Designing a Sociotechnical Infrastructure for Orchestrating Instructional Coaching

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Abstract: Instructional coaching is an important strategy to support teacher learning in early childhood, primary, and secondary education. It involves sequenced collaborative activities such as action planning, observations, and reflective discussions that are carried out by a coach and teacher in different settings, including classrooms and offices. This paper describes the participatory design and development of the Coaching Companion, a tool to support instructional coaching for Head Start pre-kindergarten teachers. We identify design tensions among stakeholder goals for the tool and how the team handled these tensions. We argue that the design decisions made by our team have broader implications for expanding the metaphor of orchestration in CSCL to apply to a "fourth circle" of usability, namely the institutional setting of teaching.

Introduction

This paper focuses on the design of Coaching Companion, a sociotechnical infrastructure for coaches and teachers in Head Start. Head Start aims to provide low-income children and families in the U.S. with high-quality preschool education and health services. Early childhood research and policy have highlighted the important role of classroom quality, in particular the quality of the interactions between teachers and children, in promoting young children's school readiness (e.g., Pianta & Hamre, 2009). A key strategy for improving teaching practice has been instructional coaching, which focuses on preparing early childhood educators to develop supportive relationships with children to foster their social, emotional, and cognitive development. Evidence exists that coaching can improve teaching quality and classroom climate (e.g., Justice, Mashburn, Hamre, & Pianta, 2008; Neuman & Cunningham, 2008). Just as collaborative technologies can be an important means of support for student learning, tools that facilitate interaction between coaches and teachers can support the coaching process. A recent study showed that teachers randomly assigned to receive online help and feedback from an instructional coach with access to videos of the teacher showed greater improvement to the quality of teacher-child interactions than teachers assigned to a control group (Pianta, Mashburn, Downer, Hamre, & Justice, 2008).

The sociotechnical infrastructure described in this paper is intended to support a model of instructional coaching addressing the breadth of Head Start readiness domains, including literacy, mathematics, and science. We employed a participatory design approach (Schuler & Namioka, 1993) to developing the system during which we documented a number of conflicting goals that emerged. We analyze them here from within a *design tensions* framework (Tatar, 2007). This framework conceptualizes a key task of design as balancing goals; it draws "explicit attention to conflicts in system design that cannot be solved but only handled via compromise" (Tatar, p. 415). Analyzing and making public to stakeholders these design tensions can facilitate accountability to the diverse values and concerns of participants in participatory design (Penuel, Confrey, Maloney, & Rupp, 2011).

In this paper, we explore how analysis of design tensions can also contribute substantively to our understanding of the metaphor of *orchestration* and its implications for design. Orchestration pertains to the activity of managing and coordinating multiple activities of teachers and learners in learning environments (DiGiano & Patton, 2002; Dillenbourg & Fischer, 2007; Dillenbourg & Jermann, 2010; Prieto et al., 2011). We extend application of this metaphor beyond classrooms to the practice of instructional coaching, in which activities must be coordinated across multiple spaces and where shared control over coordination is valued. Our analysis points to the need to analyze the ways that social processes and technical constraints can vary across spaces and that need to be coordinated to support the complex work of coaching.

Orchestration in Classrooms and Instructional Coaching

Orchestration pertains to the activity of managing and coordinating multiple activities of teachers and learners in learning environments (DiGiano & Patton, 2002; Dillenbourg & Fischer, 2007; Dillenbourg & Jermann, 2010;

Prieto, et al., 2011). A focus on orchestration foregrounds the value of designs that render workflows visible, allow for flexibility, are minimalist, and are easy to use (Dillenbourg & Jermann; Dillenbourg et al., 2011). For teachers, it is also critical that tools are "teacher-centric," that is, that they provide them with control (Dillenbourg & Jermann). To date, the focus of research on orchestration has largely focused on classrooms, where teachers and students are core participants.

Orchestration of instructional coaching—whether in Head Start or in K-12 settings—is both similar to and different from that of learning in classrooms. As in classroom teaching, orchestration involves collaboration in and coordination of multiple learning activities that typically occur in a sequence, beginning with goal setting and action planning, followed by recording of videos of teaching practice, and then reflection and feedback. Orchestration in coaching, however, spans multiple settings, from offices where coaches meet with teachers to classrooms where coaches observe or model teaching practices. In addition, when designing tools to support the work of coaching, though minimalism and ease of use are prized, some aspects of work must remain private or invisible to protect the coaching relationship. If supervisors see all aspects of the work, coaching interactions might be used punitively, rather than to support teachers' learning. Third, total coach control is not desirable. Rather, the focus of coaching is typically negotiated between teacher and coach.

