due to differences in individuals' constructed knowledge and understanding. Issues include disagreements about group meeting structure, representation on the leadership team, balancing curriculum simplicity with comprehensiveness, and what constitutes culturally responsive computing. However, along with the trust that may come from developed familiarity between researcher and teacher, O3s' teacher-then-researcher agenda sharing sequence seems to produce resolution or mutual learning that supports continued collaboration.

For example, through agenda sharing in an O3, a teacher was able to share her growing frustration with group meeting inefficiency and feeling disconnected from the project. The O3 researchers and the teacher were able to switch whom she did O3s with so that she could be more involved in meeting and project management. The researcher and teacher used subsequent O3s to make use of her skills as a project manager to support continued collaboration. The conflict came from the teacher perceiving that she could not have appropriate agency within the project. O3s allowed her to express that perception and for partners act in order to continue to collaborate.

5. Discussion and Conclusion

In CS Pathways, teachers and researchers used O3s as boundary practices to identify and address three orders of collaborative issues within a joint work at boundaries framework. Their efforts resulted in the social construct of the CS Pathways curriculum.

O3 regularity, universality, frequency, and documentation facilitated the flow of information and resource in the codesign effort, providing infrastructure to support first order issues.

These same aspects contributed to managing second order issues to maintain collaboration. The examples noted, namely the failed template and struggles with Google Classroom accessibility for teacher accounts across domains may indicate that these issues are associated with factors outside of the collaboration that require ill-fitting affordances to all parties. In the case of the unfeasible template, the factors may be classroom realities that make extra-curricular forms unfeasible and the need to standardize classroom activity for external observers. In the case of Google Classroom access, the agency to resolve this second order issue does not currently reside with O3 participants. Collaborative infrastructure through O3s may only manage such issues.

However, O3s do seem to provide their participants the means to resolve third order collaboration issues, which stem from dissonance between individuals' constructions of knowledge. O3 structure seemed to provide the conditions for teachers and researchers to essentially co-construct collaborative spaces or perhaps redraw boundaries.

We recommend adapted O3s or similar managerial techniques as a boundary practice to support shared exploration of social constructions to build and sustain partnerships and collaborative infrastructure. While the CS Pathways project also utilized group meetings, the diversity and number of partner backgrounds between and even among collaborative partners complicates structuring them as border practices in which all partners get what they need as professionals. O3s allowed researchers and teachers to work on co-design issues relevant to a specific teacher's practice, providing a forum for constructive dialog between partners.

The CS Pathways curriculum co-design project produced curriculum resources and a Google Classroom site to store, present, and further develop them. It is an approximately 18-hour curriculum consisting of 5 units with 2 to 6 modules that supports teachers' teaching students to develop mobile apps that serve their identified communities. By the end of teachers' implementation of the curriculum, students will have created an app and learned CS and digital literacy (DL) skills to do so. The curriculum provides video tutorials, curated lessons and recommended unplugged activities. Culturally relevant pedagogy integrated throughout the units either through dedicated modules or instructional suggestions. Module lesson goals and instruction address CSDL learning standards of district states.

6. LIMITATIONS

The details of our design work are not the subject of this paper. Instead, it is a description and demonstration of a specific technique that facilitated our co-design work. The paper does not examine differences in efficacy for individuals or contexts. Although the O3 interview protocol, as well as the Manager Tools protocol, attempts limit the duration of the meetings, the CS Pathways researchers allowed teachers time to talk at length and at times did so themselves.

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8. REFERENCES

[1] Sanne F. Akkerman and Arthur Bakker. 2011. Boundary Crossing and Boundary Objects. *Review of Educational Research* 81, 2 (June 2011), 132–169. DOI:https://doi.org/10.3102/0034654311404435

[2] James E. Austin and M. May Seitanidi. 2012. Collaborative Value Creation: A Review of Partnering Between Nonprofits and Businesses: Part I. Value Creation Spectrum and Collaboration Stages. *Nonprofit and Voluntary Sector Quarterly* 41, 5 (October 2012), 726–758. DOI:https://doi.org/10.1177/0899764012450777

[3] Elena Barbera, Iolanda Garcia, and Marc Fuertes-Alpiste. 2017. A Co-Design Process Microanalysis: Stages and Facilitators of an Inquiry-Based and Technology-Enhanced Learning Scenario. *irrodl* 18, 6 (2017), 104–126. DOI:https://doi.org/10.19173/irrodl.v18i6.2805

[4] Cynthia E. Coburn, William R. Penuel, and Kimberly E. Geil. 2013. *Research-Practice Partnerships: A Strategy for Leveraging Research for Educational Improvement in School Districts*. William T. Retrieved July 1, 2020 from https://eric.ed.gov/?id=ED568396

[5] Elizabeth Farley-Ripple, Henry May, Allison Karpyn, Katherine Tilley, and Kalyn McDonough. 2018. Rethinking

Connections Between Research and Practice in Education: A Conceptual Framework. *Educational Researcher* 47, 4 (May 2018), 235–245. DOI:https://doi.org/10.3102/0013189X18761042

[6] C. C. Farrell, W. R. Penuel, J. Daniel, and C. E. Coburn. 2020. *Taking stock of today's research-practice partnerships: Current practices and future possibilities*. Boulder, CO: National Center for Research in Policy and Practice.

[7] Caitlin C. Farrell, Kristen L. Davidson, Melia Repko-Erwin, William R. Penuel, Mary Quantz, Hayla Wong, Robbin Riedy, and Zane Brink. 2018. A Descriptive Study of the IES Researcher-Practitioner Partnerships in Education Research Program: Final Report. Technical Report No. 3. *National Center for Research in Policy and Practice* (2018).

[8] Caitlin C. Farrell, Christopher Harrison, and Cynthia E. Coburn. 2019. "What the Hell Is This, and Who the Hell Are You?" Role and Identity Negotiation in Research-Practice Partnerships. *AERA Open* 5, 2 (April 2019), 2332858419849595. DOI:https://doi.org/10.1177/2332858419849595

[9] Caitlin Farrell, William R. Penuel, Anna-Ruth Allen, Eleanor Anderson, Angel Bohannon, Cynthia Coburn, and Stephanie Brown. 2020. Mutual Learning at the Boundaries of Research and Practice: A Framework for Understanding Research-Practice Partnerships. (June 2020). DOI:https://doi.org/10.22318/icls2020.2515

[10] Frank Fischer (Ed.). 2018. *International handbook of the learning sciences*. Routledge, New York, NY.

[11] B. J. Fishman and W. R. Penuel. 2018. Design-based implementation research. *International handbook of the learning sciences* (2018), 393–400.

[12] Ye He, Beverly S. Faircloth, Kimberly Kappler Hewitt, Marcia L. Rock, Sophia Rodriguez, Laura M. Gonzalez, and Amy Vetter. 2020. Data management and use through research practice partnerships: A literature review. *Educational Research Review* 31, (November 2020), 100360. DOI:https://doi.org/10.1016/j.edurev.2020.100360

[13] Erin C. Henrick, Paul Cobb, William R. Penuel, Kara Jackson, and Tiffany Clark. 2017. *Assessing Research-Practice Partnerships: Five Dimensions of Effectiveness*. William T. Retrieved June 24, 2021 from https://eric.ed.gov/?id=ED610463

[14] Erin Henrick, Marco A. Munoz, and Paul Cobb. 2016. A better research-practice partnership. *Phi Delta Kappan* 98, 3 (November 2016), 23–27. DOI:https://doi.org/10.1177/0031721716677258

[15] Mark Horstman. 2016. *The effective manager*. John Wiley & Sons.

[16] Raymond Johnson, Samuel Severance, William R. Penuel, and Heather Leary. 2016. Teachers, Tasks, and Tensions: Lessons from a Research-Practice Partnership. *Journal of Mathematics Teacher Education* 19, (April 2016), 169–185. DOI:https://doi.org/10.1007/s10857-015-9338-3

[17] Susan Leigh Star. 2010. This is Not a Boundary Object: Reflections on the Origin of a Concept. *Science, Technology, & Human Values* 35, 5 (September 2010), 601–617. DOI:https://doi.org/10.1177/0162243910377624

[18] Susan McKenney. 2019. Developing the Human, Material, and Structural Aspects of Infrastructure for Collaborative Curriculum Design: Lessons Learned. In *Collaborative Curriculum Design for Sustainable Innovation and Teacher Learning*. Springer, Cham, 403–424.

[19] William R. Penuel. 2019. Co-design as infrastructuring with attention to power: Building collective capacity for equitable teaching and learning through design-based implementation research. In *Collaborative Curriculum Design for Sustainable Innovation and Teacher Learning*. Springer, Cham, 387–401.

[20] William R. Penuel. 2019. Infrastructuring as a Practice of Design-Based Research for Supporting and Studying Equitable Implementation and Sustainability of Innovations. *Journal of the Learning Sciences* 28, 4–5 (October 2019), 659–677. DOI:https://doi.org/10.1080/10508406.2018.1552151

[21] William R. Penuel, Anna-Ruth Allen, Cynthia E. Coburn, and Caitlin Farrell. 2015. Conceptualizing Research–Practice Partnerships as Joint Work at Boundaries. *Journal of Education for Students Placed at Risk (JESPAR)* 20, 1–2 (April 2015), 182–197. DOI:https://doi.org/10.1080/10824669.2014.988334

[22] William R. Penuel, T. Lee, and Bronwyn Bevan. 2014. Designing and building infrastructures to support equitable STEM learning across settings. *Research+ Practice Collaboratory Research Synthesis. San Francisco: The exploratorium* (2014).

[23] William R. Penuel, Robbin Riedy, Michael S. Barber, Donald J. Peurach, Whitney A. LeBouef, and Tiffany Clark. 2020. Principles of Collaborative Education Research With Stakeholders: Toward Requirements for a New Research and Development Infrastructure. *Review of Educational Research* 90, 5 (October 2020), 627–674. DOI:https://doi.org/10.3102/0034654320938126

[24] William R. Penuel, Jeremy Roschelle, and Nicole Shechtman. 2011. Designing Formative Assessment Software with Teachers: An Analysis of the Co-design Process. *Research and Practice in Technology Enhanced Learning* (November 2011). DOI:https://doi.org/10.1142/S1793206807000300

[25] Jules Pieters, Joke Voogt, and Natalie Pareja Roblin. 2019. *Collaborative Curriculum Design for Sustainable Innovation and Teacher Learning*.

[26] Brooks A. Rosenquist, Erin C. Henrick, and Thomas M. Smith. 2015. Research–Practice Partnerships to Support the Development of High Quality Mathematics Instruction for All Students. *Journal of Education for Students Placed at Risk (JESPAR)* 20, 1–2 (April 2015), 42–57. DOI:https://doi.org/10.1080/10824669.2014.988335

[27] Johnny Saldana. 2016. *The Coding Manual for Qualitative Researchers* (3rd edition ed.). SAGE Publications Ltd, Los Angeles ; London.

[28] Maggi Savin-Baden and Claire Howell Major. 2013. *Qualitative research: the essential guide to theory and practice*. Routledge, London; New York.

[29] Susan Leigh Star and Karen Ruhleder. 1996. Steps Toward an Ecology of Infrastructure: Design and Access for Large Information Spaces. *Information Systems Research* 7, (1996), 111–134.

[30] William R. Torbert. 1981. Why educational research has been so uneducational: the case for a new model of social science based on collaborative inquiry. (1981).

[31] William R. Torbert. 2001. The practice of action inquiry. In *Handbook of action research*, Reason, P and Bradbury, H. (eds.). Sage London, 250–260.

[32] Vivian Tseng, John Q. Easton, and Lauren H. Supplee. 2017. Research-Practice Partnerships: Building Two-Way Streets of Engagement. *Social Policy Report* 30, 4 (2017),

1–17. DOI:https://doi.org/10.1002/j.2379-3988.2017.tb00089.x

[33] Richard O. Welsh. 2021. Assessing the Quality of Education Research Through Its Relevance to Practice: An Integrative Review of Research-Practice Partnerships. *Review of Research in Education* 45, 1 (March 2021), 170–194. DOI:https://doi.org/10.3102/0091732X20985082

[34] Home | Manager Tools. Retrieved July 12, 2021 from https://manager-tools.com/

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Project moveSMART: Integrating Physical Activity and Computer Science Learning in Elementary School Classrooms

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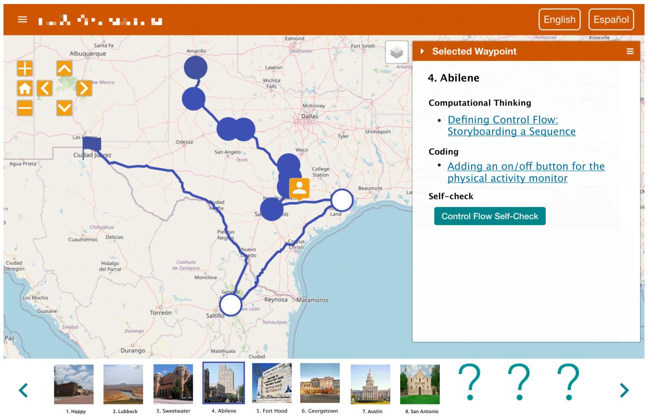
ABSTRACT

The Project moveSMART researcher-practitioner partnership (RPP) develops and delivers contextualized computer science and computational thinking (CS/CT) content in a Title I elementary school with a predominantly Hispanic student population. Project moveSMART is built around an educational game, designed to be played collaboratively by a fourth or fifth grade class, that integrates students' everyday physical activity with in-class academic learning. The class earns credit for physical activity in physical education, recess, or other in-school activities. The credit takes the form of distance traveled on a virtual journey along a physical route, and waypoints provide learning activities, including CS/CT activities that create new in-game features. For example, students program wearable activity monitors that become a physical activity data source for the game. Our experiences have surfaced multiple challenges that include pressures for all instruction to adhere to required standards, a lack of contextualization of CS/CT content, and unreliable at-home Internet that makes it difficult to reinforce lessons outside of school. By tying CS/CT to students' own physical activity, we address the dual problems of declining physical activity in children and a lack of contextualization of CS/CT content. To further address identified barriers, we co-designed game elements with classroom teachers to enable cross-curricular connections, including connecting CS/CT to language arts, cultural studies, music, etc. This paper will report on the structure of the RPP (which intentionally includes "specials" teachers like physical education teachers), the design of the game, and lessons learned in a first year pilot.

1 INTRODUCTION

Many efforts to integrate computational thinking and computer science in elementary education presuppose characteristics of school districts that may not be universally true. In this paper, we present the Project moveSMART effort, which is built around a researcher-practitioner partnership (RPP) that includes teachers from multiple schools and school districts to develop an educational learning platform that promotes both increased physical activity and computer science and computational thinking (CS/CT). The experiences reported in this paper highlight several challenges faced by school districts with traditionally underrepresented or underserved populations. In our preliminary work, we have elicited challenges that include the inability for teachers to integrate computing content that lies outside of a required curriculum, a lack of contextualization of computing material for students, and unreliable or unavailable at-home Internet infrastructure. These challenges coincide with more universal concerns about teachers' inexperience with and lack of confidence in computing material in general.

Project moveSMART and the associated RPP are part of Whole Communities Whole Health (WCWH) [21], a transdisciplinary research Grand Challenge launched by the Vice President for Research at the University of Texas. WCWH's guiding principle is the use of community engaged research, in which community members are involved in research from the outset: from defining research questions to designing and implementing solutions and analyzing results. For WCWH, the community consists of underserved children and families in eastern Travis county, Texas. For this project, therefore, the researcher-practitioner partnership includes researchers from the University of Texas and partner institutions as well as teachers, administrators, and children from the Del Valle Independent School District (DVISD). DVISD has 10,828 students, with 76% of the students rated as at risk of dropping out of school. More than 90% of DVISD students self-identify as ethnic minorities. Within DVISD, our initial partner school is Hornsby-Dunlap Elementary School (HDES). At HDES, 69% of the students are Hispanic, and 18.9% are African American. In the 2018-2019 school year, 27% of students met grade level expectations in science, and 42% met the expectations in math, with the school achieving a Texas Education Agency accountability rating of "C" [18]. The campus has been identified for targeted support and improvement. It is a Title 1 school, with high concentrations of poverty, as measured by the portion



Selected Waypoint

4. Abilene

Computational Thinking

- Defining Control Flow: Storyboarding a Sequence

Coding

- Adding an on/off button for the physical activity monitor

Self-check

Control Flow Self-Check

Figure 1: A Project moveSMART journey through Texas.

of students who receive free or reduced lunch. In a recent survey of 76 households in HDES, 80% reported that they had at-home access to the Internet, with only 65% having reliable, high speed access. In the households with access, 55% rely on a cell phone for connectivity. In contrast, the remainder of Travis County has 96% connectivity.

While students across all demographic groups express interest in learning computing, students from traditionally underserved groups, like those at Hornsby-Dunlap, often encounter structural barriers that limit access and exposure to computer science learning opportunities. They face social barriers as well, including stereotypes of who belongs in computer science and parents' and educators' beliefs that Black and Hispanic students are not as interested in pursuing CS [10, 20]. Given that the students in our community have very limited access to computers and the Internet in their homes, delivery of CS/CT material must occur during the traditional school day. While teachers at Hornsby-Dunlap Elementary are enthusiastically supportive of teaching computational thinking and computer science, their ability to add to the curriculum is constrained by the need to align with state accountability standards and to adhere to a provided curriculum. To address these challenges, we have forged connections with teachers, administrators, and students at Hornsby-Dunlap Elementary that have led to the partnership behind the Project moveSMART learning platform.

The foundation of the CS/CT content delivery within Project moveSMART occurs through a collaborative educational game that integrates physical activity into the academic curriculum. Project moveSMART exploits an open-source gamification framework [13] that has been deployed in smart city games around Europe [14]. Notably, this framework has been used to implement the KidsGoGreen game [6, 9], on which Project moveSMART is directly based. Project moveSMART has been designed to motivate lasting changes to kids' participation in physical activity, while simultaneously exploiting the known positive correlation between physical activity and academic achievement. Project moveSMART is designed to be played cooperatively by a single elementary school class that takes a virtual journey on a physical route (e.g., the current 4^{th} grade game follows a route through historical sites of Texas, see Figure 1). The class makes progress by earning "steps", which are explicitly tied to distance traveled on the route. Students earn their steps by participating in in-school physical activity. The progress, calculated by class aggregate, unlocks "waypoints" that contain learning modules that incorporate curricular material from across disciplines (science, math, cultural studies, language arts, and computer science and computational thinking) placed in the context of each waypoint. As examples of this contextualization, when in the panhandle of Texas, students may read the book *Sarah Plain and Tall* and respond to writing prompts about the worries facing people living on the plains. When traversing West Texas, the students may unlock a science lesson about the impacts of wind erosion.

The researchers and administrators and teachers at Hornsby-Dunlap Elementary school have worked together to design Project moveSMART so that it addresses the needs of the 4^{th} and 5^{th} grade teachers, is responsive to the district's required curriculum, and supports and promotes existing in-class instruction, including the addition of new CS/CT learning activities. In this paper, we first describe the Project moveSMART platform (Section 2), then we describe the nature of the RPP (Section 3). We then report on our initial experiences using Project moveSMART to deliver novel CS/CT content tied to physical activity in active elementary school classrooms (Section 4). We conclude in Section 5.

2 PROJECT MOVESMART – THE GAME

Project moveSMART is an educational "game", delivered as a web application, that is played cooperatively by elementary-aged students within a class. Each class embarks on a virtual journey through areas relevant to their educational objectives (e.g., a 5^{th} grade class that is studying American History moves through a route across America, while a 4^{th} grade class focused on Texas state history moves across the state of Texas). In the Project moveSMART game, students receive "steps" for participating in well-defined physical activity "events" during the school day (e.g., physical education class, recess, or physical activity in the classroom). Students log physical activity data by self reporting their activity level on a four-point scale ("more active", "active", "less active", and "inactive"), designated by the colors green, yellow, red, and white. These levels are based on self-reflection reports that elementary physical education teachers commonly employ. In the deployed game, 4^{th} and 5^{th} grade students can log their physical activity in one of two ways: (a) using the game's web portal or (b) through a "check-in" box that uses RFID proximity cards and a set of four colored buttons. In addition, a teacher can enter aggregate activity for the entire class. In all cases, the activity levels are converted to distances within the game and are aggregated for the whole class either at the end of each day, or upon completion of a class activity. This approach promotes autonomy for individual students, while fostering collaboration within each class.

Figure 2 shows the Project moveSMART check-in box, which contains a Raspberry Pi, an RFID reader, and four buttons. On the one hand, the use of the check-in box may hinder the scalability of the game. However, our focus group and pilot studies made it apparent that the box itself, including its transparent design, was essential to capturing and maintaining the interest of the students. The fact that the box is made with inexpensive off-the-shelf components tempers scalability concerns; it is also conceivable that, in

Figure 2: Check-in box.

PROJECT SMART

STATUS	20.25 miles	51 miles	65.25 miles	23.25 miles	9 miles
Event 0 - Event 4	PE	Recess	PE	Brain Break	Transit Home
WEATHER	☁	☀	☀	☀	☁
DURATION	45 minutes	45 minutes	45 minutes	15 minutes	30 minutes

51 miles added!

students x speed x time = distance

5 students x 1 mph x 0.75 hour(s) = 3.75 miles

12 students x 2 mph x 0.75 hour(s) = 18 miles

13 students x 3 mph x 0.75 hour(s) = 29.25 miles

COOL!

Figure 3: Project SMART, entering activity data.

the future, creating the box could be framed as a CS/CT learning activity. A student activates the box with a proximity card and then presses a button that corresponds to their activity level. The selection is transferred to the game, which computes the distance credit. RFID check-ins can be anonymous or pseudonymous [8]; in the former case, a set of RFID cards is associated with the class, and a student may use any card to check in; in the latter case, each student checks in with their own card. This design allows us to collect both aggregate data for the game and individual data that can be mapped to students' physical fitness and academic achievement for research purposes, while safeguarding student identity and privacy. As students check in, the game displays the class's activity levels in a column chart and converts the duration of the activity and the activity levels into a distance traveled.

Figure 3 shows a pair of views from a mock game for a class of 32 kids in which the class has recorded five physical activity events. The main screen shows the column chart for each activity, where each column represents the number of PA entries at a specific activity level. The inset in the figure shows a popup that appears when the teacher or students finalize an activity. Each activity level is associated with a speed; the speeds and duration are used to compute the distance traveled by the class for each activity. A math learning cue is shown after every class physical activity event is entered; this cue helps students quantitatively analyze their individual contributions to the larger goal while still maintaining student privacy (i.e., physical activity data is not individually identified). When students hover over a bar in the graph, a tooltip appears that explains how the corresponding entries were converted to distance within the game. Teachers can use these data displays to guide lessons on representing fractions and decimals, multiplying with fractions and decimals, representing rate, and interpreting graphs—all of which are learning objectives for Texas 4^{th} and 5^{th} grade students [1]. By integrating relevant and explicit computation activities related to students' own physical activity, Project moveSMART introduces students to data analysis in a way that is personally relatable.

As a class travels along its journey, it unlocks "waypoints" that contain educational content and assessments that incorporate curricular material from across disciplines. Educational content can either be embedded within the game, or be provided through links to outside resources. This flexibility allows activities delivered through Project moveSMART to take on a variety of forms. For instance, we have co-constructed learning material with elementary school content experts to align with grade-level Texas Essential Knowledge and Skills (TEKS) and Common Core learning standards. Preliminary focus group data showed that aligning the content explicitly with the required curriculum is a prerequisite for using Project moveSMART in the classroom. We have also explored tying these learning objectives into CS/CT learning activities. In a pilot study, described in more detail in Section 4, an activity that guided students through the creation of a physical activity monitor was delivered through Project moveSMART. Links in unlocked waypoints directed students to a set of tutorials and an online coding environment. Each tutorial introduced students to a specific CS/CT concept (e.g., variables, conditional statements) while guiding them through the iterative construction of a pedometer. At the end of each tutorial, students completed short assessments within Project moveSMART to solidify their understanding of the topics they had been introduced to.

We have designed the game in a way that is very flexible; each classroom can have a separate deployment that incorporates diverse modules that can include content drawn from different requirements or standards. In a given game, modules can include content from all academic subjects or simply from a subset as determined by the teacher, and individual teachers can curate the content for their particular classes. A Project moveSMART journey can also include "bonus" waypoints along the route that teachers can enable when the class's progress slows or when they want to inject new content on-the-fly.

3 PROJECT MOVESMART – THE RPP

From the inception of Project moveSMART, we have leveraged a *Community Engaged Research* (CEnR) [7] approach. CEnR is a paradigm that originated in the health sciences and transforms how research is conducted by giving voice to participants, focusing on social issues [17], acknowledging the uniqueness of vulnerable communities [4], and equitably incorporating all partners and their strengths [19]. In the model that we adopt, a community is defined as a unit that: (a) meets basic needs; (b) has a central social interaction; and (c) shares a symbolic identity [11]. The elementary school is a perfect match—in our preliminary interviews with stakeholders, one school principal told us, “schools are everything to these kids. We clothe them, feed them, and love them. We raise money to send backpacks of food home for the weekend because we know they have nothing to eat.” The elementary school, including students, teachers, and parents, is an ideal location to explore community engaged research.

Project moveSMART undertakes CEnR at the intersection of computing and health, a domain to which this style of research has not yet been applied. However, there is a natural and obvious synergy between the application of the CEnR paradigm in a school and the creation of a researcher-practitioner partnership. Project moveSMART fundamentally integrates practitioners (i.e., elementary school teachers and administrators) with researchers; our initial aims were to increase physical activity levels of elementary schoolchildren by directly connecting physical activity with the academic curriculum. While physical activity was the initial target, the academic curriculum is the conduit because teachers need to justify the use of classroom time to achieve specific learning objectives. Similarly, promoting computer science and computational thinking (CS/CT) in elementary classrooms often takes a backseat to more traditional curricular subjects. Through the Project moveSMART platform, we therefore seek to address all three goals simultaneously: increase elementary schoolchildrens’ physical activity levels, engage students in the academic curriculum, and provide an early integration of CS/CT in elementary learning. By integrating CS/CT into Project moveSMART, we present CS/CT curriculum in a way that increases students’ academic engagement and learning of computer science and computational thinking by directly connecting the academic topics to students’ physical activity. In this way, when CS/CT learning is the target, physical activity becomes the conduit.

Initially, our plan was to mimic the approach of KidsGoGreen [6] and encourage active transportation to and from school. In this conceptualization, students would use RFID badges to sign in and out at the beginning and end of a school day and indicate their utilization of active transport. However, through teacher and administrator focus groups, we discovered that our partner schools lacked the readiness to encourage active transportation since very few students actively transit to school. Further, one administrator was eager to have her students work with our team to co-construct the game but stated that using RFID badges for students to sign in to school to indicate active transport was likely out of the question, due to parental concerns relating to student data privacy, the potential for loss of the cards, risks of location tracking, and a lack of obvious benefits since most students come to school by car. Another school similarly welcomed the opportunity for teachers, students, and parents to build the application together, including support for RFID-based logging; however, the school staff encouraged a focus on physical activity within the school day rather than on active transportation. To additionally address the first administrator’s concerns related to the use of RFID cards to checkin to the platform, we also designed pseudonymous support for checkins, even with RFID cards.

