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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"

[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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