Orchestration of Coaching within the Practice-Based Coaching (PBC) Model

The goal of our project was to design and develop a digital tool to support the National Center on Quality Teaching and Learning's (NCQTL) coaching model to help improve teaching and learning in Head Start programs. NCQTL, under the auspices of the U.S. federal Government's Office of Head Start, develops research-to-practice materials and resources as well as innovative professional development options for Head Start's training and technical assistance system in order to improve teaching and learning. Instructional coaching is an important strategy for accomplishing some of the center's key goals.

The center's *Practice-Based Coaching* (PBC) model is a cyclical process to help teachers make use of evidence-based practices in order to support children's learning and development. A single cycle of coaching has three key steps. First, a teacher and coach jointly set goals and delineate steps in an action plan. Second, the there is a focused observation of the teacher's practice, which may be video recorded. Third, the coach and teacher engage in reflection on the focused observation, and the coach provides supportive and constructive feedback to the teacher. The cycle begins again with a new or revised action plan, which is expected to reflect the accomplishments of the teacher, as well as feedback on areas of needed growth. The cyclical nature of the process highlights the iterative nature of coaching, a process in which expectations and desired outcomes are constantly reviewed and updated.

Instructional coaching within this model is similar to other processes where designers have sought to facilitate orchestration; the practice of coaching requires the coordination of multiple activities. The Practice-Based Coaching model specifically requires teachers and coaches to negotiate joint goals, identify steps in an action plan, and observe and reflect on practice. Below, we highlight key features of orchestration within this model.

Orchestration Spans Multiple Settings with Different Levels of Access to the Internet

At the same time, the practice of coaching differs from other processes where orchestration has been studied in the past. Instructional coaching takes place across multiple settings. One coach may visit teachers in many childcare centers. Additionally, a key constraint is that few preschool settings have a robust technology infrastructure that includes Internet connectivity in classrooms. Teachers and coaches may be able to access the Internet in classrooms on smartphones, but the only reliable access is typically at desktop computers located in center offices. Thus, a technology tool that supports coaching in Head Start must be able to support activities that take place in the classroom without relying on the Internet during those parts of the process.

Related and also relevant to our project was skepticism among preschool staff about the value of a technology tool for supporting the work of coaching. Surfaced in our design charrette were specific concerns that a tool might interfere with the coaching relationship. Coaches and center leaders who participated worried that technology might reduce reflection on action, a key activity fostered within coaching relationships, and instead promote reactivity by making it easy for coaches and teachers to respond quickly to one another online. Our tool needed to provide a clear benefit while also not harming the relationship.

Control Is Shared by Teacher and Coach

A design principle for supporting classroom orchestration is that it should support teacher control (Dillenbourg & Jermann, 2010), but in instructional coaching, coaches and teachers share control. That is, they jointly negotiate goals and steps in action plans and to the focus and interpretation of observations.

Teachers and coaches, for example, want privacy controls to protect students and adult workers. The fact that video reflection is central to most models of coaching heightens those concerns, because it can be challenging to protect participants from all risk of harm when video is used in research and development efforts

(Derry et al., 2010). Children who appear in video are not the primary "subjects" of these efforts in coaching; instead, it is the teacher and the teachers' interactions with children that are the focus of the work. However, consent for use of video with children is required. Teachers may also have concerns about who can view videos of their teaching. Center directors and supervisors may wish to use video records of teaching to monitor staff, even though the primary purpose of video within coaching is not to penalize, but to support improvement. As with other work using video in classrooms (e.g. Hayes and Abowd, 2006), complex permissions and privacy controls are needed for who can see what kinds of evidence related to teachers and their interactions with children.

Design Approach

We employed a participatory approach to design. Stakeholder groups represented in the design process were center leadership, the team of researchers that developed the coaching model, and former and present Head Start coaches and teachers. We included stakeholders in all aspects of design, from establishing different goals for the tool to helping identify key requirements to providing feedback on system prototypes and alternate interface designs.