Based on these initial learnings, we co-created the current Project moveSMART learning platform alongside teachers and students. From students, we have learned that they desire individual credit as a behavior motivator even though they are energetic about the cooperative aspect of working together as a class on a larger goal. Throughout the effort, students have also shared creative ideas about game incentives and motivators, including earning avatars and avatar accessories. Students themselves have expressed a desire to have a physical mechanism to “check-in” and log their activity rather than having data be passively or implicitly collected. Most interestingly, students have suggested novel ways to integrate the game with their curriculum; for instance, they suggested math problems that would use their data, and they suggested having the ability to look in on their data midday so they could plan for how physically active to be for the rest of the day. Finally, students that are part of the RPP have also shared ideas for connecting game content to other in-class activities, for instance using a tabletop experiment when exploring a wetland region or earning a dance party when the class reaches a goal.

As part of the Project moveSMART RPP, we have worked with elementary school teachers, including both classroom teachers and physical education teachers to create initial game-based journeys for 4^{th} and 5^{th} grades and to develop learning modules aligned with grade-level curricula. The RPP also includes K-12 CS/CT content experts, who have co-created the computing learning activities. As parf of the RPP, the teachers identify learning activities that align with and enrich the existing curriculum and guide how and when they integrate with the students’ journey in the game so that the timing aligns with the curriculum. Given today’s standards-based focus in schools, the teachers also requested that assessment data be collected and tracked within the game.

In a now more stable form, the partnership includes elementary school administrators, physical education teachers, 4^{th} and 5^{th} grade teachers, a K-12 computer science teacher, broadening participation in computing researchers, computer science researchers, and health education researchers. We have further collaborated with the 4^{th} and 5^{th} grade students themselves as well as with an expert in elementary education equity. The development of the Project moveSMART RPP has demonstrated that having individuals from each of these roles has been essential to the success of the project.

The school administration is necessary to ensure the project is able to navigate the district’s needs and requirements and identify key resources. Classroom teachers are essential to establishing the grade level curricular integration and understanding how game play can and does intersect with day-to-day education in the classroom. Physical education teachers are necessary to understand and navigate the interplay between academics and physical education and to identify appropriate opportunities for physical activity, while the computer science teacher assists with connecting CS/CT educational activities to existing curricula. We have found that expertise in educational equity is essential in contextualizing the activities to ensure engagement of the students. On the research side, expertise in computer science and software engineering are necessary for ensuring the feasibility of the planned interventions, while expertise specific to broadening participation in computing is needed to help ensure proper contextualization of the CS/CT curriculum for the target demographic. Finally, research that combines physical activity and elementary pedagogy is necessary to leverage the interplay between academics and physical activity, which is the linchpin for Project moveSMART.

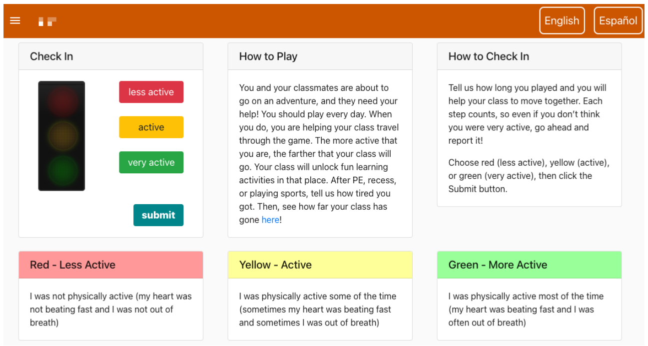
4 PROJECT MOVESMART IN ACTION

Project moveSMART has three main goals: increasing students' physical activity, improving students' understanding of computer science and computational thinking (CS/CT) concepts, and delivering content that aligns with state educational standards. However, physical activity is a typically marginalized component of the curriculum, and Texas state educational standards do not dirctly address CS/CT. This makes accomplishing the first two goals difficult, because the effectiveness of Project moveSMART depends on teacher adoption and enthusiasm. Although students can interact with Project moveSMART independently, teachers play a key role by motivating students and integrating activities into curricula. Because teachers cannot justify dedicating classroom time to activities that do not meet state standards, all content delivered through Project moveSMART must align with these standards. Project moveSMART therefore addresses its three main goals simultaneously by integrating CS/CT concepts and student physical activity with content that aligns with state standards.

In this section, we describe first how we have incrementally refined the moveSMART platform based on interactions between the members of the researcher-practioner partnership. These refinements move the delivery of the game closer to simultaneously achieving the above three goals. Then we talk in depth about the CS/CT activities that are integrated into the moveSMART learning activities and report our initial results from our first deployment of the moveSMART platform in elementary school classrooms.

4.1 Game Refinements Based on the RPP

Interactions among the members of the rsearcher-practitioner partnership (RPP) have led to continuous enhancements of the Project moveSMART platform to improve accessibility for students and practicality for teachers. By integrating the voices of students, teachers, and a multidisciplinary research team, the RPP has facilitated the creation of a platform that is better able to address the needs of the end users and progress the goals of the project.



Check In

How to Play

You and your classmates are about to go on an adventure, and they need your help! You should play every day. When you do, you are helping your class travel through the game. The more active that you are, the farther that your class will go. Your class will unlock fun learning activities in that place. After PE, recess, or playing sports, tell us how tired you got. Then, see how far your class has gone here!

How to Check In

Tell us how long you played and you will help your class to move together. Each step counts, so even if you don't think you were very active, go ahead and report it!

Choose red (less active), yellow (active), or green (very active), then click the Submit button.

Red - Less Active

I was not physically active (my heart was not beating fast and I was not out of breath)

Yellow - Active

I was physically active some of the time (sometimes my heart was beating fast and sometimes I was out of breath)

Green - More Active

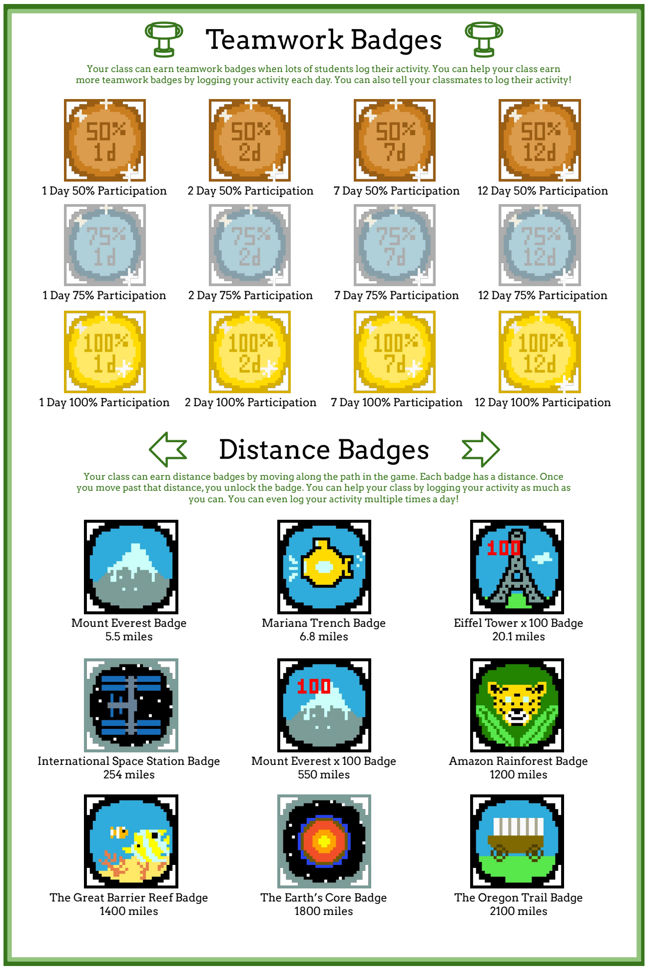
I was physically active most of the time (my heart was beating fast and I was often out of breath)

Figure 4: In-app messaging about check-in

The subject matter experts and educational and computer science researchers of the RPP regularly meet to discuss the moveSMART platform and goals. These meetings have led to insights informing project development that might not have otherwise been discovered had the team been composed of individuals with similar areas of expertise. The educational researchers and subject matter experts of the RPP often identify in-game improvements that make Project moveSMART more accessible for students. For instance, through discussions with teachers, educational researchers identified the need to better support emerging readers. Even among the fourth and fifth grade audience of Project moveSMART, an assumption of fluent reading cannot be universally made. For instance, in our partner school, in 2019, 57% of students approached or exceeded grade-level standards in reading, leaving a significant number of students in need of additional support. To address this issue, developers optimized Project moveSMART for screen reader use and changed the content of the website and in-game activities using the Flesch-Kincaid readability test [15]. While the developers had the skill set to make these changes to Project moveSMART, they would not have been aware of these tools without the input of other members of the RPP. Members of the RPP also discussed the fact that 45% of the students in the school have limited English proficiency; for this reason, the platform has a switch to transition seamlessly between English and Spanish. Because RPP meetings are face-to-face, the developers of the moveSMART platform can respond with the feasibility and estimated time to completion of these features, and the team can prioritize effort for benefit. This improves the efficiency of the development process and makes it more likely that suggested improvements will be implemented because changes can quickly be discussed.

From the outset, physical education teachers have been part of the RPP. Through collaborations with these experts, we have designed the activity levels within the moveSMART platforms to mimic daily self-reflections that the PE teachers already asked students to do upon exiting PE. These reflections help students learn to think about their own physical activity and the intensity levels they should individually be achieving. We also worked with PE teachers to develop visual communication around the activity levels, including a poster that hangs in the elementary school gym and information included within the app's check-in page (see Figure 4). To help motivate the students to achieve high activity levels, we also worked with the PE teacher to implement class-level achievement badges, as shown in Figure 5. The PE teacher also created a bulletin board with space for each class to showcase the highest badge each class had earned. The goal of this display was to encourage a low-level of competition among the classes.

Finally, to prepare for the initial deployment, the members of the RPP collaborated to develop relationships among the researchers, administrators, teachers, and students throughout the school year. This includes classroom visits (both virtually and in person) to introduce the students to the Project moveSMART platform and the integration of physical activity with classroom learning activities. It showcased the universal buy-in for the platform by the school


Teamwork Badges

Your class can earn teamwork badges when lots of students log their activity. You can help your class earn more teamwork badges by logging your activity each day. You can also tell your classmates to log their activity!

Distance Badges

Your class can earn distance badges by moving along the path in the game. Each badge has a distance. Once you move past that distance, you unlock the badge. You can help your class by logging your activity as much as you can. You can even log your activity multiple times a day!

Figure 5: Poster used in the elementary school to display badges

and their teachers (including their physical education teacher), and it introduced the students to the research team in preparation for the pilot deployment. During these visits, the team led students through a physical activity and walked them through logging that activity in the Project moveSMART platform, including modeling how to self-reflect and assess their own physical activity intensity. These visits also gave students the opportunity to ask question about how the game worked and how it was developed, to seed their interest in the coming CS/CT learning activities.

4.2 Integrating CS/CT Content in moveSMART

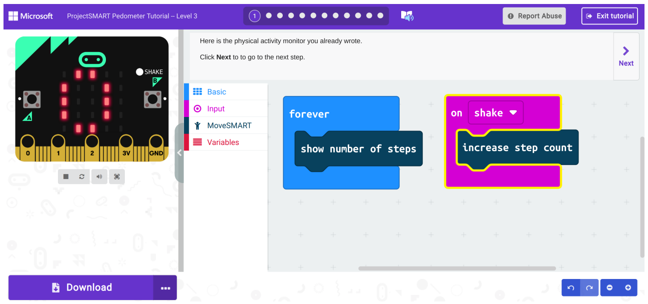
We initially launched the moveSMART platform with an integration of physical activity and classroom learning activities tied to standards across the curriculum. However, since CS/CT is not a state learning standard in the state of Texas, we did not initially integrate CS/CT learning in the platform. As part of the effort of this RPP, we developed and piloted a series of learning activities through which students create their own wearable activity monitor and integrate its reports of sensed activity levels into the Project moveSMART game.

These learning activities rely on the BBC micro:bit [2], a small computer built for educational purposes. The micro:bit is equipped with accelerometers, 25 red LEDs, and two buttons, among other features. The CS/CT learning activities we designed for Project moveSMART are meant to be completed in succession, as each one builds upon concepts introduced in earlier activities.

Using the expertise within the Project moveSMART RPP, we connected each of the CS/CT learning activities to grade-level state-learning standards and to grade-level components of the K-12 Computer Science Framework [12], a set of guidelines used to develop computer science educational standards and curricula. The K-12 CS Framework consists of both *concepts* and *practices*. Practices describe behaviors and ways of thinking that are expected of computationally literate students. Concepts are the major computer science content areas that are relevant for computationally literate students. Concepts are divided into the core concepts: *Computing Systems*, *Networks and the Internet*, *Data and Analysis*, *Algorithms and Programming*, and *Impacts of Computing*. Each core concept is further delineated by subconcepts. For instance, the Computing Systems core concept includes the *Devices*, *Hardware and Software*, and *Troubleshooting* subconcepts. By completing the moveSMART educational content, block-coding exercises, and post-tutorial assessments associated with each of the learning activities, students can quickly build an understanding of fundamental CS/CT concepts.

In general, the learning activities each start by introducing students to relevant CS/CT content delivered through age-appropriate embedded videos, text, and examples. These materials were developed through the RPP by leveraging the expertise of elementary education researchers and practitioners. After viewing this educational content, students are routed to a walk-through in the Microsoft MakeCode platform [3], a coding environment in which students can use code blocks to create programs to run on a virtual micro:bit. As an example, Figure 6 shows an intermediate step of the second learning activity, which the students undertake after learning about accelerometers in general, and how the accelerometer on the micro:bit works. As you can see in the figure, MakeCode provides a playground in which the students can experiment. The MakeCode tutorial environment also allows us to embed "hints" (see the lightbulb near the top right of Figure 6). The moveSMART research team developed a dedicated set of tutorials for MakeCode, along with moveSMART programming abstractions that allow us to hide some of the complexities of programming, which the learning activities incrementally remove as the students' programming competence and confidence grow. As an example, in Figure 6, the students use the "show number of steps" block and the "increase step count" block from the "MoveSMART" tray in MakeCode. The reason for these abstractions, at this point in the curriculum is because the students have not yet been introduced to the concept of *variables*, which is introduced later in the learning activity. At the end of each walk-through, students can easily download their completed program onto a physical micro:bit to see their program in action.

To fully integrate the CS/CT learning activities with the moveSMART platform, we also developed in-app assessments. These were requested by the practitioners within the RPP for all learning activities in the game, but they were essential for the CS/CT activities because no other forms of assessment existed for these in the



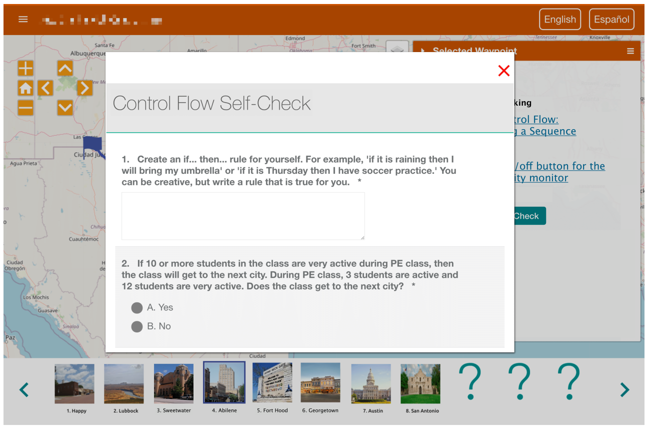
Here is the physical activity monitor you already wrote.

Click **Next** to to go to the next step.

```
forever
    show number of steps

on shake
    increase step count
```

Figure 6: The second CS/CT learning activity in moveSMART, delivered through the MakeCode tutorial platform



Control Flow Self-Check

1. Create an if... then... rule for yourself. For example, 'if it is raining then I will bring my umbrella' or 'if it is Thursday then I have soccer practice.' You can be creative, but write a rule that is true for you. *

2. If 10 or more students in the class are very active during PE class, then the class will get to the next city. During PE class, 3 students are active and 12 students are very active. Does the class get to the next city? *

● A. Yes
● B. No

Figure 7: An assessment embedded into the moveSMART platform

curriculum. These assessments integrate concepts learned during the CS/CT activities with concepts that align with state learning standards. We also leveraged the assessments implementation for evaluating the research itself, as described in greater detail below. Figure 7 shows an example of these assessments integrated into the game, in particular the assessment that follows the fourth learning activity, which introduces the students to control flow. Additionally, students used the products of their CS/CT learning activities to complete physical activity related tasks.

Below, we overview the seven CS/CT learning activities we have designed for the game. To date, we have identified these seven activities and we have integrated the first five into the moveSMART learning platform, including defining and integrating assessments associated with them. In addition, as described in more detail below, we have piloted the first two learning activities in our partner elementary school during the 2020-2021 academic year.[1]

Learning Activity 1: Introduction. The first learning activity acclimates the students to the micro:bit and MakeCode environment and guides them through creating a timer. When the timer is complete, the students work in pairs to time how long it takes each of them to complete a *Trail Making Test* [16], a cognitive flexibility measure.

Learning Activity 2: Sensing. In the second learning activity, we introduce the students to the concept of sensing, as the students create a step counter that uses the micro:bit accelerometer. Students then use the step counter to measure their physical activity during a collaborative game.

Learning Activity 3: Variables. The third learning activity introduces the concept of variables and guides students through refactoring their step counter program to use variables to store information.

Learning Activity 4: Control Flow. This learning activity introduces students to the importance of sequence and control flow in computing and connects this concept to the importance of sequence and logical flow in reading and writing. During this activity, students refine their step counter to include an on-off button.

Learning Activity 5: Rate. This learning activity introduces the concept of rate, independent of any CS/CT concepts. Students then refine their step counter even further to calculate and display their step rate by dividing the number of steps counted by the time elapsed since a button press.

Learning Activity 6: Complex Conditionals. This activity starts with a physical education lesson that demonstrates the relationship between rate and physical activity intensity. The students then refine their activity monitor to map their step rate onto a moveSMART activity level (i.e., the red, yellow, and green in Figure 4).

Learning Activity 7: Communication. In the final learning activity, the students change the Project moveSMART game itself. Rather than checking in to log their activity either with an RFID card or with using the web-based checkin, the students use a radio link to send their activity level to the checkin box shown in Figure 2.

4.3 Initial moveSMART Pilot

In the final week of the 2020-2021 academic year, we added the first five CS/CT learning activities to our active moveSMART deployment at Hornsby-Dunlap Elementary School and made them available to two 4^{th} grade classes and the entire 5^{th} grade. We joined the classes in person for their physical education lesson and guided them through the learning activities. Students worked on the CS/CT activities in pairs during a 50 minute class period. While progressing through the tutorials, students could ask teachers and the other RPP members in attendance for assistance. We worked with the two fourth grade classes in person on the first day, though because of the COVID-19 pandemic, only 9 4^{th} grade students were in attendance in person. One member of the research team engaged the virtually connected students via the remote learning platform, but they did not complete the activities with a physical micro:bit. After the visit to the fourth grade generated excitement in the school, we worked with the entire 5^{th} grade on the second day. The 4^{th} graders had been engaging with the moveSMART platform throughout the school year, so they could easily navigate the login process and were familiar with the map and navigating the website. The 5^{th} grade students had no previous exposure to the moveSMART platform.

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[1] Because of significant changes to elementary instruction in 2020-2021 due to the COVID-19 pandemic, most of our interactions with the elementary school were via virtual channels. However, in the last week of the school year, we did have one class period each with the 4^{th} and 5^{th} grade classes, where we piloted the CS/CT learning activities, with real micro:bit devices and the in-game assessments.

As a result, most of the 4^{th} grade students completed the first two CS/CT learning activities. In contrast, most, but not all, of the 5^{th} grade students completed the first CS/CT learning activity. None of the 5^{th} grade students completed the second CS/CT learning activity.

Based on these interactions and our experiences engaging these students with moveSMART throughout the school year, we made the following observations: (1) even a short intervention using the micro:bit-based learning activities has the potential to improve students' coding attitudes and (2) incremental deployment of features helped maintain engagement. Further, because the micro:bit tutorials also include physical activity components and concepts that align with state learning standards, they could be easily integrated into teachers' curricula.

Importantly, we also received feedback from the teachers with respect to the learning activities. One teacher (a physical education teacher) told us: "Initially, I thought, computer science in elementary school, it doesn't matter. After watching [the students] doing it, I was fascinated with how much they loved this activity. They initially didn't think they were capable of doing it. They had so much fun, this opened their minds to doing computer science and they really believed in themselves."

4.4 moveSMART Professional Development

A significant part of the RPP is the creation of professional development (PD) programs centered around Project moveSMART. In our initial work with elementary school teachers, we found them eager to introduce CS/CT concepts in their classrooms, but reticent to do so, primarily because of a lack of their own confidence in the material. For instance, when we asked teachers what their biggest fears about integrating CS/CT content in their classrooms were, they shared fears centered on potential technical hangups and their own (lack of) confidence in CS/CT material. For instance, one teacher characterized their fear as "comprehending enough to be able to explain it to the students", while another expressed a similar fear as "not being able to answer all of the questions". A physical education teacher expressed that they didn't want to "sacrifice skill development for a math lesson", while a classroom teacher expressed a fear of "incorporating stuff that's not in the curriculum". Therefore, the professional development sessions were designed to bolster teachers' capacity, capability, and confidence to integrate CS/CT content in the elementary school classroom in a way that dovetails rather than interferes with the regular curriculum, including the regular physical education curriculum.

Professional Development Session 1. The first of our PD sessions were hosted (virtually) in Summer 2021 across two sessions. Both sessions involved 9 participating teachers from three school districts; 6 teachers participated in both sessions. In the first session, the content focused primarily on demonstrating how to introduce CS/CT content while reinforcing the regular classroom instruction and encouraging physical activity. We presented two examples of learning activities that bring together the three principles of the Project moveSMART approach:

Activity 1. We had the participants play a modified version of the class CS Unplugged Battleship game[2]. However, rather than playing a generic version of battleship, we reframed the activity around a different 5^{th} grade learning standard: learning about explorers who visited the United States. In this activity, the students learn through gameplay about the importance of algorithmic thinking when searching and sorting. As part of the exercise with the teachers, we discussed other ways to contextualize the activity within their curriculum, including connecting to ordering relations in mathematics or to Native American tribes along the Texas/Mexico border.

Activity 2. We introduced the participants to the CS concept of conditional statements and to the importance of sequence in computing. We then asked them to create a conditional statement describing their own participation in physical activity (e.g., "**if** it is Tuesday **then** I will have soccer practice" or "**if** I run for exercise **then** I will drink more water"). Based on these starter sentences, the participants were then challenged to write a story, with details, and represent it in a six-frame storyboard. They were then asked to think about the importance of sequence in their story and then create a "buggy" version of the story by mixing up the frames. As a large group, we "debugged" the story by putting the frames back in order.

To present the learning activities, we used a variety of content, from short child-friendly video clips, brief descriptions at an elementary reading level, and guided instruction. The first activity involved the participants *being* physically active, while the second activity involved the participants *reflecting* on being physically active. Both were directly connected to grade-level state learning standards; in the first activity, the focus was on cultural studies, while the second focused on reading and writing.

After each activity, the PD session held time for discussion among the participants about how the activity could be incorporated into their classrooms, providing opportunities for peer learning and bolstering the teacher participants' confidence.

Professional Development Session 2. The second Summer 2021 professional development session was specifically focused on helping the teachers grow more comfortable and confident with the micro:bit platform. Because of the COVID-19 pandemic, the session was held remotely, but we shipped each participant a micro:bit device ahead of time. Prior to the activities, we opened the session with a group discussion about how their students can benefit from CS/CT instruction and the ways in which they already integrate some aspects of CS/CT. One of the classroom teachers told us "The kids in the demographic at our school, they don't get a lot of exposure to computer programming and the things that they can do. I've used animation in my class and coding with scratch" and that coding helped demonstrate to students "why it is important for story telling in a sequence and to be able to recall information or retell stories in a sequence." A physical education teacher relayed integrating technology in PE class, saying "I used a heart monitor and projected their activity into the gym, including the target heart rates they were shooting for, and gave them feedback on it. This seemed to especially really get girls involved and moving more." The same teacher expressed a struggle faced as well, saying "I also emailed parents about how and what [their students] were doing.

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[2] https://classic.csunplugged.org/searching-algorithms/

This helped parents get involved in caring about PE, but the biggest thing we fight in our district is Internet access."

These discussion fortified the community-based approach of the Whole Communities–Whole Health effort that Project moveSMART is a part of, and the importance of integrating CS/CT instruction in the regular school day rather than relying on extracurricular activities.

After this opening, the session moved into the activities:

Activity 1. We started with the classically silly *Robot: Make me a Sandwich* activity[3] as a simple ice breaker to get everyone thinking about computer programs as instructions in sequence. After this, the participants discussed the many ways in which sequence is important for the classrooms. One teacher observed that there are many such sequences in our lives: "cooking, getting ready in the morning, all kinds of daily activities that we don't even think about" and the physical education teachers in the room discussed the importance of sequences of steps in skill development like dribbling and throwing.

Activity 2. For the first programming activity within this session, we had the teachers complete the second learning activity in the moveSMART game itself, i.e., they followed the tutorial instructing them on using the micro:bit to make a timer. Once everyone had completed the timer, we shared the idea of having the students use the timer for activities in class and asked the teachers how they thought it might be useful. One teacher shared that the students have a list of 1000 sight words to learn; the students could use the timer while working in pairs to time how fast they could get through a partial list. Another teacher expounded that the students could also make another program that counted when the button was pressed, and the students could use a second micro:bit to count how many of the words they got correct. The physical education teachers immediately recognized the potential to use the student-built timers for pieces of the FitnessGram [22], in particular for the PACER test. Finally, several teachers wondered about using the approach to create countdown timers to help students with focus and periodic breaks, to help with social emotional learning and classroom management.

Activity 3. In the third activity, the teachers extended their approach to build the basic step counter using the micro:bit (which is analogous to learning activity 3 above).

At the conclusion of the session, the teachers again reflected on their experiences. We challenged them to continue working with the devices and shared additional grade-level appropriate resources for them to explore CS/CT concepts on their own. In the closing informal discussion, one teacher, whose class is a dual-language English-Spanish fifth grade class, wondered constructively about ways the CS/CT content could be tied into reading and writing, in particular to reading comprehension. This teacher explicitly focused in on the connection for the attention to detail in sequences from the peanut butter and jelly sandwich activity as a starting point.