Design Charrette

We started our design process by conducting a one-day design charrette with stakeholders in August 2011. Design charrettes are intensive, collaborative experiences that bring together stakeholders to develop a shared understanding of the diverse needs a design must meet and brainstorm possible ways to address such needs (Sanoff, 2000). Our design charrette involved members of NCQTL's leadership team, researchers involved in the development of the PBC model, as well as Head Start directors, coaches and teachers. During the charrette, we asked the attendees to form groups, brainstorm the needs of potential users and imagine how users may respond to certain designs. After each group constructed one potential scenario of use, we led the group in a brainstorm session of requirements that were reflected in the different scenarios. We asked participants to abstract from their scenarios key functionalities of the tool. We then asked participants to prioritize requirements. Some of the requirements that received most votes included: display and linking relevant early childhood frameworks, allow teachers to upload and view video and audio files, ability to create action plans by both selecting from prepopulated menus and creating individualized entries, ability to link to useful resources, link to assessment information and allow generation of task lists, among others.

User Testing and Feedback with Existing Planning and Video Reflection Tools

Using the requirements generated during the design charrette as well as feedback provided by NCQTL leadership, our team developed the initial list of design requirements and identified multiple commercially available tools that each provided some of the required functions. We introduced a group of coaches and teachers to pairs of applications that differed slightly in their functionality and interface design; we then asked them to test them in their coaching activities. The participants included 8 coach/teacher pairs (8 coaches and 8 teachers) from three states, and testing was conducted using a combination of touch-screen tablets (iPad and Android) and Internet-connected desktops. Participants provided feedback on what features they liked/found (or disliked/did not find) beneficial and what they found (or did not find) user friendly during guided exercises to show how certain aspects of coaching might be performed using YouTube, VoiceThread, BaseCamp, and SmartSheet.

Interface Design and Beta Development

Using input from the initial testing of commercially available tools with users in the field, we began an intensive period of design and development of a web application that integrated the functionalities of the different commercial tools and that matched the requirements. We facilitated continued stakeholder input into the process by holding weekly meetings with representatives from the NCQTL coaching team, early childhood experts, design-based researchers, programmers, and user interface experts. As we developed the web application, we also continued to invite coaches and teachers to provide feedback on an ongoing basis. Their feedback informed revisions and improvements to the design. We released a beta version of the web application in September 2012. Development of a companion mobile application has just begun (as of October 2012).

To describe the iterative process of design and development during this phase, the team adopted the term "double helix," which invokes the image of the double strands of DNA, intertwined in a helical structure. This term was introduced to the team by SRI developers, who had used it in prior projects (see also Lockheed Martin, 2008). In this design model, one strand represents the group designing and developing the technology, and the other strand represents the stakeholders, including end users. Ideally, these two groups are so tightly coupled in terms of frequent communication, collaboration, and feedback that the development team creates a system that converges quickly to satisfy stakeholders' true needs.

Research Methodology: Analyzing Design Rationales

Our approach to analysis of the design process employs a ***design tensions*** framework (Tatar, 2007). Design tensions foreground the role of choices people make in design, the objectives and values that guide those choices, and the interdependence of social and technological aspects of systems. The analysis of design tensions foregrounds choices that people make among conflicting objectives for systems.

A key methodology for analyzing design tensions is the documentation of ***design rationales.*** A design rationale is an account of the decisions teams make and the reasons for their decisions (Jarczyk, Loffler, & Shipman, 1992; Lee & Lai, 1991). Professionals in the fields of architecture, urban planning, computer science, and software engineering articulate design rationales to clarify the purposes of design, guide collaboration and coordinate joint work, record the history of the design process, and to reflect on and modify current versions of designs (Moran & Carroll, 1996). In computer-supported collaborative learning projects, articulating a design rationale for particular decisions can also serve as an analytic framework for helping identify emerging design principles.

A key task in identifying potential design tensions is to articulate objectives or goals for design. The design charrette process elicited these goals, and it also engaged participants directly in prioritization of key functionalities of the tool. The analysis of design tensions took these goals, as well as some goals that emerged in the design process, as a starting point.

The team documented tests with users using ethnographic field notes, kept notes of all internal meetings, and created design rationale documents for select decisions. The fifth author, who was not involved in the design activities, reviewed each of these to identify additional goals, as well as implicit or explicit values that animated design. She then identified tensions among goals or values that arose in tests and internal discussions, and the team then identified what it considered critical decisions related to these decisions and examined evidence from field notes and team meetings for rationales developed at the time for those decisions.