4.5 Looking Forward: the Future of the RPP

In the past, interactions between members of the RPP have directly informed design decisions within the Project moveSMART platform. This is a continual process, and more recent interactions between RPP members have led to insights into ways to further improve accessibility and usability. In addition to the feedback from all RPP members, during the deployment of the five micro:bit tutorials in the 4^{th} and 5^{th} grade classes, we were able to observe students' interactions with Project moveSMART. These observations allowed us to identify specific problems that hampered student progress. Currently we are working on addressing these problems by implementing new features.

Many students, especially those who had not interacted with Project moveSMART to a great extent, had trouble logging in because they could not remember (or did not know) their moveSMART-specific username or password. To address this, throughout Summer 2021, we have implemented single sign-on authentication using ClassLink Launchpad [5], which the students and teachers in our partner school district already use to access many digital learning resources. This integration allows a smooth login process for all students in Project moveSMART.

As students completed micro:bit based CS/CT learning activities, some were confused after clicking links that led them to outside educational resources. Additionally, some students had difficulty returning to Project moveSMART once routed to an external resource, or would continue to explore links within the outside resource instead of returning. For instance, students would continue to watch recommended videos after finishing a YouTube video included within a CS/CT learning activity. To minimize this, we added functionality that allows embedding most learning content directly within the game. Now, students can access external content such as Google Docs or YouTube videos without having to leave the Project moveSMART page. Instead, these resources appear in a modal that is overlaid on the moveSMART map page. Additionally, we disabled video recommendations within embedded YouTube videos.

We also observed that some students had difficulty reading and understanding content during the delivery of the micro:bit tutorials, despite our previous efforts to address student comprehension concerns, e.g., by optimizing the platform for screen reader use and rewriting content to have grade-level appropriate readability. In the future, we will explore improving accessibility by including audio aids within the Project moveSMART platform.

5 CONCLUSION

This paper presented the first report on the workings of the Project moveSMART Researcher-Practitioner Partnership (RPP). This partnership was designed around an existing learning platform that combined physical activity with standards-aligned classroom learning for 4^{th} and 5^{th} grade students. Through the RPP we have both developed deeper relationships among the practitioners and researchers and meaningfully integrated computer science and computational thinking (CS/CT) activities. Based on preliminary feedback from teachers and our observations from a small initial pilot, we hypothesize that this three-way integration of core curricular

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[3] https://www.scientificamerican.com/article/robot-make-me-a-sandwich/

content, physical activity, and CS/CT learning will provide emphasis and engagement across all three areas of learning. The partnership continued to grow even through the COVID-19 ravaged 2020-2021 academic year, with virtual engagement among all of the RPP partners, including the elementary school students. The team completed a small pilot of the three-part moveSMART platform, with valuable pilot feedback for refinement in the summer. The team further prepared for a full roll-out through summer professional development sessions that elicited important insights and directions from the practicing teachers and opportunities for the researchers to support the teachers' growth in competence and confidence in teaching CS/CT. These efforts situate the RPP team for a full deployment in the (in-person) 2021-2022 academic year.

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REFERENCES

[1] Texas Education Agency. 2021. Texas Essential Knowledge and Skills. https://tea.texas.gov/academics/curriculum-standards/teks/texas-essential-knowledge-and-skills.

[2] Jonny Austin, Howard Baker, Thomas Ball, James Devine, Joe Finney, Peli De Halleux, Steve Hodges, Michał Moskal, and Gareth Stockdale. 2020. The BBC micro:bit: from the U.K. to the world. *Commun ACM* 63, 3 (2020), 62–69.

[3] Thomas Ball, Abhijith Chatra, Peli de Halleux, Steve Hodges, Michał Moskal, and Jacqueline Russell. 2019. Microsoft MakeCode: Embedded Programming for Education, in Blocks and TypeScript. In *Proceedings of the 2019 ACM SIGPLAN Symposium on SPLASH-E* (Athens, Greece) *(SPLASH-E 2019)*. Association for Computing Machinery, New York, NY, USA, 7–12. https://doi.org/10.1145/3358711.3361630

[4] V. Chavez, Meredith Minkler, Nina Wallerstein, and Michael S. Spencer. 2007. Community organizing for health and social justice. In *Prevention is primary: Strategies for community well-being*. John Wiley & Sons, 95–120.

[5] ClassLink. 2021. ClassLink Launchpad. https://www.classlink.com/k-12/launchpad.

[6] CLIMB. 2019. KidsGoGreen. https://www.smartcommunitylab.it/climb-en/

[7] Centers for Disease Control, Prevention, et al. 1997. Principles of Community Engagement. *CDC/ATSDR Committee on Community Engagement. Atlanta, GA* (1997).

[8] A. Garbett et al. 2018. ThinkActive: Designing for Pseudonymous Activity Tracking in the Classroom. In *Proc. of the 2018 Conf. on Human Factors in Computing Systems*. New York, NY, USA.

[9] Matteo Gerosa, Annapaola Marconi, Marco Pistore, and Paolo Traverso. 2015. An Open Platform for Children's Independent Mobility. In *Smart Cities, Green Technologies, and Intelligent Transport Systems (Communications in Computer and Information Science)*. 50–71.

[10] Google. 2016. Diversity gaps in computer science: exploring the underrepresentation of girls, Blacks and Hispanics. (2016).

[11] A. Hunter. 1975. The Loss of Community: An Empirical Test Through Replication. *American Sociological Review* 40, 5 (1975), 537–552.

[12] K12 2021. K-12 Computer Science Framework. https://k12cs.org/

[13] R. Kazhamiakin, A. Marconi, A. Martinelli, M. Pistore, and G. Valetto. 2016. A gamification framework for the long-term engagement of smart citizens. In *IEEE International Smart Cities Conf.* 1–7.

[14] R. Khoshkangini, G. Valetto, and A. Marconi. 2017. Generating Personalized Challenges to Enhance the Persuasive Power of Gamification. In *International Workshop on Personalizing Persuasive Tech.*

[15] J.P. Kincaid, R.P. Fishburne, R.L. Rogers, and B.S. Chissom. 1975. Derivation of new readability formulas (automated readability index, fog count, and flesch reading ease formula). *Navy enlisted personnel. Research Branch Report* (1975), 8–75.

[16] Ralph M Reitan. 1986. *Trail Making Test: Manual for administration and scoring.* Reitan Neuropsychology Laboratory.

[17] R. Sen. 2003. *Stir It Up: Lessons in Community Organizing and Advocacy.* John Wiley & Sons.

[18] Texas Education Agency. 2019. Texas Accountability Rating System. https://rptsvr1.tea.texas.gov/perfreport/account/index.html

[19] N. Wallerstein, Bonnie Duran, John G. Oetzel, and Meredith Minkler. 2017. *Community-Based Participatory Research for Health: Advancing Social and Health Equity.* John Wiley & Sons.

[20] Jennifer Wang and Sepehr Hejazi Moghadam. 2017. Diversity barriers in K-12 computer science education: structural and social. In *Proceedings of the 2017 ACM SIGCSE Technical Symposium on Computer Science Education.* 615–620.

[21] WCWH 2021. Whole Communities Whole Health. https://bridgingbarriers.utexas.edu/whole-communities-whole-health/

[22] GJ Welk and Marilu D Meredith. 2008. Fitnessgram/Activitygram reference guide. *Dallas, TX: The Cooper Institute* 3 (2008).

Hadad, R., Ryoo., J.J., Flapan, J., & Ramsey, C. (2021.) Defining and Delivering Equity: How one RPP develops a definition and puts it into practice. In CSforALL & SageFox Consulting Group (Eds.), The intersection of RPPs and BPC in CS education: A culmination of papers from the RPPforCS Community [White paper]. Retrieved from https://doi.org/10.13140/RG.2.2.28768.61440

Defining and Delivering Equity

How one RPP develops a definition and puts it into practice

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ABSTRACT

Computer science (CS) has the potential to positively impact the economic well-being of those who pursue it, and the lives of those who benefit from its innovations. Yet, large CS learning opportunity gaps exist for students from systemically excluded populations. Because of these disparities, the Computer Science for All (CS for All) movement has brought nationwide attention to inequity in CS education. Funding agencies and institutions are supporting the development of research-practice partnerships (RPPs) to address these disparities, recognizing that collaboration between researchers and educators yields accurate and relevant research results, while informing teaching practice. However, for initiatives to effectively make computing inclusive, partnership members need to begin with a shared and collaboratively generated definition of equity to which all are accountable. This paper takes a critical look at the development of a shared definition of equity and its application in a CS for All RPP composed of university researchers and administrators from local education agencies across a large west coast state. Details are shared about how the RPP came together across research and practice to define equity, as well as how that definition continued to evolve and inform the larger project's work with school administrators/educators. Suggestions about how to apply key lessons from this equity exercise are offered to inform similar justice-oriented projects.

CCS CONCEPTS

• Applied Computing • Education

KEYWORDS

Equity, Research-Practice Partnership, Computer Science Education

1 Introduction

As the computer science (CS) education community confronts our history of inequitable teaching practices, structures, and policies that have resulted in Black, Latinx, Indigenous, low-income, and female students being left out of CS classes and career opportunities, the field has begun to translate research into practical applications in its initiatives. Yet there is neither a clear nor shared definition of "equity" within the field of CS education, and even less so across communities of CS education researchers and practitioners. This experience report helps to fill this gap by describing how our research-practice partnership (RPP) composed of district and county office administrators and university researchers - SCALE-CA - collaboratively developed a definition of "equity" that served as a touchstone for how we enact it in the development of resources for educators, administrators, and policymakers. The larger goals of our RPP are to scale teacher professional development, build the capacity of education leaders for local implementation, and contribute to the research base on expanding equity-minded CS teaching and learning opportunities across the state of California. The focus of this project is to build leadership capacity to ensure that equity is kept at the core of CS education expansion efforts, and our RPP has successfully created and piloted a CS Equity Guide with a corresponding Administrator Workshop (described in greater detail below). Our specific RPP was first composed of researchers five early-adopter district or county offices, otherwise known as local education agencies (LEAs). These early adopter LEAs are Compton Unified School District, Los Angeles Unified School District, Riverside Unified School District, Sacramento County Office, and San Francisco Unified School District. After the first year, the partnership expanded to seventeen LEAs that represented the varying demographics, geography, and sizes of the state's diverse school system. The additional twelve LEAs are Elk Grove Unified School District, Glenn County Office of Education, Kings County Office of Education, Los Angeles County Office of Education, Modesto City Schools, Riverside County Office of Education, San Bernardino County Superintendent of Schools, San Diego County Office of Education, San Joaquin County Office of Education, Santa Barbara County Education Office, Stanislaus County Office of Education, Valley Center High School.

In this paper, details about RPPs (including our specific RPP) and the need to focus on equity are shared to provide context. This is followed by: 1) a description of the ideas informing our own RPP's effort to define equity so that it could guide our CS education activities, 2) the step-by-step process we used toward defining equity, 3) how that definition continues to evolve, 4) key lessons learned through this exercise, and 5) suggestions for how to apply these lessons to similar equity-focused projects

2 Background

Within the past decade, the CS for All movement has been turning to RPPs as a means for supporting the growth of new curricula, professional development, and CS implementation efforts while simultaneously ensuring the creation of new knowledge that can be immediately useful to both practitioner and researcher communities. RPPs are collaborative partnerships between practitioners and researchers that investigate the education community's problems of practice and their solutions [1]. Since 2017, more than 70 RPPs have been funded by the National Science Foundation alone, and many others through various funding agencies. All NSF-funded RPP projects, specifically, not only focus on CS education, but the goal of broadening participation in computing. The focus on broadening participation is meant to address the stark inequities that exist in computing education, as well as computing as a profession [2].

Our RPP came together because we share the belief that all students deserve equitable access to high-quality CS education. Yet while many important advancements have been made in recent years to create more culturally responsive curricula and improve teaching practice through equity-minded professional development, the CS for All movement still lacks adequate support for school leaders and administrators whose decisions have major implications for whether or not students even have computing classes in their schools. To fill this gap, our RPP developed two leadership-focused resources. The CS Equity Guide (https://csforca.org/csequityguide/) was intended to assist administrators looking for practical steps and resources for equitable CS implementation in their schools, districts, and counties. After starting with the experiences of administrators from two early-CS-adopter districts, researchers interviewed administrators from other districts and counties throughout the state and grouped the content into categories and produced a 46-page guide that was available via download or print. Chapters included Developing Pathways; Students and Recruitment; In the Classroom; Preparing and Supporting Teachers; Funding; Family, Community, and Industry; and Out-of-School Learning. After feedback from the first version was analyzed, a second 54-page iteration of the guide was released a year later.

Because administrators wanted further support in using the CS Equity Guide, the RPP also developed an Administrator Workshop to help them examine bias and make decisions that affect equity in their classrooms. Since its pilot in 2019, iterations of the workshop have been implemented every six months. This Administrator Workshop has also been part of the Summer of CS, a multi-stakeholder California-focused PD experience for teams of teachers, administrators, and school counselors. Three iterations of the Summer of CS have now taken place in 2019, 2020, and 2021.

Yet what exactly does it mean to support administrators in implementing equity-minded CS through an Equity Guide and Administrator Workshop? What does "equity" mean within the context of these resources? And what does equity mean within the context of the RPP creating these resources?

We believe that in order for equity to be a focus of RPP efforts, it must also be a central tenet built into the RPP's research and learning processes; deliberate actions must be made to honor each partner's funds of knowledge, values, language, and experience. When equity is operationalized intentionally in an RPP, both practitioners and researchers feel that their input and interests are valued [3]. By challenging the structural hierarchy that oftentimes prioritizes the problems and the knowledge base of the researcher above that of the practitioner, RPPs can elevate the practitioner's needs and experience to produce more relevant research and outcomes [4]. RPPs should not only honor the expertise of practitioners, but allow for the critical examination of how power and culture can impact research and education implementations [2, 3].

Santo et al. [5] have documented how this equity-minded approach of an RPP's architecture can produce "participatory knowledge building", in which the joint development of artifacts produces much more than the artifact itself. By positioning the practitioner as collaborator, research teams produce shared language and a shared orientation toward knowledge building that elevates practitioner experience. Using equity as a foundation for their internal infrastructure facilitates RPP's focus on equitable environments and outcomes for students.

Building on these ideas, our CSforAll RPP sought to collectively make sense of "equity" as a foundation on which to build our equity-focused efforts. From the start, our RPP acknowledges that the word "equity" could have multiple meanings and that concerted effort must be made to ensure that the word was not being "deprived of its dimension of action" or simply "idle chatter...an empty word, one which cannot denounce the world, for denunciation is impossible without a commitment to transform, and there is no transformation without action" [6, p. 68]. This is because the term "equity" has been increasingly used in the field of education, but in a range of ways and contexts. In general, "equity" has signaled commitments, efforts, and research focused on challenging the inequalities experienced in educational contexts. However, exactly which aspects of inequality and oppression are actuated in the definition of equity reflect a large range of ideas, resulting in many disparate definitions for the term "equity." The concept of "equity" is exactly the "verbalism" and "idle chatter" that Freire refers to if it is not rooted in commitments to transformation through action. "Equity" cannot be fully understood and meaningful without praxis between reflections upon the concept in theory, and understandings of its practice in action.

Thus, our RPP engaged in a collaborative sense-making process in which researchers and practitioners could engage in praxis that would make the idea of equity come to life in our shared work. We wanted this term to embrace both reflection and action--theory and practice--that both researchers and practitioners brought to the table. And we sought to do this through dialogue, which Freire explains, "is the encounter in which the united reflection and action of the dialoguers are addressed to the world which is to be transformed and humanized, this dialogue cannot be reduced to the act of one person's 'depositing' ideas in another, nor can it become a simple exchange of ideas to be 'consumed' by the discussants" [6, p. 69-70]. To ensure such authentic dialogue, we thought it necessary to engage in making sense of equity from our various roles, responsibilities, experiences, and perspectives, while simultaneously couching the effort in the project we were about to embark upon (namely, developing an equity guide and workshop for administrators, supporting professional development for teachers, etc.).

Of course, such work together came from a standpoint of valuing each other's various positionalities and perspectives within the RPP and not holding academic knowledge or theory as more important than the ideas of administrators/educators. In Teaching to Transgress, hooks [7] cites Freire to describe the necessity of "intellectuals" to challenge such power hierarchies toward praxis in which all "help each other mutually, growing together in the common effort to understand the reality which they seek to transform" (p. 54). This is particularly important because researchers often take on the "privileged act of naming" ideas in the world, and have the power to "project an interpretation, a definition, a description of their work and actions, that may not be accurate, that may obscure what is really taking place" [7, p. 62]. Thus, in our RPP we believed it important to share this "act of naming" to ensure that the ways we understand and therefore position our efforts toward the concept of "equity" authentically reflects both researcher and practitioner problems of practice. Such can only be done through praxis.

3 Developing the Definition

The RPP began in 2018 with university researchers and administrators from five LEAs. When we first gathered to kick off the partnership, we spent two days defining the problems of practice we wanted to focus on in order to address equity in CS education. Nearing the end of the second day, the fourth author, an administrator from a large urban school district asked, "But how are we defining 'equity'?" We realized that we had begun our work without addressing this foundational element. By working out how we would define "equity" as a group, we could acknowledge and honor the voices, perspectives, and cultures of all stakeholders on our team to enhance the capacity of our mission. We would also have the language and understanding necessary to describe the policies, practices, and behaviors to promote CS education with equity as the base.

The RPP agreed to meet monthly after the kickoff to address the challenges. But we felt we first had to develop a process to co-create a definition of equity among the RPP. The fourth author had been through the process of collaboratively defining "equity" at his district, and led the process for SCALE.

First, both university researchers and school leaders were sent an email to individually generate perspectives on equity based on personal held beliefs, literature or research of interest, and LEA/institutional definitions:

> "As we continue our work with SCALE-CA, we would like to gather each organization's working definition of equity. We understand that some organizations do not currently have a definition of equity. For those of you in organizations without a district/county definition, please provide us with your personal definition. The form can be accessed HERE [link to Google form] and your response is needed by the end of business on Feb 11th. We are hoping to gather the unique definitions of equity from all stakeholders and have a conversation about developing a single, community-based definition of equity. This will hopefully help us to uncover what it means to provide equitable learning opportunities as a part of SCALE-CA."

The Google form that was linked to the email included a field for their name, organization, and their or their organization's definition. Partners were then randomly paired off and asked to meet on their own time to share and discuss their personal definitions. The pairs were made up of researchers with practitioners, or practitioners with practitioners, but never two researchers together. In these 2-person meetings, partners explored underlying values and divergent elements of equity beliefs, combining core values to produce a shared definition. Partners met together in brief or extended encounters up to an hour. Each pair then submitted their definition to a second Google Form that had a field for each partner's name and their definition for equity.

The joint definitions submitted varied widely in both length and content. They ranged from 30 words long to 400 words long. Some definitions included specific deliverables to aim towards for equitable implementation of CS, e.g. outlining how the RPP intended to approach the inequity through the CS Equity Guide, the multi-stakeholder professional development, and informing policymakers. Other definitions were more general, using broad strokes to define equity (e.g. "Equity is accomplished when access is based on need, and every student is provided with what they individually require to learn and succeed to fulfill their academic and social advancement"). There were definitions that focused on an approach to equity (e.g. "Equity requires interrupting inequitable practices, examining biases, and creating inclusive environments for all, while discovering and cultivating the unique gifts, talents and interests that every person possesses"), while others were focused on the results of equity (e.g. "When success and achievement are not predictable by any demographic factor, equity is accomplished"). While all of the definitions were focused on students, and getting them what they need, one definition also included what equity meant to them in terms of partnership between the different collaborators on the project (e.g. "... we seek to maintain positive and equitable relationships between researcher and District/LEA partners").

Following these two-person meetings, the larger team gathered for an hour and reviewed all of the definitions that each pair came up with by going over the summary of responses in the Google Form, discussing themes and differences. Partners who had very different definitions mentioned how much they enjoyed the process, as it not only helped them “gel” with one another, but it also allowed for interesting discussions about inequity and how their respective organizations were addressing it. One of the practitioner partners wanted to know how actionable vs how aspirational the defining of equity should be, especially for practitioner partners in districts like hers that are facing many challenges because their students have needs related to healthcare, housing, and food insecurity. She wondered if there were different stages of equity stated that you cannot define equity without having any access at all. After hearing this from her practitioner partner, a research partner recalled hearing from a speaker at a conference that “if you are in it for equity in computer science, you have to be in for equity in everything. You cannot just be an equity for computer science,” and she continued by saying that “equity is really meeting students where they are and offering those supports, but we also have to understand they are coming from very unequal systems at our door. And so how do we acknowledge that? And again, what is it that we can actually do? And what is our vision and hope for the future?” Other partners discussed the need to make a distinction between equity and equality, and to ensure that the process is cyclic, “constantly going back and saying, ‘What do students need now?’”

The discussion ended with a focus on next steps, with the idea of everyone returning to another discussion with their partner to reexamine their definition in light of the group discussion. The practitioner partner who brought up the point of the actionable vs the aspirational notion of equity had concerns about how long the process of defining equity within the group would take, when there was so much work to be done in her district. It was then decided that only if they had available time, the pairs could again work together on their definition, and then submit it to another Google Form.

The RPP reconvened three weeks later for an hour-long meeting, fifteen minutes of which was devoted to the equity definition. One of the researcher partners started the discussion off by saying she thought that an assumption being made was that anyone striving for equity believes that the system is unequal, and not everyone believes that it is, and that not everyone recognizes that inequality can be furthered through our own biases and stereotypes.

The next step was supposed to be that everyone voted on the partner-pair definition they thought best captured equity, after it being adjusted according to other definitions. But not everyone understood that they could access the other definitions and take from them, so the poll was conducted, but not taken very seriously. It was then decided that there should be a subcommittee to complete the definition, but then the process was redirected so that the various definitions would be amalgamated by the university team into one definition. This part of the process was led by the university research team in an effort to respect the time of our busy practitioner partners who had already devoted sometimes up to 4 hours to the process. The definition combining all the various aspects of definitions across the group was then shared via a Google Doc. Partners then submitted their edits before the next meeting, which was one month after the second meeting. The research team adjusted the definition based on the edits submitted.

At the third meeting of the RPP, the first fifteen minutes were again devoted to the definition. The definition was read aloud, and then partners asked clarifying questions about certain sections of the definition. One of the research partners wanted a better understanding of what the term “social advancement” and what it referred to. Another research partner wanted to clarify whether the definition should generally be about equity, or specifically about equity in education, or equity in CS education. It was decided that the definition should stay the way it was, starting off defining equity in education and then focusing on equity in CS education. At the end of the discussion, partners agreed to return to it later. Edits to the definition were again made by the research team and shared with the entire RPP via Google Docs.

The definition is as follows:

> Equity is accomplished when every student is provided with what they individually require to learn and succeed in fulfilling their personal, academic, and social advancement, and when success and achievement is not predicted by any demographic factor. This requires continually interrupting inequitable practices, examining biases, and creating inclusive environments for all, while discovering and cultivating the unique gifts, talents and interests that every student possesses.
>
> Equitable practices are based in the belief that every child’s educational experience should be rigorous and relevant, and that everyone is capable of learning. These beliefs require providing a learning environment that is safe and respects every student.
>
> While often used interchangeably, equality and equity are not the same. Equality suggests that all people should simply have access to the same resources, regardless of need. With equity, resources are distributed according to different students’ needs, while taking into account how certain students have been systematically denied access to educational resources, opportunities, and experiences based on race/ethnicity, gender, sexual orientation, socioeconomic class, and disability. An equity-based approach means acknowledging and challenging: 1) the institutional barriers impacting youth differently based on the way they look or where they come from, 2) countering practices rooted in stereotypes about who can or should excel, and 3) recognizing that people both present themselves and are treated differently in different contexts depending on how their various identities overlap and intersect. This requires an ongoing and cyclical approach to examining factors impacting youth’s experiences.
>
> Computer science and computer science education have been documented as being highly segregated along race/ethnicity, gender, and socioeconomic lines due to a lack of access to high-quality computer science learning

> opportunities for all students. However, an awareness of equity issues in the computer science education community presents an opportunity to structure learning opportunities and environments with equity considered throughout the progression from K-12, as frameworks, policies, and courses are being built. Not only is computer science an emerging field of study that leads to high-wage and high-demand careers that can address socio-economic inequality, but it can empower students to be critical users of technology and creators in all fields touched by technology, finding their voice in the digital environment that is becoming increasingly part of our communities.

An abbreviated definition with only 131 words was also created to be utilized when space was limited in publications and presentations.

4 Lessons Learned

The first lesson that our RPP learned is how important it is to build the partnership in an exercise that grounded everyone in a shared understanding of equity. If equitable CS education was the ultimate goal of the RPP, then partners needed to have a shared definition of what that means and looks like. Luckily one of the administrator partners jump-started the RPP in this direction, but if we had the opportunity to try this again, the practice of defining equity together would have been one of the first things we did at our 2-day kick off meeting, rather than following that initial time together. It would also have been beneficial to start the defining process with an activity that illustrated systemic inequity and personal bias before beginning the process of developing the definition.

The process of developing the definition immediately after the group was newly formed, as opposed to making time for it at the start of group-formation, was challenging. The practitioner partner that voiced concern over the time the process was taking never returned to another RPP meeting. She explained to a research partner that as a busy administrator, she was interested in what actions the group was going to take to improve outcomes in her district and other districts, and not in what she saw as an academic exercise of defining the term "equity." Perhaps if we had made sure to prioritize this topic as a partnership-building activity at the start of forming the RPP, and used the activity as a way to then frame our 2-day kick off meeting, she may not have seen the exercise as so "academic." Her reaction, however, serves as an important reminder of the need to ensure that these types of activities make clear connection to immediate use, practical purpose, and better align with practitioner time and needs.

Still, many in the RPP valued this process of defining equity together, and the need itself was identified by a practitioner partner (last author of this paper). The value that the majority of partners saw in this effort to define equity together suggests the importance of authentically drawing on practitioner experiences, values, and understandings to guide shared efforts in CS. One of the practitioner partners stated:

> "I think we saw strengths from the different definitions. We … worked to match the things that we liked the most. One of the conversations we had was based on some cultural and contextual differences of our districts, like [my] district is very progressive and goes out of the way to identify each kind of underrepresented or potentially marginalized group, and how factors of systemic oppression contribute to that, and it was very detailed. And so we tried to find that balance of how do we acknowledge systemic oppression and broader factors, while still keeping, I don't know ... something that's a little more tight. And we're pretty happy with how it ended up."

Furthermore, we found the definition served as useful in our CS Equity Guide, as well as for informing our Administrator Workshop and multi-stakeholder professional development activities. The definition was used in the first section of the guide, explaining to the reader how we envisioned equity in relation to education and CS education, specifically, and how the answers to the questions in the guide reflected this understanding. The Administrator Workshop and Summer of CS were structured to address the definition's issues of individual bias as well as systemic inequity.

After the murder of George Floyd, some members of the RPP pointed out that while the expansion of the RPP aligned with our understanding of equity in that the represented districts were more diverse, there was a lack of administrators of color in the RPP. We focused on ensuring that the group was composed of administrators in LEAs that represented the varying demographics, geography, and sizes of California's diverse school system. However, using these variables as metrics including partner LEAs resulted in creating a group of administrators with demographics that were not representative of the state. We were intentional about including more administrators of color in our partnership, but our struggle in doing so points to a larger problem of a lack of administrators of color throughout the state. We also need to work to ensure administrators with disabilities and LGBTQIA2+ administrators are included in our RPPs to ensure equity in all its dimensions.

Finally, the consideration of what the collective considers equitable implementation should be reexamined regularly. So much has happened in the short life of this RPP -- the COVID pandemic, the Black Lives Matter protests, the January 6 insurrection, the rise of White supremacy, the upsurge of voter suppression, and legislative action to resist discussing our country's racial history in schools -- that few of us look at equity in the same way we did when RPP first began. For this reason, we have committed to looking at our definition more often, in order to consider where we may have previously overlooked what is contributing to inequity, whom it is affecting, and how it is affecting them.

5 Discussion

The events of the past couple of years have shifted our understanding of what equity is and how it is manifested in different ways, whether in education, economics, climate or criminal justice. By using real examples to reflect on what equity is, we make it less abstract and can consider tangible solutions for how to deal with an ever-changing world. Examining actual instances of inequity brings into relief the realization that you cannot have equity in one discipline or one school without equity in society as a whole. We cannot be thinking about equity in CS alone, but instead we must consider how CS is situated within the larger context of an inequitable society.

In order to move definitions of equity beyond just academic exercises, it is important for us to revisit our definitions regularly and evaluate whether they correlate with the reality our students and teachers contend with, as well as whether we are doing what is necessary to eliminate systemic inequity. As Martin stated, conceptualizing equity as a process “highlights the fact that the necessary hard work will be ongoing and even when gains are made, a high degree of vigilance will be necessary to ensure that needs of marginalized students are attended to and that our definitions of equity are responsive to who these students are, where they come from, and where they want to go in life” [8].

We are currently reexamining this definition of equity as an RPP, and it has become increasingly clear that defining the word is not enough. Our examination of “what is equity?” is becoming more of a vision and a call to action, because actual equity involves moving beyond platitudes and idyllic notions of equality. It is a process that is difficult and sometimes painful. The very notion of defining equity requires action, moving the concept from an ideal to implementation. This realization should perhaps come as no surprise, as this RPP is focused on implementation, however, we hope to capitalize on bridging the definition with a collective vision, and a call to action. As a living, breathing and changing definition, the process and the product is coalescing our team as we collectively work to advance equity in education with computer science as our lens.

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REFERENCES

[1] Cynthia E. Coburn, William R. Penuel, and Kimberly E. Geil. 2013. Research-practice partnerships: A strategy for leveraging research for educational improvement in school districts. New York, NY: William T. Grant Foundation.

[2] Stacey Sexton and Rebecca Zarch. 2020. An RPP Approach To Computer Science Work. National Network of Education Research-Practice Partnerships Extra, 2(1).

[3] Jill Denner, Steve Bean, Shannon Campe, Jacob Martinez, and David Torres. 2019. Negotiating Trust, Power, and Culture in a Research–Practice Partnership. AERA Open, 5(2), 2332858419858635.

[4] Jean J. Ryoo, Michelle Choi, and Emily McLeod. 2015. Building equity in research-practice partnerships. Retrieved from http://researchandpractice.org/wp-content/uploads/2015/10/BuildingEquity_Oct2015.pdf

[5] Rafi Santo, Daisy Ching, Kylie Peppler, and Chris Hoadley. 2017. Participatory knowledge building within research-practice partnerships in education. SAGE Publications Ltd

[6] Paolo Freire. 1970, 1997. Pedagogy of the oppressed. Bloomsbury publishing USA.

[7] bell hooks. 1994. Teaching to transgress. Routledge.

[8] Danny Bernard Martin. 2003. Hidden assumptions and unaddressed questions in mathematics for all rhetoric. The Mathematics Educator, 13(2).

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High School Teachers Teaching Programming Online: Instructional Strategies Used and Challenges Faced

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ABSTRACT

Goode et al. [10] consider preparing thousands of teachers with high-quality, accessible professional development as a grand challenge. High School students currently take computer science courses through North Carolina Virtual Public Schools (NCVPS) due to the lack of offerings and unavailability of teacher expertise at their local schools. Through this Research to Practice Partnership (RPP) with NCVPS, we plan to design and offer online professional development for teachers across North Carolina to teach AP Computer Science Advanced courses. This paper discusses the findings from a needs assessment focus groups with 14 teachers from NCVPS.

High school teachers who teach programming online were asked to reflect on the instructional strategies used, and the challenges faced. Teachers' instructional strategies included using College Board materials, creating tests and assessments, creating code, providing practice opportunities, videos, lectures, different types of online compilers, learning blocks in announcements, and infographics. The teachers reflected on the challenges that both students and teachers face in an online computer science course. Some of these challenges included finding good free-response questions as students locate answers on the web, teachers programming skills not being strong, need to train new teachers thoroughly, the challenge of connecting with students in asynchronous format, establishing instructor presence, student technology issues due to Wi-Fi and hardware, student time management and motivation issues, and student integrity issues in the online environment. The findings from this need assessment assists in informing the research team on the creation of online professional development for high school teachers. It also benefits those who are currently teaching Computer Science or those who wish to teach Computers Science on the instructional strategies and challenges.

CCS CONCEPTS

• **Applied computing → Distance learning**; • **Social and professional topics → Computer science education**; **CS1**; **K-12 education**.

KEYWORDS

AP Computer Science A Course, AP Computer Science Principles Course, High School Computer Science Teacher, Online Education, Research- Practitioner Partnership, Computer Science, online teaching, teacher challenges, student challenges, COVID-19

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1 INTRODUCTION

Over the last decade, significant technological advancements have shifted the world as it operates, resulting in creating careers that are now available for students after graduation [27]. Many jobs in Computer Science have existed for years, such as software and web developers. Still, according to Computer Science Zone [26], there are several new positions within the Computer Science field

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that are projected to see a sharp increase within the next ten years. For example, Computer and Information Research Scientists are forecasted to see a 22 percent job growth projection over the next ten years, significantly faster than the average for all occupations [30].

As the United States continues to rely on technology and its advancements, we see a noticeable interest increase among high school (CS for All) and college-aged students entering technology-focused careers. The number of students registering to take computer science courses increases every year, resulting in an increased demand for high schools, colleges, and universities to offer computer science courses. However, due to increased course demands and the allures of the convenience and flexibility in distance learning (DS), many introductory courses are now being offered through distance learning programs [15]. Additionally, virtual computer science opportunities have become more popular, partially due to the COVID-19 pandemic. However, the push to include basic Computer Science skills into the national primary and secondary curriculum (CS for All) can also be attributed to the United States government's efforts to introduce Computer Science ideas at an earlier stage in a student's formal education to promote future interest in technology-focused careers [16][28][36]. According to Buckingham [6] and Yadav et al. [35], the underlying goal of injecting Computer Science principles into K-12 education is to promote an early shift in our students from being solely consumers of technology to being creators and producers in the technological field.

Furthermore, the increase in online Computer Science opportunities has become more popular as many school districts have begun offering online high school courses, as seen in examples such as the North Carolina Virtual Public High School. However, several challenges are associated with teaching Computer Science online [36]. To be successful in a virtual setting, teachers must successfully use multiple instructional strategies to teach Computer Science. These challenges impact and create hurdles for the students enrolled in the online Computer Science course and affect those who choose to teach Computer Science online both at the high school and college level.

1.1 Advanced Placement Computer Science Principles (AP CSP) and Advanced Placement Computer Science A (AP CSA)

Several studies have been conducted regarding the new Advanced Placement (AP) Computer Science Principles (CSP) College Board course and related examination. AP Computer Science Principles was introduced in 2016 and was the most significant course launch in AP Program history to date. According to the College Board, AP Computer Science Principles is an introductory college-level computing course introducing students to computer science. As students' progress through the course, they learn to design and evaluate solutions and apply computer science to solve problems by developing algorithms and programs. They incorporate abstraction into programs and use data to discover new knowledge. Students also explain how computing innovations and computing systems—including the internet explore their potential impacts and contribute to a computing culture that is collaborative and ethical.

According to College Board, the AP Computer Science A (AP CSA) course is an introductory college-level computer science course designed to cultivate student's understanding of coding through multiple modalities. Students are given tasks to support their ability to analyze, write, and test code as they explore concepts like modularity, variables, control structures, and object oriented throughout the course. While there is no set order in which to take these courses, considerable research [34] supports that students should begin their computer science education by taking the College Board course, AP Computer Science Principles (AP CSP).

1.2 Teaching Computer Science Online

Teaching Computer Science in an online environment provides students and teachers with a unique opportunity to engage in ways that differ from traditional face-to-face instruction. With this novel approach to teaching, conventional teaching methods in face-to-face instruction are not always the best fit for students in asynchronous, synchronous, or hybrid situations. As teachers prepare to teach online, they must also employ instructional strategies suited for online instruction and course design. It is also worth noting that many teachers are not prepared to engage in best practices for online teaching in their preservice teacher preparation program. The norm among most universities is that most teachers will be teaching in traditional face-to-face settings, and those graduating from traditional teaching colleges may not be prepared to teach online courses. However, additional research shows that online courses are becoming increasingly more popular among higher education for numerous reasons [1].

If teachers are not adequately prepared before entering the teaching profession, they may encounter challenges once they begin teaching online. Within the context of teaching Computer Science online, teachers may be presented with challenges related to lack of familiarity with instructional strategies geared towards online learning, challenges with the content material, lack of appropriate and engaging materials, and various other technological difficulties both on the side of teacher and student. Online teachers must stay informed of the current literature to best support their students and assist in their completion and success in online coursework.

Regardless of the course content or subject matter, the literature shows definite challenges for students taking online courses. Similar to the struggles teachers may face engaging in an online teaching opportunity, students may face similar challenges participating in an online course. The studies conducted over the last fifteen years show alarmingly high dropout rates and overall achievement problems in online classes [19][25][29].

1.3 Instructional Strategies to Teach Computer Science Online

According to Moore [24], instructional strategies are tools teachers use to help students become independent and strategic learners. Instructors intentionally select instructional strategies to support students' goals and align with the course objectives outlined in the syllabus or planning document. Instructional strategies are strategically chosen depending on the course level, the instructor, and the students taking the course. However, instructional strategies include instructors providing detailed directions, in-depth and complete lessons, various instructional approaches and materials, and an opportunity to practice the skills taught in a context related to the student's lives. Additionally, as Gregory and Chapman [11] demonstrated, there is no "one size fits" approach to education, which applies when selecting appropriate instructional strategies. Differentiated instruction is a required best practice when teaching in all educational situations, regardless of the content area, which means that the method of differentiation is appropriate and necessary when teaching Computer Science, online, and in traditional face-to-face settings. There is limited research to support specific research-based practices designed for Computer Science courses. However, several of the sources suggest adapting well-known general instructional strategies to fit the needs of your content and learners. Engineering is Elementary (EiE), a curricula division of the Museum of Science, Boston, recommends multiple instructional strategies to teachers to support student learning, such as providing visual aids for students (multiple modality learning), encouraging students, and building comprehension into coding projects [4]. Additionally, EiE recommends promoting activities that encourage peer-to-peer support, situating tasks in a real-world context, providing opportunities for students to collaborate and share, and building a "growth mindset" in students. According to Watson[33], while the recent increase in online opportunities has prompted online instructors to share instructional strategies that have been successful in their classrooms, they also suggest instructors ask students to identify online instructional practices and strategies that they felt were successful. Seeking out students as experts in online learning presents a unique perspective of successful online teaching strategies.

1.4 Teacher Challenges during Teaching Computer Science Online

It is well known that teachers in any situation have to be flexible to meet the needs of their students, and Computer Science teachers, especially those teaching through online platforms, are no exception. The challenges teachers commonly encounter while teaching traditional face-to-face instruction are exacerbated when the course modality is changed to online teaching as many of the possible solutions to supporting students are no longer available. The literature states three common challenges among Computer Science teachers that also apply to those teaching online: content challenges, pedagogical challenges, and assessment challenges [35]. According to a study by Yadav et al. [35], the results indicated that teachers faced several challenges while teaching Computer Science, citing difficulty gaining proficiency in the course content and the pedagogical aspects of teaching computer science. Reflection included from the participants accredited their lack of formal Computer Science training to their difficulty facilitating the course and limiting their ability to support their students when providing detailed or complex explanations. Within this same study, the instructors noted a significant challenge while teaching Computer Science to high school students: the lack of assessments created to gain accurate information into learning gaps. While the lack of evaluations provided difficulty, many stated the challenge was finding standardized reviews or "quick checks" that accurately assessed skills in isolation to support targeted reteaching. While teachers are experiencing curriculum and pedagogical challenges within their classrooms, they are also navigating the aftermath of a curriculum shift without the accompanying preparation for pre-service and veteran teachers. Vivian et al. [32] highlight the necessary professional development training and curriculum adaptations in teacher preparation that need to take place to accurately and effectively teach students the new content standards and curriculum. Bender et al. [3] mirror the challenges associated with the content shift but extend the impact of those challenges to include their effects on teachers' morale, motivation, and sense of ability to teach computer science in an online environment.

1.5 Student Challenges in Online Computer Science Courses

As students enroll in online coursework, specific skills are required to succeed, such as practicing self-discipline and self-motivation. Additionally, staying organized and having adequate time management skills will support academic success. However, even when students strive to demonstrate these skills and work to support themselves if the course or instructor does not employ effective instructional strategies or appropriate online course design, students will have difficulty throughout the course. Students' common challenges in online computer coursework include the lack of an available content expert, programs that lack user interactivity (i.e., Microsoft Word, PowerPoint, or PDFs), and online course retention. Additional challenges such as the practice of "gatekeeping" seats in a course and bias exist for students of color and women within Computer Science, which often leads to exclusion and lack of opportunity [9]. According to Huan et al. [15], successful Computer Science courses involve high-level demonstrations and interactivity between the instructor and students. It is impossible to have high-level demonstrations from instructors who lack the depth necessary to explain the complex processes of computer programming and the context of the course content accurately and adequately. Further research conducted on online Computer Science courses has shown that students in foundation CS courses have difficulty visualizing abstract concepts [23]. Similarly, a study by Benda et al. [2] found an apparent disconnect between the time requirements associated with the programming assignments and the expectation by the instructor of the course. Due to the flexibility of online learning and underestimating the time commitment associated with the class, many students found that the assignments could not be completed or prioritized. Numerous factors impacted individuals' productivity, but several students accredited outside factors such as part-employment, family commitments, or enrolled in other courses. Additionally, as the Computer Science principles build upon each other, when instructors inefficiently teach the foundational skills, they set students up for future frustration. Unfortunately, poor instructor practice supports the troubling statistic that introductory programming classes' dropout and failure rates are high. According to Bergin and Reilly [5], "It is well known in the Computer Science Education (CSE) community that students have difficulty with programming courses, and this can result in high drop-out and failure rates." Even with a large body of research over the last fifteen years stating that Computer Science students struggle with introductory courses, we continue to see ineffective under-prepared practices taking hold. In 2004, Fincher and Petre attributed student retention and online education among the ten significant research challenges within computer science education research [8].

1.6 Purpose of the Study

Computer Science courses are not offered at all school districts in North Carolina, and therefore students enroll to complete Computer Science courses online through NCVPS. Teaching Computer Science online requires different instructional strategies, and both students and instructors have other challenges. In this study, we examine the instructional strategies used by high school teachers who teach Computer Science online and the challenges they face, and their students face.

- What are some instructional strategies teachers use to design and deliver APCSA online?
- What are some of the challenges in teaching APCSA online?
- What are some challenges the students have faced while taking APCSA online?

2 METHODS

This qualitative study included three focus groups conducted with teachers who teach Computer Science at North Carolina Virtual Public School. NCVPS has supported over 175,000 middle and high school students since its initial launch in the summer of 2007 [31]. The focus groups were conducted via zoom in May 2021 with ten teachers who teach middle and high school computer science courses.

2.1 Research-Practice Partnership

As the Department of Education aims to prepare their K-12 students to graduate high school and enter either the workforce or college, they need to consider supporting the teachers charged with preparing thousands of students. Teachers, before service, need entrance to high-quality, accessible professional development, which Goode et al. [10] support is a grand challenge that computer science teachers currently face. As part of a National Science Foundation Grant - Computer Science for All, the University of North Carolina Charlotte research team collaborated with North Carolina Virtual Public School Computer Science Team to create and offer professional development to teach AP Computer Science Advanced Course to high school teachers. We established a research-practice partnership (RPP) to guide the development of professional development for online computer science instruction. Establishing an intentional, long-standing, and collaborative partnership between researchers and computer science teachers at the NC Virtual Public School is critical to addressing the professional development needs of a larger audience of online computer science teachers. Our RPP approach stresses the role of our lead teachers from the NC Virtual Public School as key researchers in shaping the design of the professional development. Using participatory research approaches, the project team engaged the lead teachers during the first year of the project in identifying key instructional approaches and resources that were vital to their success in teaching computer science online. Through the RPP, the lead teachers' role as key stakeholders in the design process was reinforced. The leaders were reminded of their role as experts in the partnership and the critical role their input plays in the future design and implementation of the professional development program. Through a one-week summer online professional development, the teachers were put into a role of identifying best practices online instruction and extending their thinking to also consider approaches to formative assessment and methods for promoting equity in computer science instruction. The participatory research approach allowed the project team to capture ideas and outcomes from the teachers that will guide professional development design. An ongoing process of sharing and refining establishes a synergistic partnership that will continue to be the foundation of this RPP project. Thus, our goals are to engage a group of online computer science lead teachers as key stakeholders in the partnership conveying their roles as experts and researchers with the larger project team, collect data that focuses on the experiences and perspectives of these lead teachers to inform the overall project goal of designing online professional development focusing on best practices for online computer science instruction and to use principles of our RPP to enable the University team and the educators from the NC Virtual Public school to engage identify key features of a professional development program and to identify specific research needs to guide the efficacy of the professional development design and delivery. The RPP establishes a process for coordinating the development of common goals that will support the lead teachers while extending the instructional expertise of a broader group of online computer science teachers. Our Research-Practice Partnerships (RPP) establishes a collaborative framework for curricular development and professional development for the NCVPS and the broader online computer science ecosystem in North Carolina [7]. Our full engagement of educators from the NCVPS is an equal positioning where each stakeholder plays a central collaborative role in identifying critical needs, designing effective solutions, collecting and analyzing related data, testing solutions, and planning for sustainable and scalable reform strategies [26]. Our approach is intended to situate University researchers and the NCVPS leadership and teachers as equal experts who will work together to investigate problems of practice and develop compelling solutions that improve outcomes as they relate to teaching computer science virtually.

2.2 Participants

The Computer Science Instructional Director at NCVPS facilitated the recruitment of teachers who teach Computer Science at NCVPS. The teachers were then sent invitations to participate in the study. Teachers who were interested completed the consent form to participate in a focus group. Purposive sampling was used to select participants for this focus group. Three focus groups were scheduled with ten teachers. The focus groups included two groups of 3 and one group of 4 participants, facilitated by members of the research team. The teachers who participated in the focus groups varied in their background and experience but taught a computer science course for NCVPS.

2.2.1 Data Sources and Data Collection. The researchers conducted three semi-structured focus groups using the breakout room functionality in Zoom. Each interview averaged about 26 minutes. The sessions were audio-recorded and then transcribed using Otter machine transcription, initially followed by human transcription. Three focus group questions were discussed and finalized by the research team. The focus group questions were directly aligned to the research questions of this study and were 1) What are some instructional strategies you use to design and deliver APCSA online? 2) What are some of your challenges in teaching APCSA? 3) What are some challenges your students have faced while taking APCSA? The responses from the additional three questions are not included in this study.

2.2.2 Data Analysis. The researchers used an inductive coding process [14] to analyze the data. Two researchers analyzed the data from each research question using the same process. The transcribed interviews were initially coded using an open coding process. These were color-coded to form different categories, and categories were grouped to develop themes. Once the coding was completed, the larger research team met to discuss the codes and categories generated.

3 RESULTS

The results section includes the response to the three research questions on instructional strategies, teacher challenges, and student challenges.

3.1 Instructional Strategies

Eight themes emerged when teachers who teach Computer Science online identified instructional strategies to design and deliver APCSA online. The top three themes were online resources that included computing and pedagogy tools, course facilitation, and connection to College Board. The remaining five themes were collaboration for design and teaching, assessment and evaluation, student engagement, and evidence-based teaching practices. The results of this study and the resulting themes that were identified mirrored the conclusions drawn by another study that identified instructional strategies to help online students learn [21]. Similar to the findings in this study, the faculty described expert online instructors as being experienced and comfortable in the online environment, utilizing a wide range of instructional strategies, a willingness to learn and improve, and analyze student data.

3.1.1 Computing and Pedagogical Tools and Resources. Several teachers proposed this theme, online resources, as an essential instructional strategy and included both computing/programming resources and pedagogy tools. Some of the online resources used by the teachers are mentioned in Table 1.

Table 1: Computing and Pedagogical Tools/Resources

Computing Tool Resources	Pedagogical Tool Resources
GitHub	Kahoot
BlueJ	Jam Board
ReplIt	Snap
Different types of online compilers for Java	Microsoft Teams
W3Schools	Collaboratory
Azura	Video resources
Visual Studio	
Gmetrix	
auto grader in CodeHS	
new certify	
Code.org	
java.org	
Code HS	

3.1.2 Course Facilitation. Course Facilitation was the next theme that included a variety of instructional strategies. While some of the teachers who participated in the focus groups were involved in course design, several were only tasked with teaching and facilitating the course.

Weekly announcements. Some of the instructional strategies mentioned as part of the course facilitation included "weekly announcements" and "we can add materials to our announcements." One teacher commented, "we don't really have flexibility in designing the courses. They're structured for us, and the teachers get a Canvas shell, but we do have the flexibility to add supplemental material."

Live synchronous sessions. Live synchronous sessions were also mentioned as part of the facilitation. A teacher added, "a few kids that would come in and ask questions, she would always record our sessions and make them available as archives so that students could then go back and view them." A teacher added that the live sessions might not have worked for all students, but they did a live session for each topic.

3.1.3 More practice videos. Teachers thought it was essential to include more practice videos as part of the course facilitation. They noted that providing students with various videos for each standard or concept provided similar explanations in slightly different ways to allow students multiple opportunities for enhanced clarity. Providing additional practice videos was a course facilitation strategy the teachers implemented to assist students in an asynchronous online setting.

3.1.4 Connection to College Board. Teachers mentioned several instructional strategies exercised in their classrooms to align with the College Board examination. They used college board materials, videos in the AP classroom, and AP free-response style questions to prepare students for the AP classroom. One teacher commented, "we've added things that have made it a much better course. We've added structure to it to make it seem more realistic, as far as testing is concerned with the AP exam."

3.1.5 Collaboration in Design and Teaching. The interviewed teachers discussed the collaborative aspect of both design and facilitation used by this virtual public school. The course was assigned a course lead and included a large team of teachers. A teacher commented, "…have a team of the content experts develop the course, lay out the outline, and actually develop the content for the course." While every teacher's opinion is considered, changes are made based on the consensus. Also, one teacher noted, "Typically, we don't take them away unless it's a group decision…"

3.1.6 Assessment and Evaluation. Teachers mentioned utilizing a variety of assessments in their online computer science course. Some of the teachers' assessments included checkpoints to ensure students are prepared, tests including multiple-choice questions, projects, and timed free-response questions. They also emphasized the importance of providing feedback. In addition, teachers mentioned the importance of including an evaluation in the end. Evaluation is used to collect student feedback on the course to make improvements before the following implementation.

3.1.7 Student Engagement. A few of the teachers discussed the importance of student engagement. While getting the content on time is essential, it is also crucial to embed engaging and collaborative activities. One teacher commented, "A major platform that we started using to facilitate our content which allowed the students to be more engaging, more engaged in the course as well as access to those tools." They discussed the importance of including short videos about 10 minutes long to engage the students.

3.1.8 Evidence-based teaching practices. A few teachers described using evidence-based practices such as modeling, guided practice, tutorials explaining how something is done, and scaffolding as instructional strategies in their online computer science course.

3.2 Teacher Challenges

This section presents the challenges that teachers mentioned as ones they face while teaching computer science online. Teacher challenges were grouped into six themes: assessment and evaluation, course facilitation, prior student experience, instructor experience/expertise, technology, and student engagement.

3.2.1 Assessment and Evaluation. Assessment and Evaluation was a significant challenge for teachers who teach computer science online. They discussed plagiarism as a big challenge, how students use Google to find code, and the AP free-response questions. They discussed the importance of setting time limits on free-response questions and having proctors if they complete this in a computer lab at their local school.

3.2.2 Course Facilitation. While course facilitation was described as an instructional strategy, there were teacher challenges during facilitation. One teacher commented, "how to program and actually get through their code, I think, is the biggest challenge." Though the course was online, it was offered at the state level, and it was challenging to identify a meeting time that worked for all the students as they worked online but were physically enrolled in various schools. Also, not seeing the students face-to-face regarding what information they are retaining and genuinely learning was a challenge for the teachers.

3.2.3 Student Prior Experience. Teachers mentioned the challenge of getting a lot of students who are new to computer science. Students enroll in AP CSA without any foundation courses in programming, which hinders their success in the course. Not having a prerequisite to enroll in AP CSA allows students to enroll in this course without prior programming experience. In addition, time management is a challenge for online high school students.

3.2.4 Instructor Experience/Expertise. Teachers who did not have strong programming skills were assigned to teach the course. This requires teachers to be trained to teach computer science. One of the teachers commented, "I've been teaching it for 15 years, or more than 15 years, and they're still like, concepts out there and problems that can trip me up." Teachers also mentioned that they were not familiar with the various platforms to teach computer science online. This shows that there are challenging programming concepts to teach even with years of experience.

3.2.5 Technology. Teachers mentioned technology as another challenge. Students have different computers and different compilers. Some students have Chromebooks which can be challenging for compiling since they have to use web-based compilers. For example, there are significant differences among the languages used in Microsoft Visual Studio (1997) compared to Replit (2016). Also, teachers discussed the importance of seeing the student's computer screen to assist in troubleshooting. This was not always the case and hence was considered a challenge.

3.2.6 Engaging Students. Engaging students online was a challenge that teachers mentioned. Teachers do not receive feedback from students like when they are in the classroom where they can see facial responses with the nod or confusion. Also, it is harder to make the connection online, which is critical to motivating them to do the work. It is also challenging to get the students to log in consistently to participate in the online course.

3.3 Student Challenges

This section presents the challenges that teachers mentioned their students face while participating in an online course. Six themes emerged: technology, student experience, COVID-19, student engagement, course design, and instructor experience/expertise.