Our purpose in this retrospective analysis was not to achieve reliability with respect to our coding of design rationales; rather, the analysis' function was to support reflection within an ongoing participatory design process. Thus, the analysis we present here should be read as a collective effort to take stock of the adequacy with which the team has addressed objectives identified by users thus far in the project.

Analysis: Accounts of Key Design Decisions

In the analysis that follows, we present accounts of our key design decisions for the coaching tool. Each account is organized by the design tension among goals or values that decisions addressed. We then identify alternate solutions we considered and the rationales that made those solutions appealing to the team, as well as counter-arguments against particular solutions. Finally, we describe the solution the team developed to address the tension. In this section, we also analyze tensions that remain unresolved.

Portability Versus Accessibility

One of the earliest tensions that emerged in the design was between designing a tool that was portable with the desire to have core functions of the tool be accessible anywhere a coach and teacher might be engaged in coaching activities. Key stakeholders hoped that the tool could function on a tablet with a large enough screen to formulate and update action plans; capture, upload, and annotate video; and capture notes from a coach's observation of a teacher's practice in a classroom. Yet, making all these functions accessible all the time on a tablet would require wireless high-speed Internet, which is not available in most Head Start centers.

The tension between these two objectives did not fully emerge until we loaned tablets to users to test available commercial tools. Initially, our plan had been to develop the tool as a tablet-based application. The tablets proved relatively easy to use, but the functions worked well only in a center with ubiquitous wireless connectivity in the building, an unusual situation for most preschools. Also, few Head Start sites have tablets yet, but all sites where our users were located had Internet-connected desktops. From a development perspective, tablets presented more difficulties for the team to develop and change quickly. Finally, we realized that a mobile application or a web-based application would need a back-end database designed to handle the communication and media traffic of teachers using the tool. Together, these considerations led the team to first develop a web application that could be used when coaches and teachers had Internet access. We deferred develop of a mobile application that could capture and cache video and other data (including changes to action plans) that could later be uploaded when a portable device connected to the Internet.

Importantly, the resolution of this tension was shaped by development constraints that were orthogonal to users' objectives. Choosing to develop a web application first had many advantages given the resources available to the development team. Once a custom server application is set up, offering web page access to it is a very small step in development costs compared to developing a mobile application. Moreover, web browsers are relatively standardized and web pages are cross platform—they can run on a tablet's browser or on a computer's. Design updates can be deployed more quickly and consistently for a website than for a mobile,

allowing us to could get multiple versions out quickly, updating the application as we learned from the field tests. In choosing our web application framework, we were also able to find a range of open-source solutions that provide some basic features (e.g., video storage, web-flows, authentication, security), allow for granular permission settings, and would allow us to rapidly develop new features. Given these requirements and the expertise of our development team, we built on functionality from MySQL, Spring MVC and Spring Security, and Kaltura for video management, and we pursued a design that would also support a service layer for mobile access via RESTful APIs.