3.3.1 Technology. The main student challenge mentioned by several of the teachers was technology related. They discussed both hardware and internet connectivity issues. They also said they had to adapt to the technology used in the schools, such as Chromebooks. Since many students used Chromebooks, installing Java and Java Integrated Development Environments (IDEs) can be a problem. Teachers mentioned that students could not complete some assignments due to software issues and computer issues. Students were also challenged with debugging if they are using other Integrated Development Environments. When students were working on compiling programs, they just looked at the first compile error and tried to solve that instead of looking at all of them, causing them to get overwhelmed.

3.3.2 Student Experience. Teachers identified student experience also a challenge. They mentioned that students enter the course ill-prepared. They commented, "had they had some introductory material, even the opportunity to make it summer, a summer prerequisite, even a couple of weeks just to introduce them to some of the concepts that they could learn in AP CSP, that would really help them. I do feel like they need some sort of introductory programming course to introduce them to logic as well". Students also did not understand the expectations of an AP level course; often, students come into AP CSA as their first computer science or first AP course. As stated by multiple focus group members, when students begin with AP CSA as their initial introduction to Computer Science or Advanced Placement courses, they don't understand the expectations or rigor associated with the course demands.

3.3.3 COVID-19. Students were also faced with additional challenges related to COVID-19 during the time of this focus group. The challenges teachers faced and student's experiences that the focus group teachers shared, while insightful, were not isolated to a single experience. Much of the recent research regarding online teaching and learning challenges includes the impact that COVID-19 has had on their students and teachers' effectiveness at overcompensating for outside challenges. While the teacher's identified student challenges during their time teaching AP CSA through a virtual public high school, it is difficult to separate which issues were associated with online coursework and which issues were even more emphasized due to COVID-19.

3.3.4 Student Engagement. Students were also challenged with being engaged in an online learning environment. In some courses, the students were not as engaged as teachers had witnessed in previous years of teaching the same AP CSA course. Additionally, teachers noted that many students had mentally "checked out," resulting in unfocused or distracted participants. Similarly, the same students described as being "checked out" demonstrated difficulty with sufficient time management skills. Overall, teachers' perceptions of students in their online Computer Science courses were that students were not motivated, independent, or self-directed learners due to multiple factors.

3.3.5 Course Design & Sequence. An additional challenge that emerged from this study was the course sequence that some students take. Students come into CSA via numerous paths, thus arriving with different levels of preparations. And we've seen the data to show where students are much more successful when they follow that core sequence versus those schools that have students who are dropped into AP CSA. However, not all students follow this and start with AP CSA as the first course. The rigor and speed of the course are challenging to the students.

3.3.6 Instructor Experience & Expertise. Finally, students are challenged because of instructor experience. Students struggle, especially for new teachers who are new to the content. Sometimes, while teachers are gaining comfortability in a new content area, the students grapple with understanding the concepts as they are only exposed to surface-level explanations. Also, when students are very creative, lack of instructor experience or expertise impacts their ability to support and cultivate creativity. Teachers may not be ready to take them to the next level yet.

4 DISCUSSION

4.1 Variety of Instructional Strategies Used to Teach Programming Online

Several instructional strategies, including computing and pedagogy tools, course facilitation strategies, aligning instruction and assessment with College Board, collaboration strategies for design and teaching, assessment and evaluation methods, student engagement strategies, and evidence-based teaching practices, were used by the teachers when teaching computer science online. Several of these strategies were consistent with the related literature on teaching computer science online [35]. However, there is a gap in the literature regarding online teaching strategies for computer science teachers that would benefit from additional research. As many of the strategies used by computer science teachers can be applied to other disciplines, it would benefit the field to identify specific strategies that are best suited to computer science instruction [15]. Course facilitation is critical to the success of online classes [22]. Examples of online strategies in course facilitation that emerged from the focus group interviews include weekly announcements via a learning management system (Canvas), live synchronous sessions, and supplemental video resources. As supported by the larger body of research and Martin et al. [22], online facilitation strategies are most successful and valuable for both student and teacher when they enhance the instructor's presence, build connections among participants, and promote engagement and learning. As noted by Martin and Bolliger [20] student engagement increases student satisfaction, enhances student motivation to learn, reduces the sense of isolation, and improves student performance in online courses.

4.2 Teacher Challenges

Teachers were challenged by finding adequate assessments and evaluation tools, difficulty with online course facilitation, a general lack of student's prior experience, instructor experience or expertise, technology, and student engagement when teaching computer science online. The experiences shared through the focus groups and those themes that emerged are not isolated occurrences. The challenges identified within this study are supported and documented by a larger body of literature [12][13] which demonstrates the need for overarching support at a large-scale level [32]. Related studies conducted within a similar context recommended the need to further engage teachers in professional development sessions to increase their ability to address issues as they arise within an online environment, to combat the isolation commonly encountered in online learning [18].

4.3 Student Challenges

Several challenges arose for students during their online AP Computer Science course. According to the teachers in our focus group, students experienced technological difficulties related to their district-provided Chromebooks, restricted programming platforms, and unstable internet connectivity. Additionally, COVID-19 provided significant challenges for students based on the experiences shared by the instructors. Student engagement, course design, and instructor experience and expertise are all issues that led to an overall diminished student learning experience during the 2020 school year. While similar struggles have been identified by related studies, it is difficult to separate the challenges associated with online learning from those associated with remote learning during COVID-19 [17].

4.4 Implications

The findings of this study have implications for teachers who currently teach or wish to teach computer science online in the future. The various strategies used by the teachers will be beneficial when teaching computer science online. Teachers must use multiple computing and pedagogy tools, course facilitation strategies, collaboration strategies for design and teaching, assessment and evaluation methods, student engagement strategies, and evidence-based teaching practices. Also, using the resources from the College Board is helpful. The findings also have implications for administrators and instructional designers who support teachers in designing and delivering online courses. Finally, the study has implications for online students who will benefit from various instructional strategies used in the courses.

The findings on teachers' challenges will assist teachers, administrators, instructional designers plan proactively to overcome the difficulties. Similarly, the results indicating common student challenges will help teachers, students, parents, and administrators find solutions to these challenges.

4.5 Future Directions for Research

While this study was conducted using interviews from online teachers at one virtual public school, NCVPS, this could be extended to teachers teaching online in various settings nationwide. Also, a large-scale survey will assist in collecting data on teacher perceptions regarding instructional strategies they use and teacher and student challenges. In addition, interviewing administrators, parents and students will help us understand successful online teaching and learning strategies and challenges identified from various perspectives.

4.6 Limitations

There were a few methodological limitations to this study. This study used teachers only from one virtual public school from one state, and data was collected in three online focus groups. This data may not be generalizable to non-virtual school settings or virtual school settings in other states. Teachers may have responded differently to the online facilitation of the focus groups through Zoom than with face-to-face focus groups. Accessing the meeting with a phone instead of a computer or only some teachers turning on their video may have impacted how they participated in the focus group.

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REFERENCES

[1] I Elaine Allen and Jeff Seaman. 2014. *Grade Change: Tracking Online Education in the United States.* Technical Report. 1–45 pages.

[2] Klara Benda, Amy Bruckman, and Mark Guzdial. 2012. When life and learning do not fit: Challenges of workload and communication in introductory computer science online. *ACM Transactions on Computing Education (TOCE)* 12, 4 (2012), 1–38.

[3] Elena Bender, Niclas Schaper, Michael E Caspersen, Melanie Margaritis, and Peter Hubwieser. 2016. Identifying and formulating teachers' beliefs and motivational orientations for computer science teacher education. *Studies in Higher Education* 41, 11 (2016), 1958–1973.

[4] Cynthia Berger. 2016. Learning from failure. https://blog.eie.org/learning-from-failure

[5] Susan Bergin and Ronan Reilly. 2005. The influence of motivation and comfort-level on learning to program. In *Proceedings of the 17th Workshop of the Psychology of Programming Interest Group.* Psychology of Programming Interest Group, 293–304. https://mural.maynoothuniversity.ie/8685/

[6] David Buckingham. 2015. Defining digital literacy: What do young people need to know about digital media? *Medienbildung in Neuen Kulturräumen Die Deutschprachige Und Britische Diskussion* 2015 (11 2015), 21–34. https://doi.org/10.18261/ISSN1891-943X-2006-04-03

[7] Cynthia E Coburn, William R Penuel, and Kimberly E Geil. 2013. Practice Partnerships: A Strategy for Leveraging Research for Educational Improvement in School Districts. *William T. Grant Foundation* (2013), 1–37.

[8] Sally Fincher and Marian Petre. 2004. *Computer science education research.* CRC Press.

[9] Joanna Goode, Gail Chapman, and Jane Margolis. 2012. Beyond Curriculum: The Exploring Computer Science Program. *ACM Inroads* 3, 2 (June 2012), 47–53. https://doi.org/10.1145/2189835.2189851

[10] J. Goode, K. Peterson, J. Malyn-Smith, and G. Chapman. 2020. Online Professional Development for High School Computer Science Teachers: Features That Support an Equity-Based Professional Learning Community. *Computing in Science & Engineering* 22, 05 (sep 2020), 51–59. https://doi.org/10.1109/MCSE.2020.2989622

[11] G.H. Gregory and C. Chapman. 2013. *Differentiated Instructional Strategies: One Size Doesn't Fit All.* SAGE Publications. https://books.google.com/books?id=ABiCUHWfptIC

[12] Yuwanuch Gulatee and Barbara Combes. 2006. Idenifying the Challenges in Teaching Computer Science Topics Online. *ECU Publications* (01 2006).

[13] Yuwanuch Gulatee and Barbara Combes. 2006. Identifying Social Barriers in Teaching Computer Science Topics in a Wholly Online Environment. *The Fifth International Conference on Science, Mathematics and Technology Education* (January 2006), 173–182.

[14] Elmar Hashimov. 2015. Qualitative Data Analysis: A Methods Sourcebook and The Coding Manual for Qualitative Researchers. *Technical Communication Quarterly* 24, 1 (2015), 109–112. https://doi.org/10.1080/10572252.2015.975966 arXiv:https://doi.org/10.1080/10572252.2015.975966

[15] Xiaoli Huan, R. Shehane, and Adel L. Ali. 2011. Teaching Computer Science Courses in Distance Learning. *Journal of Instructional Pedagogies* 6 (2011), 1–14.

[16] I ISTE and C CSTA. 2011. Operational definition of computational thinking for K–12 education. *National Science Foundation* (2011).

[17] Robin Lake and Alvin Makori. 2020. The Digital Divide Among Students During COVID-19: Who Has Access? Who Doesn't? https://www.crpe.org/thelens/digital-divide-among-students-during-covid-19-who-has-access-who-doesnt

[18] Lisa R. Lattuca, Inger Bergom, and David B. Knight. 2014. Professional Development, Departmental Contexts, and Use of Instructional Strategies. *Journal of Engineering Education* 103, 4 (2014), 549–572. https://doi.org/10.1002/jee.20055 arXiv:https://onlinelibrary.wiley.com/doi/pdf/10.1002/jee.20055

[19] Ilka Luyt. 2013. Bridging Spaces: Cross-Cultural Perspectives on Promoting Positive Online Learning Experiences. *Journal of Educational Technology Systems* 42 (09 2013), 3–20. https://doi.org/10.2190/ET.42.1.b

[20] Florence Martin and Doris Bolliger. 2018. Engagement Matters: Student Perceptions on the Importance of Engagement Strategies in the Online Learning Environment. *Online Learning* 22, 1 (2018), 1–18. https://doi.org/10.24059/olj.v22i1.1092

[21] Florence Martin, Albert Ritzhaupt, Swapna Kumar, and Kiran Budhrani. 2019. Award-winning faculty online teaching practices: Course design, assessment and evaluation, and facilitation. *The Internet and Higher Education* 42 (2019), 34–43. https://doi.org/10.1016/j.iheduc.2019.04.001

[22] Florence Martin, Chuang Wang, and Ayesha Sadaf. 2020. Facilitation Matters: Instructor Perception of Helpfulness of Facilitation Strategies in Online Courses. *Online Learning* 24, 1 (2020), 1–22. https://doi.org/10.24059/olj.v24i1.1980

[23] Mae McSporran and Caroline King. 2005. Blended Is Better: Choosing Educational Delivery Methods. In *Proceedings of EdMedia + Innovate Learning 2005*, Piet Kommers and Griff Richards (Eds.). Association for the Advancement of Computing in Education (AACE), Montreal, Canada, 4932–4939. https://www.learntechlib.org/p/21876

[24] K.D. Moore. 2014. *Effective Instructional Strategies: From Theory to Practice.* SAGE Publications. https://books.google.com/books?id=qA5EBAAAQBAJ

[25] Libby V. Morris, Haixia Xu, and Catherine L. Finnegan. 2019. Roles of Faculty in Teaching Asynchronous Undergraduate Courses.

[26] William Penuel, Barry Fishman, Britte Cheng, and Nora Sabelli. 2011. Organizing Research and Development at the Intersection of Learning, Implementation, and Design. *Educational Researcher* 40 (10 2011), 331–337. https://doi.org/10.3102/0013189X11421826

[27] Adam Saunders. 2017. *Technology's Impact on Growth and Employment.* BBVA, 279–295.

[28] Cynthia C. Selby. 2015. Relationships: Computational Thinking, Pedagogy of Programming, and Bloom's Taxonomy. In *Proceedings of the Workshop in Primary and Secondary Computing Education* (London, United Kingdom) *(WiPSCE '15)*. Association for Computing Machinery, New York, NY, USA, 80–87. https://doi.org/10.1145/2818314.2818315

[29] Keith Tyler-Smith. 2006. Early Attrition among First Time eLearners: A Review of Factors that Contribute to Drop-out, Withdrawal and Non-completion Rates of Adult Learners undertaking eLearning Programmes. *MERLOT Journal of Online Learning and Teaching* 2, 2 (2006), 1–13.

[30] Bureau of Labor Statistics U.S. Department of Labor. 2021. Computer and Information Research Scientists. https://www.bls.gov/ooh/computer-and-information-technology/computer-and-information-research-scientists.htm

[31] North Carolina Virtual. 2021. About us. https://ncvps.org/about-us/

[32] Rebecca Vivian, Katrina Falkner, and Nickolas Falkner. 2014. Addressing the challenges of a new digital technologies curriculum: MOOCs as a scalable solution for teacher professional development. *Research in Learning Technology* 22 (Aug. 2014), 1–19. https://doi.org/10.3402/rlt.v22.24691

[33] Firm Faith Watson, Marianne Castano Bishop, and Debra Ferdinand-James. 2017. Instructional Strategies to Help Online Students Learn: Feedback from Online Students. *TechTrends* 61, 5 (01 Sep 2017), 420–427. https://doi.org/10.1007/s11528-017-0216-y

[34] Project Lead The Way. 2021. AP PLTW: Preparing Students for College and Careers. https://www.pltw.org/our-programs/ap-pltw

[35] Aman Yadav, Sarah Gretter, Susanne Hambrusch, and Phil Sands. 2016. Expanding computer science education in schools: understanding teacher experiences and challenges. *Computer Science Education* 26, 4 (2016), 235–254. https://doi.org/10.1080/08993408.2016.1257418 arXiv:https://doi.org/10.1080/08993408.2016.1257418

[36] Aman Yadav, Hai Hong, and Chris Stephenson. 2016. Computational Thinking for All: Pedagogical Approaches to Embedding 21st Century Problem Solving in K-12 Classrooms. *TechTrends* 60, 6 (01 Nov 2016), 565–568. https://doi.org/10.1007/s11528-016-0087-7

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A Network Mapping Approach to Integrating Computational Thinking and Computer Science into the Rural K-8 Classroom

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ABSTRACT

The Integrate-2-Innovate (i2i) Research-to-Practice Partnership (RPP) was developed to answer the research question: **What are the key elements needed to support rural K-8 educators' integration of computational thinking (CT) and computer science (CS) into math and science instruction?** I2i implements an innovative design approach that encourages building trust and shared knowledge among educators, administrators, and local CS related business from three rural Maine communities.

To best facilitate acquisition of deep, shared knowledge, the i2i RPP utilized a network analysis graph. Participants developed understanding of CS through the creation of a network analysis of CS integration in the rural K-8 setting. Engaging in focus groups, interviews, and collaborative classroom visits, participants identified barriers to rural CS integration and visually mapped their connectivity to each other. Identifying barriers is not unusual or even difficult for many participants, but the innovation of this tool is in the understanding of the relationship between barriers.

The network analysis graph allowed the participants to shift their thinking about CS integration from a problem-focused approach to an opportunity-focused approach. As participants grew more knowledgeable, they were able to identify tools and professional learning to increase CS integration. As their understanding increased, so did their ability to communicate their ideas to their peers, generating more conversations about CS integration and laying the groundwork for school and community engagement. Connections between barriers were reexamined as potential pathways for CS integration. The network analysis itself became an adaptable map for future rural integration strategies.

CCS CONCEPTS

• CSEd • RPP

KEYWORDS

Computer Science, Computational Thinking, Network Analysis, Boundary Mapping

1 INTRODUCTION

Rural students are limited in computational thinking (CT) and computer science (CS) education in ways that may be different from their urban counterparts [Google & Gallup 2017]. Many rural schools do not have the teachers, funds, or expertise to teach stand-alone CS—making accessibility to computer science a question of equity. Rural districts struggle to know what integration strategies and instruments are applicable and appropriate for their specific setting, especially when teachers are under the constraints of specific curriculum requirements for subjects like English Language Arts (ELA) and Math.

Building off of these learned experiences, the authors partnered with rural districts to design the Integrate - 2 - Innovate (i2i) Research-to-Practice Partnership (RPP) with intent to answer the research question: What are the key design elements needed to support rural K-8 educators' integration of CS into math and science instruction?

1.1 Understanding the Rural School Context

Rural schools occupy a unique space in under-served populations, especially since the definition of a rural community is as diverse as the intricacies of each of those communities. This project has built the RPP community with a rural Maine context and culture. Maine has over 500 elementary schools scattered across 36,000 square miles, including 13 un-bridged island schools (two of which are in the i2i partner school district, Mount Desert Island) and state-run schools in unorganized territories. About a quarter of US students reside in rural communities and the rural schools in which they attend can vary significantly from the suburban and urban schools of their peers. Google Inc. and Gallup Inc.'s [2017] report on CS in rural and small towns found that successful CS programs need to understand the unique challenges of each rural community. In rural communities the combination of small populations, high per-pupil costs, strained school budgets, and lack of resources puts schools at a significant disadvantage, especially regarding access to professional development [Autio 2017]. However, there are bright spots and opportunities that rural communities can leverage. Many rural communities have numerous untapped CS resources present in the community, yet those resources often go unnoticed or underappreciated. CS activities and professions are truly embedded in the culture of the rural community. For example, snowmakers at a ski mountain rely on a specific set of algorithmic processes to produce snow that is perfect powder. By naming the CS skills and practices that are underlying many CS educational programs today, business leaders identify where those skills and practices overlap with the skills needed for their employees, while teachers and community members are able to see the importance of preparing all of our students for the CS enriched workplace.

To gain a holistic understanding of CS learning in a rural context, i2i engaged in the boundary work dynamic. Boundaries are representative of a lack of overlap between organizations and/or ideas, in this case, CS learning and the rural K-8 classroom. While research on RPP approaches has expanded in the last decade to explore organizational dynamics and the learning that occurs across them, there is still relatively little known about the role of RPPs and CS integration in middle and elementary schools—especially in rural areas. The boundary work dynamic is essential for learning to occur throughout the partnership and to broker between integration ideas, objectives, and research findings [Davidson 2019].

As a community, i2i worked to explore the challenges to integrating CS education and uncover existing connections among them to utilize as steppingstones for crossing the boundary. As mutual learning occurs at boundaries, participants are more likely to see changes in collective knowledge, policies, and routines for participating organizations [Farrell 2020].

1 METHODS

2.1 Supporting Local Relationships to Advance CS Education

I2i focused on taking a holistic approach to understanding the problems of practice in rural communities by beginning with a diverse group of stakeholders across three unique rural districts in, by some measures, the most rural state in the nation—Maine [US Census Bureau 2011]. From the rocky coastline to the Western mountains, K-8 teachers, school administrators (principals, curriculum coordinators, technology coordinators), researchers, and local business leaders collaborated to understand the barriers of CS and CT integration.

Participants from the three rural school districts participated in a design-based research (DBR) approach, engaging in iterative cycles of testing, refinement, and cross district collaboration, where they shared new learning and approaches, discussed successes and challenges, and recorded implications for future implementation of select CT and CS lessons. Inherent in this paradigm is the belief that teachers bring deep knowledge of practice and expertise to the table when trying to understand how people learn. This iterative process mirrors the co-investigation process of figuring it out together. Louie and Buffington [2017], who informed and assisted in the i2i process, have a successful history in the Maine context, including suburban and small rural schools in Maine using RPPs to improve science, technology, engineering, and mathematics (STEM) learning and local sense-making. This process allows for designs and findings that are "highly local, adaptive, [and] responsive" and yet can be generalized [Bevan 2017, p. 17]. These collaborative engagements provide rich opportunities to build trust and relationships that can anchor the work and create mutually beneficial results, not just useful for the initial participating districts but also for the broader rural school community.

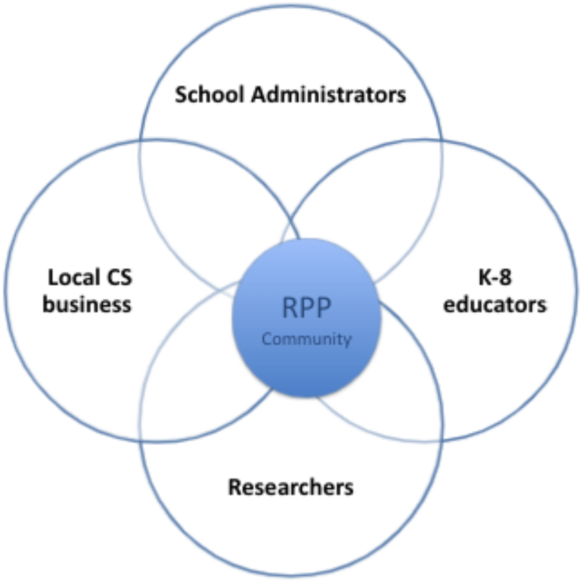

Figure 1: The diverse intersectionality of the i2i RPP community to accurately represent the rural Maine context

The project implemented an innovative design approach that encourages the building of trust and shared knowledge among educators across disciplines and grade levels, tech integrators, administrators, and local CS related business from three communities. Building trusting relationships across the three districts is key for creating a holistic vision of rural CS integration processes (see Figure 1), defining common goals and finding the will and capacity to achieve them together. I2i incorporates activities and guidelines from the Research + Practice Collaboratory to foster the development of this productive RPP with activities such as value-mapping [Ryoo 2015], community asset mapping [Appalachia Educational Laboratory 2000], partnership inquiry processes to identify shared goals, active listening skill development, "in my shoes" activities, visiting each other's work sites, and short iterative design cycles of the grounded theory of action.

Each participant was responsible for contributing a key perspective to the RPP's work. Through continual, collaborative events, participants would share their experience with and vision for CS in the community. Business leaders would report that CS learning in the classroom would support the workforce in their local communities. Throughout the RPP activities educators learned about the importance of CS skills in both Maine's traditional natural resource-based economies as well as the innovation sector in biosciences that has been growing rapidly in the state - combating misconception that highly talented STEM youth need to leave rural Maine to find successful and exciting careers. The RPP's teachers brought a deep understanding of student learning capabilities and lesson material. Tech integrators assisted teachers, helping them identify CS integration potential in ELA, science, and math lessons. Administrators advocated for the support of CS by seeking resources for their staff, such as the acquisition of devices for one district and the creation of a "tech integrator" position in another district to help teachers make best use of their existing CS and CT resources. Building on this deep knowledge of experience throughout the 2019-2020 school year, i2i participants designed and led research opportunities by: 1) implementing select CS activities within their STEM courses and existing curriculum; 2) observing levels of student engagement; 3) examining and adjusting pedagogical approaches; and 4) making adaptations, while considering the context of their rural schools and classrooms.

In addition to these explorations of CS activities and workforce needs, RPP members also dove deep into understanding each district's cultural context through site visits to each district, observing each other's classrooms, and sharing lessons learned as the RPP activities advanced. In addition, the RPP as a whole would build collective knowledge together as they reviewed and reflected on emerging published research in CS and CT education to translate rigorous research to apply to their classrooms. RPP members also reviewed and analyzed interview and survey data collected from the RPP members and anonymized to inform the direction and research questions members of the RPP explored.

2.2 Advancing Research and Understanding in Partnership

In order to capture a community's worth of perspectives, i2i developed a DBR approach, iterating on cycles of mixed methods data collection over 18 months. The RPP participants acted as co-researchers, wholly engaged in the research process that began by developing a consensus understanding of CT and CS. Developing and working around this definition laid the groundwork for the participants to assess and analyze rural school cultures, district resources, and regulations that impact CS and CT integration. The RPP participants particularly found it important that CS is defined through a rural lens. Initial opinions of CS, as revealed through an early participant workshop, were that it was nearly synonymous with technology use. In under resourced areas, such as many rural areas, technology is far less common and advanced compared to urban areas. While defining CS, participants focused on how it related to the average person living in a rural area.

After a series of protocols based on resources from the Research + Practice Collaboratory to illicit our fundamental understanding of CS (including reviewing multiple research and practice viewpoints on the importance of CS, how CS and CT can be defined, how to structure CS education goals, and the potential outcomes of CS education for students), the RPP came to consensus on a shared definition that was appropriate for the rural Maine context:

CS is the study / process of:

- *problem solving and design through computational thinking*
- *programming, analysis, and creative modeling using computers hardware, software, and algorithmic processes in order to solve real world problems*
- *being ethically responsible, improving efficiency, and increasing access to knowledge.*

Following the development of a CS definition, the RPP began the work of uncovering the challenges that existed in the boundary between CS learning and the rural K-8 classroom. Participants from one of the rural districts in Mount Desert Island hosted a site visit for the RPP to conduct in situ classroom observations. Educators, administrators, and researchers followed an observation template that allowed them to document opportunities for CS and CT learning in the observed lesson as well as any CS and CT learning that was already taking place. Pulling from personal and observed experience, participants filled out a survey which was then followed by individual interviews with a research associate, allowing them to share the existing barriers to bringing their vision of CS education into their school culture and classrooms.

Participant qualitative data from surveys, focus groups, individual participant interviews, and artifacts such as diagrams and brainstorming documents from site visits was coded using NVivo software. Quantitative data, specifically participant ranking of the most impactful barriers, was analyzed using SPSS. The data culminated in a comprehensive list of barriers that greatly impact the perpetuating boundary between CS learning and the rural K-8 classroom.

With this data we took a boundary mapping approach [Farrell 2020; Davidson 2019] as a basis for building rural-specific CS integration strategies aligned with local resources and existing connections in their communities. Given the inherently relational aspects to barriers as boundaries we encountered during the RPP DBR process, the team developed an innovative epistemic network analysis approach [Shaffer 2016] to identify the relationships between the integration barriers and potential opportunities that we term boundary mapping. Using GEPHI software and the results of the qualitative data analyzation, researchers were able to determine what barriers were frequently mentioned to be connected with one another. This process resulted in a network analysis graph (see figure 2), which could then be used as a navigable integration map that illuminates strategies for integrating CS and CT into rural schools.

At a second site visit, hosted at a different district site in Bethel, Maine, participants worked with each other to identify the core barriers (see colored nodes in figure 2) that were all collectively connected to the remaining, peripheral barriers. Participants strategized best practices to address these core barriers with the help of business representatives, who offered insights into community and workforce perspectives that holistically emphasized and contextualized the important of CS and CT learning in rural areas. Participants then identified which of the network barriers were most impactful in their own district and which ones they had already overcome or mitigated. Once participants were able to identify their own personal experience in the network map, they began strategizing best practices for using connections between barriers as opportunity pathways.

3 RESULTS AND DISCUSSION

Figure 2 represents the culmination of data from i2i surveys, retreat artifacts, transcripts, and the connections between barriers that were tracked during interviews and in-person events of the RPP throughout the school year. Larger nodes represent barriers that were mentioned more frequently. Portraying the qualitative data from the above sources in a network graph enables the visualization of connections and relationships between the practices, which were not previously recognizable through a traditional ranking approach. Instead, analyzing the connections or relationships between all identified barriers allowed the RPP participants to clearly understand not only the key barriers and potential solutions to the integration of CS in rural K-8 classrooms, but also where they might apply existing resources and assets to the integration process. From this perspective, we believe this mapping process to be an essential tool in enabling RPP participants to both coordinate and mediate discussions with knowledge generation while developing integration strategies to match their local assets [Thompson 2019].

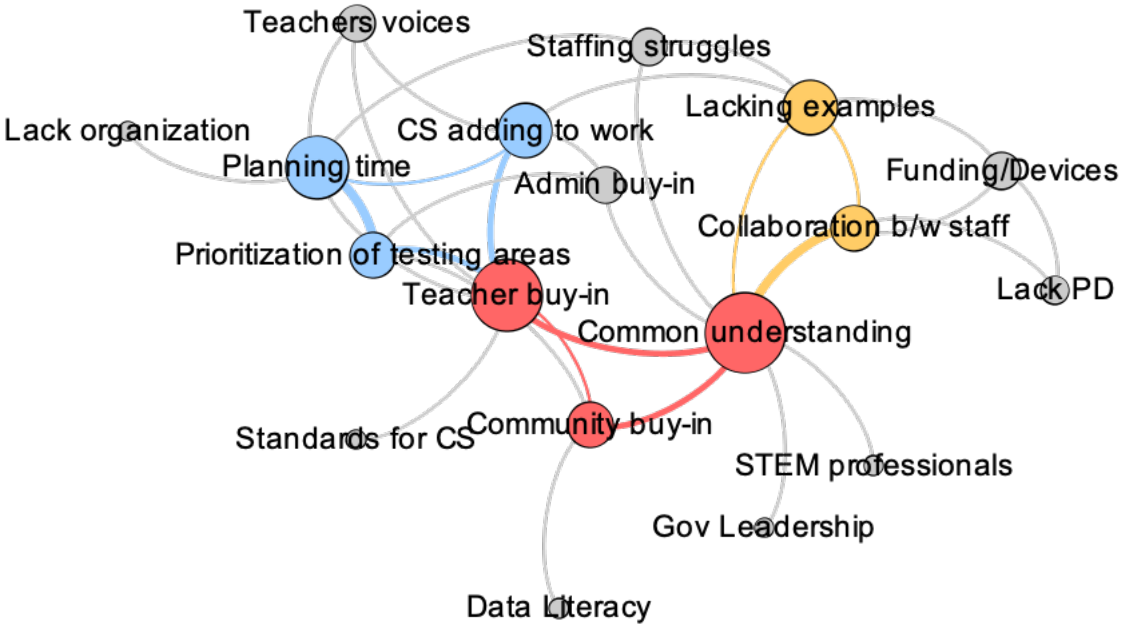

Figure 2: Connections between barriers to CS integration in the rural Maine K-8 Classroom

Red Nodes - Common Understanding of CS/CT:

The lack of a **common understanding** of what CS and CT are and their role in rural school classrooms contributes to a school (lack of **teacher buy-in**) and community (lack of **community buy-in**) culture that is not conducive to integration.

One participant explained this by recounting their personal journey in understanding CS through the project:

> "I, myself, have learned a lot just from being involved in this [i2i project] of what computer science can look like even without the use of a computer, like the whole computational thinking aspect. I think there are probably a lot of teachers who wouldn't realize some stuff that they're doing that could be considered computer science and computational thinking."

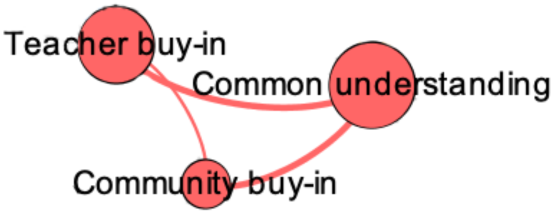

Figure 3: Red Nodes in the Network Analysis Graph

Blue Nodes - District Buy-in and Collaboration:

The scarcity of mechanisms and structural supports for educational leaders and curriculum developers to share examples of CS integration with educators in rural districts is shown by a lack of curriculum **planning time**, the **prioritization of testing areas** (i.e., ELA and math), and the ongoing belief that integrating **CS adds to work** that is already overwhelming. This contributes to the lack of **teacher buy-in** for CS integration.

In an individual interview, one participant emphasized the prioritization of standardized testing in schools and the community, leading to educators getting defensive over their time and work:

> "Unfortunately, we still have a large constituency that's still very committed to and dedicated, not dedicated, but really want to make sure that our standardized test scores are doing well [. . .] And so our staff get defensive and our administrators get defensive so part of what I feel that we have to do is, if we are really going to [create more CS integration examples], it can't just be at the teacher level; it has to be at the administrative level too. And if the administrative level is constantly being hammered by the public and the school boards saying your scores need to improve, we have to show how these will improve these areas."

Another participant in a separate interview explained the difficulty of fitting all the learning content into their limited schedule:

> "The teachers I work with will say, 'we're supposed to have this much time for math and this much time for ELA, and we only have this much for content, and how do we squeeze this all in?' —which again comes back to time and fear."

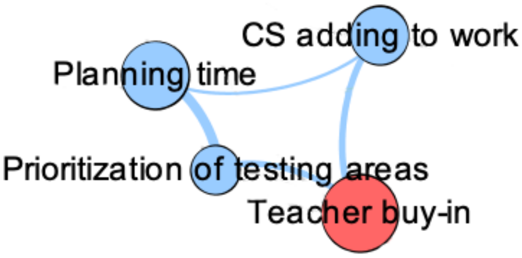

Figure 4: Blue Nodes in the Network Analysis Graph and their connection to the Red Nodes

Yellow Nodes - Classroom Integration Strategies:

Educators **lacking examples** of culturally relevant CS integration activities and curricula is impacted by educators not having enough **collaboration between staff** focused on sharing these examples. The lack of **common understanding** of CS deeply impacts the perspective of valid examples of CS integration.

One participant stated the problem simply:

> "We don't have the resources and materials. There are no examples either, and we have nobody to get that information to pass on to the teachers."

Other participants echoed the idea of having too few examples, but more specifically, needing the guidance to support their attempts for CS integration. Collaboration and shared resources, such as the code.org lesson one participant discovered, offers ideas on how CS and CT learning examples can connect to existing curriculum:

> "But at the end of every single [code.org] lesson it tells you your connections. It tells you if it's connected to geometry standards, it tells you which math practices are highlighted in that lesson, ELA. So, I do feel like having a guide like that is very helpful because you don't have

to do the guesswork . . . Teachers don't need to create another thing; they need some guidance."

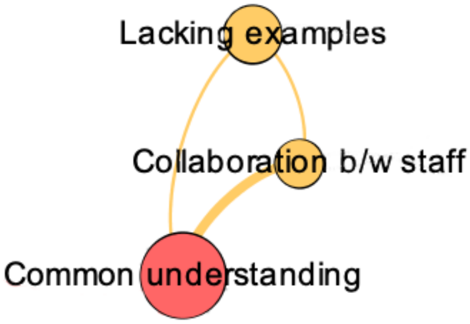

Figure 5: Yellow Nodes in the Network Analysis Graph and their connection to the Red Nodes

Gray Nodes:

All other identified barriers are connected to the core barriers (represented by colored nodes) more than they are connected to each other. While an educator can personally **lack organization**, see that **teacher voices** are not heard or adequately represented by administrators, and/or **lack PD**, these were not identified as connected to or influenced by many other barriers. However, these barriers (including **staffing struggles**, lacking **funding/devices** for CS, lacking qualified **STEM professionals** or **Gov leadership**, students lacking **data literacy**, an absence of **admin buy-in** for integrating CS, and a lack of testable **standards for CS**) are all valid barriers to CS integration in the rural PreK-8 classroom.

The boundary mapping approach allows us to see myriad factors, both in and out of school, that contribute to the current rural landscape of CS integration in schools and how those factors relate to one another. For example, teachers rarely struggle to identify barriers but understanding the context and impact of the barriers is a challenge that was made easier by the boundary mapping approach. "Lack of Planning Time" was frequently cited as a barrier in initial surveys, but thoughtful discussions and analyses among the participants revealed that the problem of not having enough time was not just about the number of hours in a day. Instead, it was revealed that "Lack of Planning Time" is largely impacted by the prioritization of specific subject areas that are tested by the state and a belief that CS learning has to be born out of nothing (however, integration can be a lighter lift once an educator recognizes connections between CS content and practices and other learning requirements). This approach deepens the understanding of the most interconnected and impactful barriers (represented by colored nodes), which in turn, represent boundaries that we understand to be related to successful integration strategies.

While the barriers uncovered by the social network analysis activities may not seem, on the surface, to be unique to a rural setting, it is through the understanding of these barriers, their root causes, and more importantly, their relationships with each other, that the power of the analysis and its implication on rural schools is revealed. Rural schools are under-resourced in time, money, and expertise. By understanding the barriers as a series of interwoven nodes and focusing on addressing the connections between the nodes, rural districts can prioritize their action steps and make large gains through strategic interventions.

In Spring 2020, the RPP divided into working groups to begin exploring the necessary strategies for minimizing and/or overcoming these rural barriers. Together, they began developing strategies to use the network analysis as an adaptable mapping tool for integrating CS. Recognizing their district's successes and shortcomings on the map allowed the participants to leverage their stronger assets to address connected key barriers. By exploring the opportunity pathways, the working groups found some necessary strategies that serve as the foundation for successfully integrating CS and CT learning in the rural K-8 classroom, including:

1. Working with businesses creates a real-world connection by developing units that portray computer science in practice with other subject areas like science and math, and
2. increasing collaboration among peers generates common language and understanding of CS, making the subject more accessible and approachable to educators and the community.

The working groups shared their experiences and findings in May 2020 during a virtual CS learning series hosted by the RPP. The virtual series brought together educators, administrators, business leaders, and community members spanning across the United States. One attendee noted in a post-session survey that they "learned that other educators from other districts share the same barriers and ideas for breaking down the barriers."

To shed additional light on what this process looked like and the results, below we highlight two examples of CS integration in rural classrooms developed by RPP members.

Lucy Hayes - Middle School Science

The cell model is a cornerstone experience in most 7th grade, science classrooms. Lucy Hayes, a middle level teacher in coastal Maine, has been leading her students through the construction of the Cell Model for years. This year, Lucy decided to team up with the school's Technology Integrator, Caitlin Pierce, to reimagine the process. Lucy, a veteran science teacher, had no previous knowledge of block-based coding, Scratch, but had seen it used in other contexts as she explored already existing CS activities in the i2i project. With the support of Caitlin, they created a Cell Model project assignment that asked students to design their cell on

Scratch. Students were supported in their use of Scratch by Caitlin and their technology class. While the science content was the same, Lucy's students were able to weave in what they were learning in their Technology class, engaging with not only science learning but CS learning as well. Lucy was able to see what was possible for her students to achieve while using Scratch and began the process of finding other areas for CS integration. The partnership with Caitlin was just the support Lucy needed to try something new.

Angela Lewis - 2nd Grade

For Angela, a 2nd grade teacher in Western Maine, there was no technology integrator to partner with. Angela's district, like so many in rural regions, has struggled to fill technology positions. Despite this lack of support, Angela was motivated to find ways to integrate CS/CT principles into her classroom. With the support of the RPP, Angela discovered the Hello Ruby books that had been aligned with the Computer Science in San Francisco (CSinSF) initiative. Using their lesson plans as a jumping off point, Angela fundraised for a classroom set of Beebots, programmable robots that look like bees, and began the process of using them and their block-based coding platform in many classroom activities. Instead of plotting a storyline on paper, Angela used the Beebots to trace the arc of a story in ELA. Instead of a table-top activity, Angela used the Beebots to model plant growth in science class. By baby-stepping into CS with Beebots, Angela gained the confidence to use these simple, low-cost, robots across her curriculum.

3 CONCLUSIONS AND FUTURE WORK

The methods and results shared above provide a unique model to empower rural communities in identifying barriers to CS integration as well as some unique proposed solutions. Our hope is that our experiences as an RPP community can be leveraged to advance equitable CS education access in other rural regions, in Maine, and across the nation. By involving the rural community in the research process, i2i has already laid the groundwork for cultivating collaboration, sourcing tools and professional learning opportunities, and developing a common understanding of CS. The research and findings presented here are unique in making essential the contextual perspective and engagement of the rural community, establishing recommendations with more credibility than having come from researchers alone.

Rural communities have a wealth of assets to support CS understanding, which often go unnoticed and un-named. Our RPP community has only just begun the journey of identifying culturally responsive CS integration activities and associated professional learning mechanisms that are designed with the needs, assets, and context of rural classrooms as the driver of innovation. Evolving partnerships between CS business partners, education leaders, and an educational research and program development nonprofit organization will continue building supports needed to change existing systems in order to advance CS teaching and learning. Overall, the design of the i2i RPP will generate a model that can be used in other rural regions to build their own RPP from the ground up, based on the unique strengths and opportunities present in each region. The lessons learned through i2i will begin to address the inequities in CS education between rural, urban, and suburban regions to truly design initiatives to bring CS to all, even schools in the most geographically isolated communities.

ACKNOWLEDGMENTS

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REFERENCES

Appalachia Educational Laboratory. 2000. Community Asset Mapping. In Rural School Administrators' Resources. Charleston: AEL.

Elizabeth Autio and Theresa Deussen. 2017. Recruiting rural schools for education research: Challenges and Strategies. In Rural Education Research in the United States (pp. 77-93). Springer, Cham.

Bronwyn Bevan, William R. Penuel, Philip Bell, and Pam Buffington. 2017. Learning, Generalizing, and Local Sense-Making in Research-Practice Partnerships. In Connecting Research and Practice for Educational Improvement Ethical and Equitable Approaches. Routledge.

Kristen L. Davidson and William R. Penuel. 2019. The role of brokers in sustaining partnership work in education. The Role of Knowledge Brokers in Education: Connecting the Dots Between Research and Practice, 154.

Caitlin Farrell, William R. Penuel, Anna-Ruth Allen, Eleanor Anderson, Angel Bohannon, Cynthia Coburn, and Stephanie Brown. 2020. Mutual Learning at the Boundaries of Research and Practice: A Framework for Understanding Research-Practice Partnerships. ICLS, 2020

Google Inc. and Gallup Inc. 2017. Computer science learning: Closing the gap: Rural and small town school districts. Results from the 2015-2016 Google-Gallup study of computer science in U.S. K-12 schools (Issue Brief No. 4). https://goo.gl/hYxqCr

Josephine Louie, Pam Buffington, and Jennifer Stiles. 2017. A Screencasting Strategy to Support STEM Learning in the Early Grades Breadcrumb. Connected Science Learning, 1(4). https://www.nsta.org/connected-science-learning/connected-science-learning-october-december-2017-0/screencasting

Jean Ryoo and Molly Shea. 2015. Activity: Mapping shared goals in a partnership. http://researchandpractice.org/resource/value-mapping/

David Williamson Shaffer, Wesley Collier, and Andrew R. Ruis. 2016. A tutorial on epistemic network analysis: Analyzing the structure of connections in cognitive, social, and interaction data. Journal of Learning Analytics, 3(3), 9-45.

Jessica Thompson, Jennifer Richards, Soo-Yean Shim, Karin Lohwasser, Kerry Soo Von Esch, Christine Chew, Bethany Sjoberg, and Ann Morris. 2019. Launching Networked PLCs: Footholds Into Creating and Improving Knowledge of Ambitious and Equitable Teaching Practices in an RPP. AERA Open. https://doi.org/10.1177/2332858419875718

U.S. Census Bureau. 2011. Population distribution and change: 2000 to 2010. Retrieved from http://www.census.gov/prod/cen2010/briefs/c2010br-01.pdf

Sayler, B., Her Many Horses, I., Kertzman, D., Belden, T., Carroll, B., & Caffee, H. (2021.) Introducing Computer Science within South Dakota High Schools through a Research-Practice Partnership. In CSforALL & SageFox Consulting Group (Eds.), The intersection of RPPs and BPC in CS education: A culmination of papers from the RPPforCS Community [White paper]. Retrieved from https://doi.org/10.13140/RG.2.2.30216.96009

Introducing Computer Science within South Dakota High Schools through a Research-Practice Partnership

Exploring Student Enrollment, Attitudes, and Problem-solving with a Focus on Broadening Participation

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ABSTRACT

This paper examines the impact of two closely related projects, both taking a research-practice partnership (RPP) approach and both funded by the National Science Foundation, to support high schools across the state of South Dakota in adding *Exploring Computer Science* (ECS) to their curriculum. Over the past seven years, 66 teachers have participated from 51 high schools and 45 districts. A majority of the schools have enrollments of 250 students or fewer and are highly rural. A sample of 756 students from 18 of the participating high schools completed assessments between 2015 and 2021. The resulting data show gaps and disparities associated with gender and race in student enrollment, attitudes about computer science, and problem-solving skills. Despite concerted efforts to recruit female students into the ECS course, enrollment has skewed heavily male (65% male, 35% female). Of the disproportionately few female students choosing to enroll in the course, their confidence related to computer science at the start of the course has been significantly lower than the confidence of their male peers. Underrepresented minority (URM) students – predominantly American Indian, consistent with the demographics of South Dakota – have also entered the ECS course with attitudes significantly less favorable toward computer science than non-URM students and with lower performance on problem-solving tasks. Confidence and problem-solving skills have increased for both female and URM students from the beginning to the end of the course, but statistically significant gaps are still evident for both subgroups at the end of the course. Data about the nature of the participating schools and the demographics, attitudes, and problem-solving skills of participating students have played a central role in the continuous improvement efforts of the research-practice partnership. These data have served as a springboard for discussions and reflection among project teachers and members of the project support team about how best to support high school students within computer science across South Dakota, especially female students and underrepresented minorities.

KEYWORDS

High school computer science, student enrollment, student attitudes, student problem-solving, equity

Reference format:

Sayler, B., et al. (2021). Introducing computer science within South Dakota high schools through a research-practice partnership: Exploring student enrollment, attitudes, and problem-solving with a focus on broadening participation. In CSforAll & Sage Fox Consulting (Eds.), *The intersection of RPPs and BPC in CS education: A compendium of papers from the RPPforCS community* [White Paper], CSEdResearch.org.

1 Project Context

This effort began in 2014 with the goal of testing a year-long introductory computer science course at the high school level. Project leaders were not aware of any high schools in South Dakota offering a survey course in computer science at the time. There were classes that focused on using computer applications (e.g., *Microsoft Office*) and some web design and stand-alone programming classes, but there were no general introductory computer science classes as far as project leaders were aware.

An initial *STEM-Computing Partnership* grant from the National Science Foundation supported the early efforts of five school districts, two universities, an educational service agency, and an external evaluator. In 2017, the project team was awarded a second NSF grant to expand its reach across all

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of South Dakota. The second grant was a *CS for All: Researcher-Practitioner Partnership*. The RPP approach is based in part on the work of C. Coburn and colleagues, 2013 [1]. To date, 66 teachers from 51 partner schools representing 45 school districts across South Dakota have participated.

2 Problems of Practice the RPP is Addressing

2.1 Access to Computer Science

Many high schools across South Dakota, especially the smallest and most rural ones, find it challenging to offer a class in computer science. As a result, many South Dakota high school students have little or no access. One reason that a school may not offer a class in computer science is that they do not have a teacher who feels comfortable teaching it. This RPP has sought to determine and to offer supports for teachers who have little or no background in computer science such that they feel comfortable teaching an introductory-level class.

2.2 Student Recruitment

Another significant challenge has been recruiting sufficient student numbers, especially within the smallest high schools, to justify the offering of a stand-alone introductory computer science course. The high school curriculum is quite full already, many students are intimidated, and others do not perceive sufficient value in taking a computer science class in place of another elective. Recruiting female students has also been a challenge.

2.3 Student Attitudes and Problem-Solving

To determine characteristics of enrolling students and to examine the impact of the introductory computer science course, the RPP has collected student-level data about attitudes and problem-solving skills both at the beginning and at the end of the course. By examining these data, the RPP has sought to gain insights into student recruitment and to improve support for historically underserved and underrepresented populations within computer science.

3 Curriculum

The project has focused on supporting teachers in learning and implementing the *Exploring Computer Science* (ECS) curriculum [2]. Partner teachers from the initial cohort – together with members of the project support team – surveyed the landscape of available high school computer science curricula in 2014 and selected ECS for its comprehensive nature, the fact that it was freely available to schools, its constructivist pedagogy, and its focus on broadening participation within computer science. ECS includes six core units, each of which takes four to six weeks to implement in the classroom. The six core units are: Human Computer Interaction; Problem Solving; Web Design; Introduction to Programming; Computing and Data Analysis; and Robotics. Three strands are woven throughout the curriculum: Computer science concepts, equity, and inquiry [3]. The South Dakota effort has sought to remain true to these three strands.

Participating schools and teachers in the earliest cohorts were asked to implement the curriculum as a year-long, stand-alone course. Over time, that expectation evolved to be more flexible, asking that teachers implement at least one semester of the curriculum either as a stand-alone course or integrated within an existing course.

4 Professional Development

Every cohort of teachers (a total of seven cohorts to date) has begun with a 5-day summer institute. Multiple follow-up sessions, typically three or four days in total, have been spread through each school year. In the project's first year (2014-15), participating teachers and members of the project support team worked together to become familiar with the ECS curriculum and took turns teaching it to one another. Every year since, teachers who have taught the curriculum within their own classrooms have served as lead facilitators of the professional development (PD), helping to bring new teachers onboard.

The PD has asked teachers to work through many of the ECS lessons as "students" first and then shift to wearing a "teacher hat" afterwards. Teachers have also typically been asked to practice teaching lessons to one another. Most of the PD has been developed internally within the project, but the project has also drawn upon and learned from the national ECS professional development group. In addition to the ECS curriculum, the project has supplied teachers with supporting resources such as *Computer Science Unplugged* [4], *Stuck in the Shallow End* [5], and *Read Write Code* [6].

Most participating teachers have reported having had little or no background in computer science when joining the project. Summer and school-year PD sessions have been offered using both face-to-face and virtual formats. The project has also offered classroom coaching opportunities – sometimes face-to-face and sometimes virtual, sometimes under a peer coaching model and sometimes utilizing coaches from a supporting partner organization.

Teachers who have participated in any of the project's summer institutes have been invited year after year to participate in subsequent professional development offerings, together with the newest cohort of teachers. A professional learning community (PLC) has evolved over time. The PLC maintains a Facebook page, shares contact information so that project members can reach out to one another and convenes sessions at the state technology conference.

5 Schools Involved

Of the 154 public high schools in South Dakota, the project has worked with 48 (31%), and of the 12 non-public high schools that enroll predominately American Indian students (Bureau of Indian Education, tribally controlled, and private), the project has worked with 3 (25%). Altogether, the 51 schools enroll 19,054 students, which represents 44% of South Dakota's total high school population.

Distribution of Participating High Schools by Enrollment:

1 – 100 students	20 schools
101- 250 students	16 schools
251 - 500 students	7 schools
501–2,500 students	8 schools

While the project has succeeded in introducing the ECS curriculum to many schools in South Dakota, there has been considerable teacher turnover, and some schools that have had a teacher participate are not currently offering the course. The project is aware of numerous cases where a participating teacher discontinued teaching the curriculum due to reassignment by their administration, sometimes due to low course enrollment and sometimes due to a vacancy in another discipline considered by the administration to be a higher priority. In buildings where the curriculum has become well established and a teacher has moved away, a new teacher from that school has joined the program. In other cases, however, when a teacher has moved on, the school has ceased to offer the curriculum. The project's external evaluator plans to conduct case studies moving forward about schools where ECS gained a strong foothold and to draw comparisons with schools where the foothold has been more tenuous.

6 Student-level Assessments

6.1 Sample

A total of 756 students from 18 of the 51 schools that have had a teacher participate are included in the sample. Data were collected between fall of 2015 and spring of 2021. Teachers volunteered to participate in the data collection. Teachers could elect to administer an attitude survey by itself or to administer it together with a problem-solving assessment. Some teachers administered pre-assessments only and others administered both pre- and post-assessments.

- Size distribution of the schools included in the sample: 5 schools with enrollment of 0 to 100 students; 5 with enrollment from 101 to 250 students; 2 with enrollment from 251 to 500 students; and 6 with enrollment from 501 to 2,500 students.
- Grade-level distribution of students in sample: 35% 9th graders; 31% 10th graders; 17% 11th graders; 17% 12th graders.
- Gender distribution: 65% male, 35% female.
- Race/ethnicity distribution: 1.3% Asian; 14.4% American Indian; 1.5% Black; 4.2% Hispanic; 11.4% Mixed/Other; 67.4% White.

For disaggregating data by race, White and Asian students have been categorized as non-underrepresented minority students (non-URM), and all other students have been categorized as URM. Using these definitions, the sample is 68.5% non-URM and 31.5% URM. The proportion of URM students is higher than what would be predicted based on the overall URM representation within the 18 participating schools (28.5%) and higher still than the statewide percentage (25.8%) [7]. The fact that URM students are overrepresented within the sample compared to the student bodies of the participating schools is consistent with and affirming of project's emphasis on broadening participation within computer science.

6.2 Student Attitudes

The project's 21-question attitude assessment was adapted from the *Attitudes Towards Mathematics Inventory* (ATMI) [8]. Teachers from the project's initial cohort and members of the project support team selected 19 questions from the ATMI as being of particular interest and replaced the word "Mathematics" with "Computer Science." Two additional questions were developed locally by project team members (questions 19 and 20). The survey measures student confidence, motivation, enjoyment, the degree to which students value computer science, and preferred modes of instruction. All of the questions, together with baseline results for the 736 students completing the survey as a pre-assessment, are shown in Figure 1 (see Appendix A).

Disaggregated data reveal statistically significant differences in attitudes between male and female students and between URM and non-URM students at the beginning of the class. The most pronounced difference on the pre-assessment between male and female students relates to confidence. Female students within the sample were less confident about computer science (question 9) than male students with a Cohen's effect size of 0.65. This difference is highly statistically significant ($p < 0.001$). Female students rated the value of computer science similarly to male students but reported lower enjoyment (question 12, effect size = 0.49, $p < 0.001$).

The most pronounced difference on the pre-assessment between URM and non-URM students pertains to pedagogical style. URM students were neutral on the statement that they "learn more from listening to teachers' explanations than by doing activities" (question 19), whereas non-URM students somewhat disagreed that they "learn more from listening than by doing" (effect size 0.35, $p < 0.001$). URM students also reported lower perceived value of computer science for everyday life (question 4, effect size = 0.28, $p < 0.001$).

From pre to post, students across the entire sample gained confidence. Female students gained more confidence than male students, but a statistically significant gap was still evident between male and female confidence by the end of course. Furthermore, female confidence on the post-survey was still lower than male confidence on the pre-survey. URM students gained less confidence as a subgroup than female students, but the gain is still statistically significant. Numerous other indicators show only nominal improvement from pre to post, and some show a decline.

6.3 Problem-Solving Assessment

The problem-solving assessment was developed by project team members and participating teachers within the initial cohort. The first question on the assessment asks students to find the shortest and the longest paths through a maze, following a prescribed set of rules about what movements are allowed, and to justify their reasoning. The second question specifies that a collection of bicycles and go-carts have a total of 21 seats and 54 wheels combined. Go-carts have four wheels, bicycles have two wheels, and each has one seat. The question asks students to determine how many bicycles and how many go-carts are in the collection, to show their work, and to explain how they figured it out.

Performance of male and female students was statistically equivalent on the pre-assessment. URM students performed lower on the pre-assessment with an effect size of 0.59 ($p < 0.001$). Growth from pre-test to post-test for all students had an effect size of 0.45 and is statistically significant ($p < 0.001$). Growth for male students had effect size of 0.47, growth for female students had an effect size of 0.42, growth for non-URM students had an effect size of 0.49, and growth for URM students had an effect size of 0.42 (all statistically significant with $p < 0.001$).

7 Discussion

7.1 Value of these data from RPP Perspective

Student data serve as the basis for discussions and reflection among participating teachers and project support team members._Teachers benefit from having a sense of the beliefs and attitudes that students are likely to hold related to computer science when they arrive in their class and the degree to which those attitudes are likely to change through participating in the class. Favorable data help in recruiting additional teachers and schools to the project. Less favorable data prompt discussions about strategies to have a more positive impact on students. These data have also been helpful in thinking about how to recruit greater numbers of students, especially those from underrepresented subgroups. And finally, these data have served to inspire computer science efforts at other grade levels. In particular, data from this high school effort motivated team members to launch a new NSF-funded RPP focused on elementary grades. The elementary project is exploring the idea that increased exposure to computational thinking at younger grades will yield stronger problem-solving skills and greater confidence among students entering high school.

7.2 Value to the CS Education Community

Data from South Dakota are useful for comparison with other geographic regions and with different approaches to adding computer science to the high school curriculum. Schools and teachers across the country are encouraged to examine how their student demographics, attitudes, and problem-solving skills compare.

8 Limitations of this Study

While 56% of the high schools in the sample enroll 250 students or fewer, only 31% of the students in the sample are from schools that small. The findings reported here are more representative of South Dakota's larger schools than they are of the smaller schools.

The analysis does not differentiate between teachers who taught the ECS curriculum as a full year course, those who taught a portion of the curriculum as a semester course, and those who integrated ECS units within an existing course. The analysis also does not consider teacher experience or expertise in implementing the ECS curriculum.

The assessments were administered to students as low-stakes assignments with no grades attached. This may have influenced the amount of effort that students invested and the seriousness with which they responded.

The time of year that the assessments were administered and external conditions such as the Covid-19 pandemic may also have influenced students' attitudes and their motivation to invest full effort in completing the assessments.

ACKNOWLEDGMENTS

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The authors are grateful for the support of the primary partner organizations: Black Hills State University, the 51 participating high schools across South Dakota, Inverness Research, Technology and Innovation in Education, and South Dakota Mines.

REFERENCES

[1] Research-Practice Partnerships: A Strategy for Leveraging Research for Educational Improvement in School Districts, Coburn, C.E., Penuel, W.R., and K. E. Geil, William T. Grant Foundation, 2013.
[2] *Exploring Computer Science*, Goode, J. and G. Chapman, University of Oregon, Curriculum Version 4 (2014) through 9 (2019).
[3] Exploring Computer Science: A K-12/University Partnership to Democratize Computer Science, http://exploringcs.org/
[4] *Computer Science Unplugged: An enrichment and extension programme for primary-aged students*, Bell, T., Whitten, I. H., and B. Fallows, http://csunplgged.org, licensed under Creative Commons, 2015.
[5] *Stuck in the Shallow End: Education, Race, and Computing*, J. Margolis, The MIT Press, Cambridge, MA, 2008, 2017.
[6] Read Write Code: A friendly introduction to the world of coding, and why it's the new literacy, Keeshin, J., Lioncrest Publishing, 2021.
[7] South Dakota Department of Education, Student Enrollment Data, 2019 Fall Enrollment, https://doe.sd.gov/ofm/enrollment.aspx.
[8] Tapia, M. and G. E. Marsh II, "An Instrument to Measure Mathematics Attitudes," *Academic Exchange Quarterly*, Vol. 8, 2004.

APPENDIX A

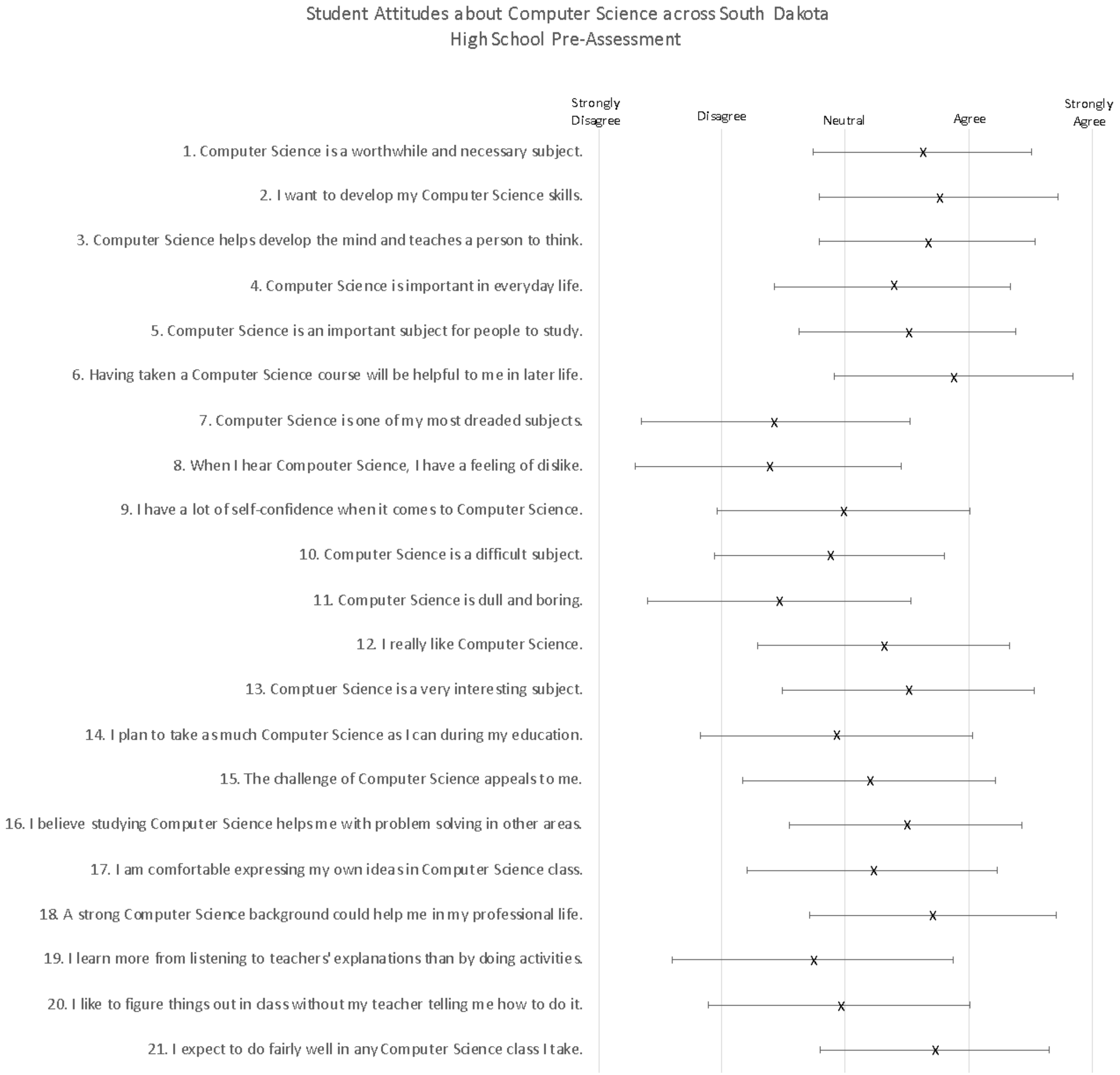

Figure 1: Student Attitudes at the beginning of the ECS course. Pre-survey data were collected from fall of 2015 through fall of 2020. Total number of respondents = 736. Average response for each question is indicated by an X. One standard deviation on either side is indicated with line segment.

Yonezawa, S., Mai, M., Simon, B., & Rogers, Jr., K.. (2021.) CS-LISTEN: Students as Active Changemakers in RPPs. In CSforALL & SageFox Consulting Group (Eds.), The intersection of RPPs and BPC in CS education: A culmination of papers from the RPPforCS Community [White paper]. Retrieved from https://doi.org/10.13140/RG.2.2.25327.97443

CS-LISTEN: Students as Active Changemakers in RPPs

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Abstract

The CS-LISTEN National Science Foundation (NSF) Research Practice Partnership (RPP) is housed within the Center for Research in Education Equity Assessment & Teaching Excellence (CREATE) at UC San Diego. For 23 years, CREATE has housed trusted, long-standing partnerships with districts, schools, and local educators. CS-LISTEN's RPP meets with an advisory board of non-profit, university, and K12 teachers (bi-annually), four districts' and school-level administrative leaders (quarterly), ten high school teachers (weekly), and 112 participating students in small teams (weekly) at schools. Youth Participatory Action Research (YPAR) methods allow CS-LISTEN Student Co-Researchers (SCRs) to work alongside teachers and CREATE researchers to gather data and research their schools/peers as to why many underrepresented students do not participate in computer science (CS) classes. Nine SCR teams designed unique research questions and surveys, collected data, and conducted analyses. SCRs reported findings and recommendations to school and district leaders, and designed, coordinated, and led Action Cycles to increase CS participation at schools. In Action Cycles, students, CS-lead teachers, and administrators worked to enact SCR teams' recommendations. They did this through the creation of new a) virtual re-branding via promotional projects and presentations, b) coding bootcamps and hackathons, and c) incorporation of novel systems-level changes at their schools and districts. Preliminary findings from RPP member (student, teacher, and administrator) interviews reveal that CS-LISTEN student RPP members have helped expose CS broadening participation in computing (BPC) issues in novel ways. The nine SCR teams and the RPP efforts overall show how students can act as changemakers within RPP structures to catalyze BPC equity projects in schools and districts. This paper shares best practices and strategies for designing and implementing YPAR, and specifically student-co-research, as a foundational pillar of RPPs to improve BPC projects and increase more equitable student engagement in computer science.

Keywords

Computer Science Education, Youth Participatory Action Research, Research-Practice Partnerships

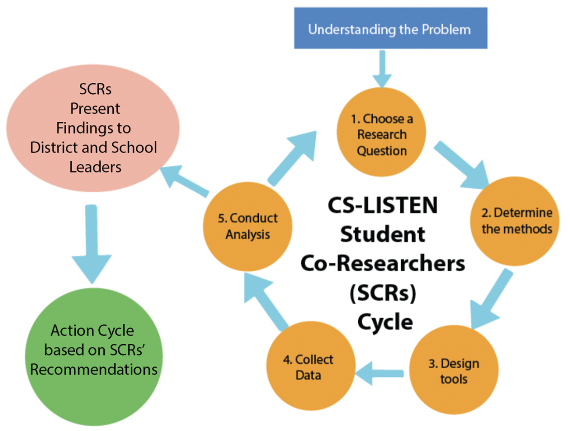
Why Computer Science Needs YPAR + RPP

In the United States, broadening participation in computer science has become a paramount call to action. According to the U.S. Labor Statistics, the demand for students learning computer science (CS) has risen in the past two decades [13]. With the global pandemic, improving participation in CS is even more important [6]. But participation among low-income students, students of color, and female students has stagnated [3]. To tackle this dire issue, many governmental, non-profit organizations, and school districts have partnered to address CS rates through research-practice-partnerships (RPPs). Nonetheless, within RPPs, K12 students as changemakers remain rare. In this article, we demonstrate how CS-LISTEN places students in the driver's seat, alongside teachers, district and school leaders, and university researchers, through the use of Youth Participatory Action Research (YPAR) structures and practices.

CS-LISTEN: Computer Science Learning and Inquiring with Students through Equity Networks

CS-LISTEN is a National Science Foundation funded RPP that includes four districts' and school-level administrative leaders (meeting quarterly), ten high school teachers (meeting weekly), and 112 participating students (in small teams) (meeting weekly) across nine high schools.

The work of the CS-LISTEN RPP is to investigate: *How can the inclusion of student voice in the design process increase engagement in K12 CS pathways?* By employing YPAR practices and structures, CS-LISTEN researchers worked with Student Co-Researchers (SCRs) and teachers from January 2020 to June 2021 to gather, analyze, and present data on CS at their schools. Overall the groups studied why their schools/peers do or do not enroll larger numbers of underrepresented students in CS classes. (See figure below for an example of the SCR Cycle within CS-LISTEN.)



During the first five phases of work (see the orange cycle above), the nine CS-LISTEN SCR teams and their teachers designed unique research questions and surveys, collected data, and conducted analyses. The SCR teams then reported findings and recommendations to their respective school and district leaders, at a large (virtual) conference -- CS LISTEN UP -- attended by 250+ students, parents, educators and administrators including district superintendents in November 2020. (See pink circle above.)

Lastly, RPP teams of university leaders, students and teachers -- periodically joined by administrators at the school and/or district levels -- designed, coordinated, and led Action Cycles to increase CS participation at schools. (See green circle above.)

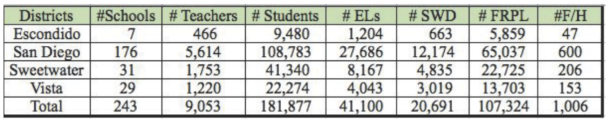
In Action Cycles, students, with CS-lead teachers, enacted recommendations through the a) creation of new virtual re-branding and promotional projects and presentations, b) coding bootcamps & hackathons, and c) incorporation of new systems-level changes at their schools and districts. By describing this process, we share our initial findings and recommendations for doing YPAR in the scope of RPPs.

What is Youth Participatory Action Research (YPAR)?

Starting in the mid-2000s, social scientists began exploring how to engage youth in research and practice. Epistemologically, YPAR extends from participatory action research (PAR), which uses both quantitative and qualitative methods "to interrogate the conditions of oppression and surface leverage points for resistance and change" [4]. Theoretically, YPAR comes from critical psychology and positions youth as agents and experts of their own lived experiences [7]. Essentially, YPAR work is 1) grounded (in students' experiences) 2) participatory (with students as partners) and 3) transformative (make communities/lives better). Anyon and her colleagues' meta-analysis of 67 YPAR studies conducted from (1995 to 2015) suggests that engaging in YPAR positively impacts participating youth who experience an increased sense of agency/leadership, interest levels in career development, and critical consciousness [1]. Yet, while the third dimension of student voice/YPAR work demands "transformation", there is far less published work on the qualitative or quantitative impact of student voice work on institutional change. Few studies have tracked how student-driven research impacts institutions and systems [8].

School and District Contextual Factors for CS-LISTEN Sites

CS-LISTEN engaged YPAR student teams that we call Student Co-Researchers (SCRs) within our collective RPP. Our goal: to investigate and begin to address uneven school and district patterns on CS enrollment at the nine participating high schools and within their four respective districts. Altogether the districts serve a majority of San Diego County high school students. The four districts were San Diego Unified School District (SDUSD), Sweetwater Union High School District (Sweetwater), Escondido Union High School District (EUHSD) and Vista Unified School District (Vista). All nine participating CS-LISTEN comprehensive high schools serve highly diverse populations. Their districts are equally diverse overall, as noted in the table below: "EL" (English learners); "SWD" (students with disabilities); "FRPL" (free/reduced price lunch); and "F/H" (Foster/Homeless).[1]



Districts	#Schools	# Teachers	# Students	# ELs	# SWD	# FRPL	#F/H
Escondido	7	466	9,480	1,204	663	5,859	47
San Diego	176	5,614	108,783	27,686	12,174	65,037	600
Sweetwater	31	1,753	41,340	8,167	4,835	22,725	206
Vista	29	1,220	22,274	4,043	3,019	13,703	153
Total	243	9,053	181,877	41,100	20,691	107,324	1,006

During the 2020-21 CS-LISTEN project, the nine participating high schools enrolled students from grades 9th-12th, averaging 1,955 students per school. Approximately 72 percent of the students at the schools were eligible for free or reduced-price meals and the majority of the schools' students are Latinx. The nine CS-LISTEN high schools enroll a total of 12,440 Latinx, 2,487 White, 677 Black, 639 Asian, and 102 Pacific Islander students.

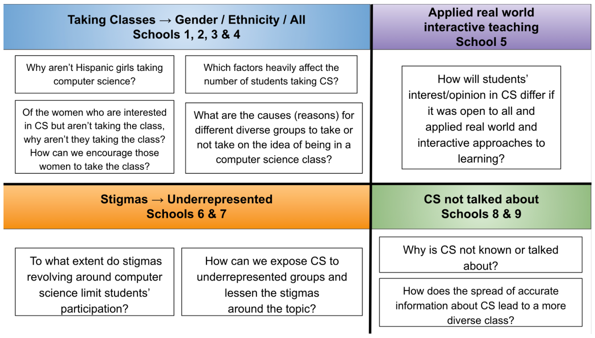
CS-offerings: The participating schools all offered Advanced Placement CS Principles (AP-CSP) during the 2019-21 school years. In addition, the majority of schools also offered the more advanced AP-CSA course and/or a more advanced comparable CS course (e.g. Computer Gaming). A few schools offered an even earlier sequenced course (pre AP-CSP) using curriculum such as Exploring CS, and CS Discoveries. A couple of schools also had additional supplemental/related courses such as Data Sciences that were positioned within the mathematics departments rather than college and career readiness or technical education units of their districts.

YPAR Student Recruitment

The 112 participating CS-LISTEN SCR students were recruited through a combination of teacher solicitation through classroom presentations, school announcements, and personal invitations by teachers/administrators to potentially interested students. Students who joined their schools' SCR teams also helped to recruit peers to join the teams. Special efforts were made to recruit among both CS experienced and non-CS students as well as to recruit a diverse team of students at each school regarding their academic backgrounds, grade levels, and race/ethnicity/gender. Participating students received a thank you gift card of $100 at the end of their participation, along with a certificate.

What Did the Student Co-Researcher RPP Teams Accomplish?

All nine CS-LISTEN SCR teams worked with their teachers and university leads to identify and then investigate a joint CS research question. The SCRs used primarily survey data to answer their respective research questions. (See the following figure for the nine SCR teams' questions categorized by type.) The CS-LISTEN university researchers lead a series of meetings and brainstorming sessions to assist SCR teams and their teachers. In these meetings, teams crafted meaningful research questions. Researchers helped ensure that the questions were operationally definable and pursuable within the four-month time frame. In all cases, preservation of the students' collective voice and perspective remained paramount during research question creation.



Taking Classes → Gender / Ethnicity / All
Schools 1, 2, 3 & 4

Why aren't Hispanic girls taking computer science?

Which factors heavily affect the number of students taking CS?

Of the women who are interested in CS but aren't taking the class, why aren't they taking the class? How can we encourage those women to take the class?

What are the causes (reasons) for different diverse groups to take or not take on the idea of being in a computer science class?

Applied real world interactive teaching
School 5

How will students' interest/opinion in CS differ if it was open to all and applied real world and interactive approaches to learning?

Stigmas → Underrepresented
Schools 6 & 7

To what extent do stigmas revolving around computer science limit students' participation?

How can we expose CS to underrepresented groups and lessen the stigmas around the topic?

CS not talked about
Schools 8 & 9

Why is CS not known or talked about?

How does the spread of accurate information about CS lead to a more diverse class?

After research questions were identified, researchers continued to work with the SCRs and the teachers on methods. The nine teams ended up using survey methods. University leads were impressed by the amount of data gathered and analyzed by the SCR teams with their teacher leads, particularly during the pandemic. Across the nine SCR teams, survey responses ranged depending on the topic being addressed, with some teams surveying over 700 students at their schools and others a more targeted 80+ students.

Next, we describe the scope of work SCR teams accomplished while conducting their research projects. Then, we describe how some members of the SCR teams (and other students who joined later) worked with teachers, administrators, and university leads to move the SCR teams' recommendations into Action Cycles.

SCR Data Collection and Data Analyses

After identifying their research question and study populations, each SCR team worked carefully with their teacher leads and UC San Diego CS-LISTEN researchers to develop methods that would help answer their questions. In the end, the SCR teams used Google Forms to gather their data because of the familiarity of Google Forms among their student populations. Although all nine SCR teams ended up using surveys, surveys are not necessarily the only method YPAR projects can deploy. SCR teams were encouraged to

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[1] While this table helps lay out demographic patterns, we recognize students live in an intersectional world of underrepresentedness, occupying more than one subgroup simultaneously.

think about adding interviews to their data collection and some had planned to before the Covid-19 disruption in March 2020. As for the data collected, the surveys varied by schools in terms of length, format, questions asked, and respondents surveyed. As a support, UC San Diego team leaders created informative slide decks for the teachers and SCR teams as they crafted their surveys. These decks introduced survey methods, question construction, skip logic instructions, scales, and access to public databases, among other topics.

All nine SCR teams and their teachers used these slide decks within the weekly meetings with UC San Diego researchers to craft nine distinct surveys that focused on their research questions. Then the SCR teams deployed their surveys.

Once the SCR teams completed data collection (most were finished just prior to the shutdown in March 2020), data analyses were paused until fall 2020. Data analyses were also supported by the UC San Diego team and teachers through the creation of slide decks and mini-lessons on data analyses. Teachers also helped SCRs make sense of the data they had collected.

The SCR teams and their teacher leaders uncovered many findings from their survey analyses. For instance, at Morse High School the SCR team and teachers asked, “To what extent do stigmas revolving around computer science limit students’ participation?” They came to the conclusion that the majority of surveyed students were both open to CS information and woefully uninformed at the same time. While a majority of students surveyed (67%) appreciated the importance of CS to society, a majority (57%) also had no idea what it was exactly. Students knew it was important, but they didn’t know what it was. Indeed only 7% of surveyed students at MHS rejected the idea of having CS introduced to them at all. At the end of their analyses, the MHS SCR team and their teachers concluded:

> We should strive to provide more opportunities to learn more about coding specifically, we believe that with more effort thrown into communities like ours, we can raise the number of minorities pursuing Computer Science in their post-education career.
>
> *Morse High School SCR team*

At Orange Glen High, the SCR team was interested in finding out, “What factors heavily affect the number of students taking CS?” In their survey of 303 students, the OGHS SCRs found that the majority of students did not know what CS is, and female students were less likely to want to take CS. The OGHS SCRs analyzed that one of the factors may be due to the fact that female students reported using their class schedules more often to plan out their future courses. This sometimes led female students to conclude that CS classes did not fit into their schedules. Because of this, OGHS SCRs posited that there may be a systemic scheduling issue (real or perceived by females), preventing some young women in particular from pursuing CS classes.

Finally, at Hoover High School, the SCRs and their teacher asked, “How will students’ interest/opinion in CS differ if it was open to all and applied real world and interactive approaches to learning?” They concluded that Advanced Placement CS Principles (AP-CSP) should be open to all students regardless of their tracks and academies. Since Hoover High students apply to Academies at the start of their freshmen year, SCRs pinpointed that the opportunity to take CS classes was only available to students in the Academy of Information Technology, (AOIT). AOIT students represented only a subset of students within the larger high school. Students outside of AOIT were unable to enroll in the AP-CSP course. As a result of their research, the Hoover SCRs and their teacher then recommended that a brand-new section of AP-CSP should be opened at Hoover, but this time for all Hoover HS students.

These are just three examples of how SCR teams moved from their research questions to data instrumentation, collection, and analyses. All nine schools’ SCR teams followed a similar trajectory.

SCR Teams’ Findings and Next Steps

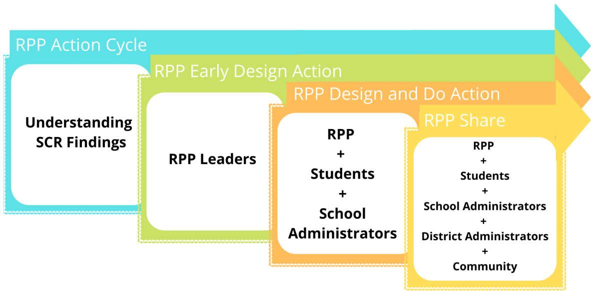
By fall 2020, the SCR teams had produced a mountain of data and analyzed their findings alongside UC San Diego researchers and their teacher leaders. These findings were later compiled and shared with a large audience of 250+ at the CS-LISTEN UP conference in November 2020. They also produced a list of recommendations for each school to broaden participation in computer science.

For many YPAR projects, this is often where the story ends. YPAR students do studies, and then present findings. Usually it is up to the adults with power to then enact (or not) the changes recommended. Fortunately, the RPP structure of the CS-LISTEN UP grant and the NSF support allowed for the second phase of our collective work to begin: The Action Cycles.

Action Cycles: YPAR to Practice

What are Action Cycles? CS-LISTEN Action Cycles involve small teams of students, educators, administrators, and UC San Diego researchers taking SCRs’ recommendations and designing, testing, and re-testing the SCR recommendations as interventions. In an Action Cycle, newly designed interventions might take the form of early prototype efforts field-tested at one school or with a small group of students (in a single class period for example) or even larger campus initiatives (e.g. a new school-wide recruitment strategy for women). In this way, CS-LISTEN, as a RPP, leans on the structures and practices of SCRs (as YPAR) and Action Cycles to gather new insights (through student research) which lead to potentially new school or district practices and policies over time (through Action Cycles).

Whatever the interventions, **the CS-LISTEN Action Cycle is where the research transforms to practice** — in the form of prototyping, testing, and retesting.



Early Assumptions and Shifts in Practice

Early on, and in our original grant proposal, we assumed that adult RPP members (teachers, administrators, and district folks) would largely run the Action Cycles. After meeting twice with our project's advisory board, however, we heard the strong suggestion that students might continue to play important roles in the Action Cycles. District officials also stated that they saw tremendous value in encouraging the SCRs to continue as active members.

Once the transition started from SCR work to the Action Cycles, we quickly learned that a high number of SCRs were indeed interested in actively working on their school's Action Cycle teams. They were interested in seeing where their recommendations would go. They were intrigued with the idea of having a voice in allocating the Action Cycle budgets afforded to their sites by the grant. Many SCRs seemed to have developed a collective sense of social justice around the need to broaden participation in CS.

> I like the fact that we are working towards diversifying the computer science field because as a school, we have a lot of minorities here, and I just want them to be represented more in that field.
>
> *Latinx female student from Hoover High School*

> What I find exciting about CS-LISTEN is working with people that I really don't see everyday and working towards a problem that we may actually make a difference within our school.
>
> *Black male student from Morse High School*

As a result, at all nine schools, SCR team members stayed involved as leaders of the Action Cycles. Schools varied with some schools retaining a single SCR team member and others actually growing their student involvement to 30+ students. All but two of the lead teachers also stayed with the Action Cycles and continued to provide a space (usually virtual) where the involved students could work in teams and with other educators on Action Cycle tasks when needed.

Examples of Student Co-Research to Action Cycle Work in CS-LISTEN RPP Teams

At Morse High School, for example, the SCR team's research had identified a **key issue — outreach to younger grades.** Students, they found, through their survey work, were unaware of CS opportunities and courses at their high school. When the school shifted to the Action Cycle period, the first step was for the students and teachers to discuss these recommendations with the Morse High principal in a follow-up meeting. In addition, a district resource teacher who was placed at Morse High also became keen on working on this recommendation. The MHS RPP team had transitioned to include UC San Diego CS-LISTEN researchers, SCRs, new students, the lead teacher, and the principal and district resource teacher. (While the principal was unable to attend weekly meetings, she attended some and willingly responded to emails, requests for in-person meetings, and took on tasks to review letters and advocate for the RPP's work.)

Through the efforts of the school administration, district resource teacher, students and the MHS CS-LISTEN teacher lead, the MHS RPP tested the idea of creating an on-campus club called Morse Codes that would then spearhead various types of student-led outreach. The Morse Codes group (which ended up being over 20 active students who created their own Discord group to work collectively online) then worked with the district resource teacher to create online coding camps for younger students in the school's feeder pattern. The high school principal committed to using her substantial social capital to convey to her feeder pattern principals at local K-8 schools to advertise and actively promote the camp to their younger students.

The SCRs at Orange Glen High School in the Escondido Union High School District (EUHSD) uncovered a **key issue — an under awareness at their own school about CS**

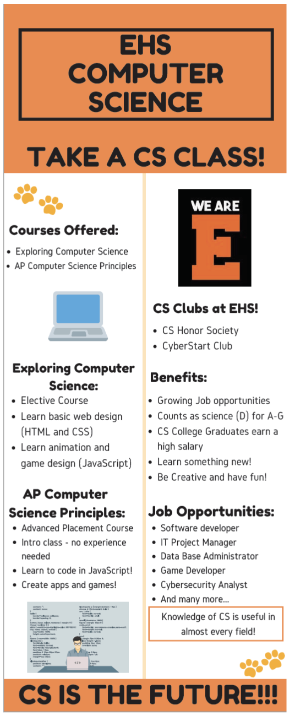
courses. Within this school, a key connection was a very active district-level Director of College and Technical Education, who also oversaw all the district's CS pathways and courses. This director became very involved in the SCR team's work at OGHS (and at the other two participating high schools too). She attended many of their meetings and helped shape the types of work that might happen in the schools' Action Cycles. This included launching a "Choose You" campaign in English and Spanish on the district's website, which highlighted CS courses that could be taken in the career and college pathways. In the end, at OGHS and across the other two participating district high schools (Escondido and San Pasqual), the Action Cycles focused on a mix of targeted CS outreach (e.g. guest speakers targeting female students) and a focus on greater cooperation with counselors to insert a CS course description in the catalog/schedule that could dispel misconceptions about CS courses. The district director helped the students by advising them, placing some of their newly created artifacts on the district website to champion the CS courses at their schools, and sharing the Action Cycle work with the superintendent, district leaders, and notably the school board.

At the school site level at OGHS, Action Cycle work also included students talking to school counselors to promote more active advising of students as to how they might fit CS in what students saw as an already impacted four-year schedule. The district leadership helped the Action Cycle students even present to the districts' counselors as a whole about the affordances of taking CS.

As mentioned in the section before, the Hoover HS SCR team's research also unveiled a **key issue — that computer science was restricted to only one academy within their larger high school.** As the team and school moved to an Action Cycle phase, the teacher and continuing students were excited to have the support of their principal who had attended the CS-LISTEN UP conference and who had heard their presentation. He and another site coordinator at the school met with the Action Cycle student and teacher team to brainstorm their next step efforts. Over the course of the next few months several important changes occurred. Most notably, the school decided to change its enrollment offerings by placing another CS course on the schedule, and for the 2021-22 school year, the course (for the first time) will now be accessible to all students at the high school, not just those in the Information Technology academy.

Although we have highlighted three of the nine schools above, it is important to note that the RPP work in the Action Cycles varied tremendously by schools. If we look across the nine schools, work in the Action Cycles can be grouped into three broad categories: Promotion/marketing, virtual CS introductions, and systematic change.

Promotion/Marketing: Given restrictions of online schooling during Covid-19, the Action Cycles at each school focused efforts on revamping their schools' social media efforts around CS. RPP Social media campaigns were led by the students, teachers, and when appropriate administrators, who launched new student-drafted content on Instagram and TikTok as well as created new web-based content, digital flyers (in Spanish and English), infographics, and videos for webinars. Online materials such as these were used by Action Cycle teams to raise CS awareness. Escondido High School's (EHS) Action Cycle team, for example, created and then distributed to students new CS promotional materials. These materials were meant to assist students, particularly female students and Spanish-speaking students, as they planned their next classes for fall 2021. For instance, the EHS RPP drafted and printed out the infographics (below) to hand out to parents/guardians and students. The infographic, in English and Spanish, highlighted available opportunities and the affordances to learn CS, including taking AP-CSP, joining CS clubs, and future job opportunities relating to CS.


EHS COMPUTER SCIENCE

TAKE A CS CLASS!

Courses Offered:
- Exploring Computer Science
- AP Computer Science Principles

Exploring Computer Science:
- Elective Course
- Learn basic web design (HTML and CSS)
- Learn animation and game design (JavaScript)

AP Computer Science Principles:
- Advanced Placement Course
- Intro class - no experience needed
- Learn to code in JavaScript!
- Create apps and games!

WE ARE E

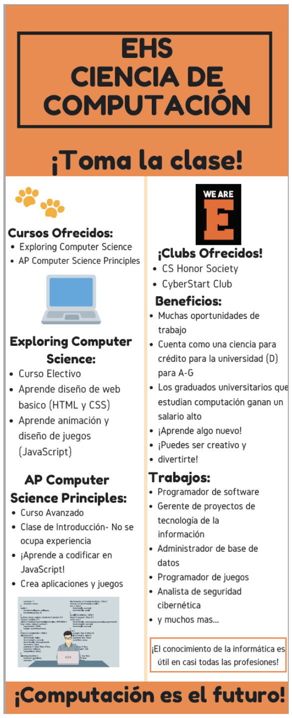
CS Clubs at EHS!
- CS Honor Society
- CyberStart Club

Benefits:
- Growing Job opportunities
- Counts as science (D) for A-G
- CS College Graduates earn a high salary
- Learn something new!
- Be Creative and have fun!

Job Opportunities:
- Software developer
- IT Project Manager
- Data Base Administrator
- Game Developer
- Cybersecurity Analyst
- And many more...

Knowledge of CS is useful in almost every field!

CS IS THE FUTURE!!!


EHS CIENCIA DE COMPUTACIÓN

¡Toma la clase!

Cursos Ofrecidos:
- Exploring Computer Science
- AP Computer Science Principles

Exploring Computer Science:
- Curso Electivo
- Aprende diseño de web basico (HTML y CSS)
- Aprende animación y diseño de juegos (JavaScript)

AP Computer Science Principles:
- Curso Avanzado
- Clase de Introducción- No se ocupa experiencia
- ¡Aprende a codificar en JavaScript!
- Crea aplicaciones y juegos

WE ARE E

¡Clubs Ofrecidos!
- CS Honor Society
- CyberStart Club

Beneficios:
- Muchas oportunidades de trabajo
- Cuenta como una ciencia para crédito para la universidad (D) para A-G
- Los graduados universitarios que estudian computación ganan un salario alto
- ¡Aprende algo nuevo!
- ¡Puedes ser creativo y
- divertirte!

Trabajos:
- Programador de software
- Gerente de proyectos de tecnología de la información
- Administrador de base de datos
- Programador de juegos
- Analista de seguridad cibernética
- y muchos mas...

¡El conocimiento de la informática es útil en casi todas las profesiones!

¡Computación es el futuro!

Virtual Events to Introduce CS: Other work launched in the Action Cycles centered on teams hosting virtual events to introduce coding using Code.org's Hour of Code. These events aimed at promoting CS often among younger students (pre-high school). For example, in the Sweetwater High School Action Cycle RPP, the teacher and students collaborated with local middle school administrators and teachers to recruit younger students to extracurricular opportunities so that they could know what CS is and, hopefully, enjoy it. Over winter break, the Sweetwater High RPP held two coding camps, one for middle school and one for students from their high school. Later, Sweetwater held a second promotional coding camp with Castle Park High Action Cycle leaders during their joint spring break. Similarly, Mission Vista High School's Action Cycle team also hosted a virtual introductory hackathon during their spring break. All camps were well attended, often co-facilitated by educators, and always co-promoted and informed by district/school administrators and teachers, including from the feeder schools. All addressed the research findings of under awareness of CS in these schools.

Systematic Change: Action Cycle teams also dove into systematic change. We already described how, at Hoover High, the principal, school administrators, and counselors listened to the Hoover SCRs' recommendation to expand the school's CS course offerings starting fall 2021. In addition, in the Vista Unified School District, Mission Vista High and Rancho Buena Vista High Action Cycle efforts worked with their schools' administrations to improve the diversity of their CS pathways and expand interest among all students. Mission Vista High worked on reformulating the ways in which their school's CS courses were (or were not) treated and advertised in official course descriptions as a pathway. They also worked on making CS classes count towards a-g requirements for the University of California and California State University admissions requirements. Both RBVHS's and MVHS's Action Cycles focused on re-branding their CS courses by providing more age-appropriate marketing materials. Mission Vista even went a step further and in summer 2021 offered a class for CS1, so students had more room in their schedules to take CS2 in the fall. They also recently lobbied the California Scholastic Federation (CSF) to grant higher CSF status to these same courses. In the Vista Unified School District, RPP students and teachers from both high schools were invited into the districtwide STEAM team discussions which brought together leaders from across the district to reformulate STEAM offerings K12.

Lastly, in the Escondido Union High School District each school (Escondido, Orange Glen, and San Pasqual High) conducted their own respective Action Cycles. But the work also was raised to a systemic level when the three Escondido high schools began working more closely with district leaders and school counselors to add to the district website's "Choose You" campaign. In their case, the schools' Action Cycle work was elevated through the addition of the District's Career College and Technical Education Director more directly into the RPP team.

Across the nine schools, the move to Action Cycles rendered adjustments in the RPP team members, their commitment to the work, and their generation of new materials, tools, artifacts and organizations. District and school administration and teacher participation increased at most sites. Still what was unexpected was the sustained interest and energy from SCR students, and, in some cases, new students (recruited by SCRs) to RPP efforts during the Action Cycle period.

CS-LISTEN Learning from Communities of Practice

According to Penuel and Gallagher's *Creating Research Practice Partnership in Education* [9], effective RPPs share some important characteristics: They 1) focus on problems of practice 2) engage in long-commitment with school districts and key stakeholders 3) establish a mutualistic relationship and 4) generate original analyses.

CS-LISTEN is an innovative RPP because it focuses on broadening participation in CS by incorporating student voice. But the act of including students in RPP work of this nature requires that adults be particularly mindful of how RPP work needs to be adapted to consider the needs of student participants, specifically.

In our case, we borrowed thinking on what it means to become a successful RPP (as one that merges SCRs/students, university researchers, and district and school leaders/teachers) from literature on communities of practice (CoP). From its onset, CS-LISTEN used a CoP framework to evoke learning collectively and individually. More specifically, our team attended to the research that effective CoPs have the following features [5, 10, 11, 12].

1. **Joint Enterprise:** Deciding on a shared pursuit or aim – note this can and should be negotiated and re-negotiated over time by members of the CoP.

2. **Mutual Engagement:** Regular and desired interaction and the building of relationships toward the joint enterprise.

3. **Shared Repertoire:** Description of the tools, language and knowledge, and artifacts that characterize group participation.

Enacting Joint Enterprise in a Student-inclusive RPP

Using the CoP literature as a guide, we began the CS-LISTEN SCR teams' development with teachers and students by launching the work at a **joint enterprise** event — CS-LISTEN Launch — in January 2020. At this in-person (pre-pandemic), multi-hour event, speakers made presentations so that the SCRs, teacher leaders and university researchers could develop a collective understanding of the problem of CS underrepresentation, and the goals of broadening participation. The launch occurred at the start of the CS-LISTEN **joint enterprise** as a collective move. We did this as CS-LISTEN required joint work, but new SCR (and adult) participants likely needed individual professional learning on CS underrepresentation.

Following the January 2020 CS-LISTEN Launch, we engaged with the 100+ SCRS and 14 teacher leaders in weekly sessions from January-March 2020. These weekly sessions enabled the teacher-student-university teams to develop a sense of deep commitment towards our **joint enterprise** of broadening participation in CS. In March-April 2020, the pandemic abruptly shutdown in-person work causing us to pause the CS-LISTEN project while our K12 partners got their bearings and dealt with the chaos of the spring shutdown. But we knew we had achieved a sense of joint enterprise when in fall 2020, we re-started the project with the SCR teams (few were seniors the year prior) and a majority of students in all nine SCR teams, and every educator, rejoined the work.

Work on **joint enterprise occurred a second time** during the overall project as we shifted from the SCR teams' research to the RPP Action Cycle phase of our collective work. This time, however, the SCRs work drove the discussions. At the CS-LISTEN UP conference in November 2020, SCR teams and their teachers showcased their newfound knowledge about the CS inequities at their schools. With a substantial audience of administrators, teachers, and counselors (from across the county), the SCR teams and their teachers shared understanding within a larger CS broadening participation community of actors.

Like the students quoted earlier, students across SCR teams reported in June 2021 that they better understood the need to broaden participation in CS, at their schools and throughout the U.S.. Focus groups with small groups of students at all nine schools confirmed this as students expressed how much they had learned about the need to broaden participation in CS. One student stated in spring 2021:

> This project has made me realize the extent to which, computer science is isolated to only one specific gender or one specific race, and others are kind of intimidated by that, or they don't want to pursue computer science because it's dominated by a certain group of people.
>
> *Latinx female student from San Pasqual High School*

Moreover, students and teachers alike expressed how they not only saw the need to grow CS pipelines in K12 systems, but they also saw how doing so was connected to larger issues of workforce development, college and career access and even the ambitious goal of disrupting cycles of generational poverty. As one student explained why s/he/they thought the project was important:

> I feel like you can help them get it, step out of the generational poverty, because there's millions of jobs open for CS, because it's currently one of the most increasing job markets there is right now. Generally, very decent salary that could help many students...leave that cycle of, like, just graduating and going to work. So I feel like it's something that could definitely help many minorities break a cycle in their family, and go more towards higher education, because like by helping build this path that we did right now, it'll help them be more [likely] to do this in college.
>
> *Latinx female student from Orange Glen High School*

Mutual Engagement as a Way to Build RPP/BPC Connections

Mutual engagement (another key facet of an effective CoP and our RPP) was fostered, we believe, through the regular weekly meetings of the SCR teams in the first half of the project and the usually weekly or bi-weekly meetings of Action Cycle RPP teams in the second half.

Through 2020-21, Action Cycles at each of the nine schools had student leadership and participation, enjoyed weekly teacher leadership, and engaged their school/district administrators as partners in broadening participation in CS. Later they added more teachers, administrators, and other students in the Action Cycles further enhancing this sense of **mutual engagement**. Students and teachers and even administrators who attended the meetings became committed to one another and the work. As one SCR team member from Orange Glen and the Sweetwater High Principal who attended many meetings also said,

> I'm very grateful to be exposed to leaders such as [Kirk Rogers, from UC San Diego] and Ms. Coching [teacher], who have really been supporting us throughout this whole thing, guiding us, but also letting us [do] our own thing.
>
> *Latinx female student from Orange Glen High School*

> I felt it was very interactive and engaging and all students participated. I don't remember a single student idly sitting by or in the meeting, but not participating. Because if that would happen, we would have maybe asked, ‘So do you have any ideas or anything you would like to contribute?’ We never felt the need to do that. Everyone participated.
>
> *Principal Sweetwater High School*

Mutual engagement was accomplished through the weekly SCR meetings, weekly larger RPP Action Cycles team meetings, as well as through bi-annual meetings with advisory board members and periodic meetings (usually quarterly) with district officials. Feedback from the advisory and district officials were incorporated into CS-LISTEN throughout the year. Both the advisories and the district meetings also restarted in the fall of 2020 and had high participation throughout 2020-21, despite remaining virtual and despite the continued Covid-19 shutdown of all the high schools through February 2021 and hybrid reopenings.

Focus on Shared Repertoire: Artifacts, Tools, Knowledge as RPP/BPC work

What do we attribute to this sustained sense of joint enterprise and mutual engagement? Research on the deliberate construction of communities of practice suggests that providing CoPs with flexibility in their focus (to match their specific contexts) and creating a **shared repertoire** of artifacts, tools, language, and knowledge can be helpful in sustaining CoP work. We found this also to be the case.

Shared repertoire in the context of CS-LISTEN occurred in the form of jointly constructed artifacts. During the initial SCR phase of the project, UC San Diego CS-LISTEN researchers worked to create and then use with teachers and SCR teams a series of slide decks that researchers produced weekly to guide SCR team meetings (before and after the Covid-19 shutdown). This series supported the teams' understanding and research over time. They were created to be flexible scaffolds for the teams, which were encouraged to adapt them to their weekly meeting needs.

Another example of a CS-LISTEN shared artifact was the video presentation that each team of students and teachers made of their SCR team findings. These video presentations were all created by SCR teams and shared at the CS-LISTEN-UP Conference in November 2020.

Finally, a joint professional video was created of all the SCRs' and teachers' work and was used to showcase and celebrate the collective group's work from spring 2020 to fall 2021 and beyond. The individual presentations by school SCR teams and the professionally produced video can all be found on our CS-LISTEN website: https://cslisten.ucsd.edu/resources/

Later, during the Action Cycles, the definition and development of **shared repertoire** were also fostered as teams generated new tools and artifacts of their own. The Action Cycle period was particularly successful at supporting shared repertoire because it often explicitly called on RPP members to create numerous tools and artifacts.

The Power of Community in YPAR RPPs

Key to CS-LISTEN's success of launching an effective student-inclusive RPP has been meeting regularly enough such that 1) we launched successfully and then regularly met (weekly) in order to develop local meanings, jointly constructed and re-negotiated over time, on what the students, teachers, administrators and university members worked on (**joint enterprise**), 2) we negotiated with all members how often, when and where and how we worked (**mutual engagement**), and 3) we developed specific knowledge, practices, and tools for our work (**shared repertoire**) that were able to be deployed flexibly by members. CS-LISTEN used these three frames from the CoP literature to guide our meaning making and practices. While we attended to the joint work and practices of the RPP as a whole, we also attended to the individual engagement and development of CS-LISTEN members, students, and adults.

Youth Can Make Meaningful Contributions to RPP Work

Bringing student voice into broadening CS participation is a fresh contribution to the RPP paradigm. More specifically, we used Youth Participatory Action Research (YPAR) strategies through student co-research into CS-LISTEN RPPs. This proved to be a novel and fruitful way to tackle CS underrepresentation. CS-LISTEN, allowed small teams of students at nine high schools an active role in both the *research and practice* as foundational pillars of RPP work. In this way, the students became true partners and leaders of CS-LISTEN's RPP research and action cycles.

But embedding CS-LISTEN's YPAR work into full-fledged RPPs required significant attention to youth professional and scholarly development. We realized this early on and designed our project with youth in mind so that they could legitimately become full partners in the RPP. Students who were in CS-LISTEN SCR and Action Cycles have had many opportunities for professional growth because we realized that the students needed explicit instruction on how to bring their recommendations into action. Examples of explicit instructions we engaged in included making sure students had an understanding and focus on critical content, breaking down complex skills and strategies into smaller instructional units, and providing frequent and corrective feedback [2].

In addition, we learned that all parties (educators, admin and students) required assistance in social science research skills and knowledge. Even CS knowledgeable educators wanted CS-LISTEN UC San Diego researchers to scaffold them into social science research paradigms. Students, teachers and administrators early on confessed they felt ill-equipped to conduct social science research. But with support and scaffolding, they found their footing and became more confident in their ability to do this work in the RPP.

> Research in general I thought that was like a foreign concept to me like I thought it was very scary like only smart, smart people do it. But after this, I feel like it's something that's more. It's more. How do I say, like, you can do it, like, 'Hey I like it's not as inaccessible as I thought it was.'
>
> *Latinx female student Orange Glen High School*

At the same time, CS-LISTEN researchers learned a great deal from this RPP work. We recognize that the CS-LISTEN project thus far work is imperfect. Our reliance on joint enterprise, mutual engagement and shared repertoire as features of a robust Community of Practice, while helpful, were helpful but sometimes fell short when it came to addressing underlying issues of educational inequity we too faced as a project. For instance, while we opened the SCR/YPAR experience to all students, we had to work extra hard to recruit and retain students from outside high-track/Advanced Placement (AP) courses. While we were reasonably satisfied with our initial recruitment in January 2020-March 2020, we found that after the pandemic and the restart in October 2020, more academically successful students sustained their participation in the SCR and Action Cycles than their peers who were struggling a bit more academically. And, we are painfully aware that some original CS-LISTEN students, whose life circumstances had left them more vulnerable, disappeared from the RPP entirely. Our teammates (teachers, students, and ourselves) made extra efforts to reach out and retain these missing students, yet, regardless of our intentions to retain/recruit more students from less advanced/honors track academic backgrounds, doing so was challenging. Honestly, our RPPs were not always successful at doing so. Undoubtedly, this project was greatly affected by the fact that it had to persist during a global pandemic, where students from the most vulnerable and housing insecure populations had to pivot to being breadwinners for their families. Check-ins with some of our missing students confirmed that some of them who had started on CS-LISTEN prior to the pandemic had pressing family monetary or health concerns. Despite their desire to continue with CS-LISTEN, they were forced to prioritize other facets of their lives. But we are determined not to hide behind the pandemic as an excuse. We aim to do better to address these inclusivity issues within our RPP work.

We also learned a great deal about the critical role of fully engaging district and school administrators. More than anyone else, they and the lead teachers have been essential at taking RPP work to scale during the Action Cycle period.. Without these individuals and the organizational capital they possess in their sanctioned roles, all three Escondido Union High School District SCRs and Action Cycle teams would not have been able to advertise their work districtwide on the website. Hoover High teams would not have been able to add a second CS course for all students. Sweetwater, Mission Vista, Morse, and Castle Park High teams would not have run as successful coding camps for their younger peers. Even though they were not always able to meet weekly with Action Cycle teams, principals, counselors, district-level directors and superintendents were essential in the RPPs.

Although CS-LISTEN has established a solid ground game in student-inclusive RPP work in broadening participation in CS, the project has two more years of support to continue improving our collective practice. Over the next two academic years, 2021-2023, we anticipate working with 18 more teams of students, educators, and administrators to refine our work on YPAR/SCRs and RPPs. We also acknowledge that it is (as of August 2021) too early to tell as to whether or not our collective work has impacted actual CS enrollment in course pathways. Early reports from schools during spring 2021 enrollment periods suggested the numbers are up — we will have to see when fall 2021 numbers are solidified: Have we broadened participation in CS at these nine schools? We do not yet know for sure.

What we do know is that students are on board for working alongside us, and their educator colleagues, to find out.

References

[1] Anyon, Yolanda, Kimberly Bender, Heather Kennedy, and Jonah Dechants. 2018. A systematic review of youth participatory action research (YPAR) in the United States: Methodologies, youth outcomes, and future directions. In *Health Education & Behavior* 45, 6, 865-878.

[2] Archer, Anita L. and Charles A. Hughes. 2010. Explicit instruction: Effective and efficient teaching. Guilford Publications. New York, NY.

[3] Code.org, CSTA, and ECEP Alliance. 2020. 2020 State of computer science education: Illuminating disparities. https://advocacy.code.org/stateofcs

[4] Fine, Michelle. 2012. Youth participatory action research. In *Keywords in Youth Studies*. Routledge. Oxfordshire, England, UK

[5] Lave, Jean and Wenger, Etienne. 1991. Situated learning: Legitimate peripheral participation. Cambridge: Cambridge University Press.

[6] Mai, Minhtuyen and Simon, Beth. December, 2020. Commentary: Why prioritizing computer science education is critical to California’s future. In *The San Diego Union Tribune.* https://www.sandiegouniontribune.com/opinion/commentary/story/2020-12-15/technology-workforce-pandemic-covid-19-education-commentary?fbclid=IwAR2rx4dObOYPGWJI2ogFPYpxv78CTtR5ivszOBuo2daLHLdv2IZ6jqX4VH4

[7] McIntyre, Alice. 2000. Constructing meaning about violence, school, and community: Participatory action research with urban youth. In *The Urban Review* 32, 2, 123-154.

[8] Ozer, Emily J. 2016. Youth-led participatory action research: Developmental and equity perspectives. In *Advances in Child Development and Behavior* 50, 189-207.

[9] Penuel, William R. and Daniel J. Gallagher. 2017. Creating research practice partnerships in education. Harvard Education Press. Cambridge, MA.

[10] Wenger, Etienne. 1998. Communities of practice . New York: Cambridge University Press.

[11] Wenger, Etienne. 2000. Communities of Practice and Social Learning Systems. In *Organization*, 7 (2), 225–246.

[12] Wenger, Etienne, McDermott, Richard & Snyder, William. 2002. Cultivating communities of practice . Boston: Harvard Business Press.

[13] U.S. Bureau of Labor Statistics. 2021. https://www.bls.gov/ooh/computer-and-information-technology/home.htm

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