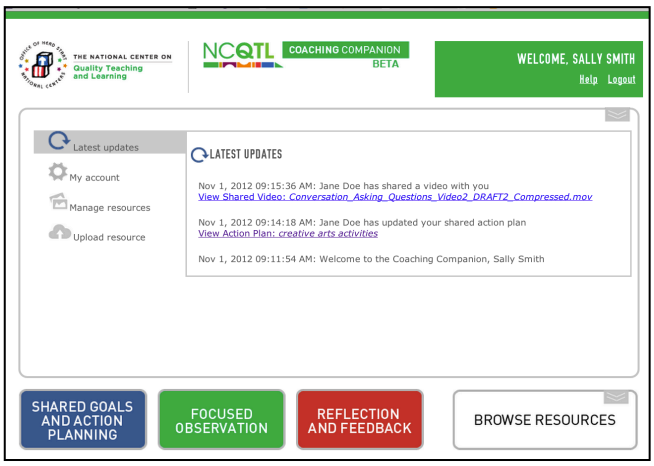

Figure 1. Welcome Screen for Coaching Companion

Coaching Model Alignment Versus Flexibility

A second tension that emerged in user testing was between the need to align the tool tightly to the NCQTL model of Practice-Based Coaching versus the desire to have the tool flexibly support coaches and teachers with a wide range of skill and in different kinds of situations. On the one hand, key center stakeholders expected that the tool might serve as a support for a "collaborative script" (Dillenbourg & Jermann, 2007) of Practice-Based Coaching. That is, it could facilitate coach-teacher pairs' adherence to the sequence of practice-based coaching. On the other hand, users—even those trained in the coaching model—could be expected to have a wide range of skill in implementing the model and knowledge of evidence-based practice. In addition, if the tool "over-scripted" (Dillenbourg, 2002) the collaboration, it would not allow for user goals that emerged in the coaching process but that did not map onto any prescribed or easily anticipated use of the tool. For example, a video reflection might inspire coaches and teachers to seek out an additional resource, repeat a step in an action plan, or conduct a deeper analysis of a single video with an entire teaching team. Prescribing a single path through the tool could frustrate users in those situations.

The tension between these two goals emerged as we began to develop user interfaces and consider what user interactions to support. Foregrounding the model implied the need both to make visually prominent the three key components of the Practice-Based Coaching: Shared Goals and Action Planning, Focused Observation, Reflection and Feedback. It also implied a need to scaffold the process of action planning as a sequence that begins with a needs assessment, joint negotiation of goals, and articulation of steps to be followed to meet those goals. But the three key components did not map readily onto actions that users engaged in coaching (including Practice-Based Coaching) might want to perform such as "upload a video" or "conduct a needs assessment." In other words, key functions would not be as visible as they could be, violating a key principle of user-centered design, the need to provide users with an obvious starting point for how users can interact with the content (Blair-Early & Zender, 2008). We proposed to design the interface in such a way to provide an obvious start, but the coaching team felt this would not provide scaffolds to users for adhering to the Practice-Based Coaching model.

As a solution to address the need for providing clear starting points, we identified a subset of actions users might take "out of sequence" that could be accessed from the home page of the tool. Users can upload a video or notes, for example, from the home page, without having to click through several screens embedded within one of the steps of the cycle (see Figure 1). When uploading, the tool does invite users to associate a video to an action plan or to defer that decision. In this way, we permitted flexible and obvious starting points for a range of situations, while still signaling the significance of the model.

A related solution was to embed help resources within the tool when users were engaged in particular tasks. In action planning, users can see resources in a library of digital artifacts produced by the center related to the outcome domain or practices targeted in their plan. They can then select these artifacts to associate with their

plan and use them as part of coaching. When formulating goals, they can link to tips developed by the NCQTL on how to formulate measurable objectives for action plans. In this way, the tool aims to provide (but not require the user to engage with) context-sensitive help and embed guidance aligned to the model. In this respect, we adopted a "companion model" of interaction design (Murray, 2012) intended as a helpful social partner to the pair engaged in coaching. The name we gave to the tool, the Coaching Companion, reflects this choice.

Individual Learning Versus Program Improvement

A third design tension arises from the two objectives of promoting individual teacher learning and program-wide improvement. In principle, these two goals are compatible, because individual teacher growth contributes directly to program improvement. Where tensions arise are occasions where different actors in the system require feedback as to progress toward goals. The coaching relationship is intended first and foremost to be a relationship guided by learning and improvement goals. Any feedback is intended to support the growth of teachers, though this feedback may need to point to specific instances that show evidence where teachers need to improve practice (Hemmeter & Fox, 2009). Participants in the design charrette believed that this type of feedback, though, in the hands of supervisors, could be used in a punitive manner against teachers. They worried especially about coaches who played dual roles of coach and supervisor, fearing that the use of the tool could exacerbate this conflict. To guide our team's attention to this potential problem, participants went so far as to create design personas (Nathan et al., 2008) that reflected this potential misuse of a coaching tool (Penuel, Dominguez, Llorente, & Schank, 2011).

Our initial solution to this tension has been to provide extensive privacy controls for data in the tool. The coach and teacher together decide who can edit and view an action plan, a particular video of practice, or notes from an observation. The pair also decides who can view data collected that informs a determination of the key needs that action plans will address. The system allows teachers to share certain information with a supervisor while keeping other data excluded from the supervisor's view but still allowing the teacher to share with a coach or peer for feedback that can help improve practice. This solution privileges the learning goals of the relationship, as the Practice-Based Coaching model does. Moreover, the decision to privilege privacy is consistent with a key orientation of the practice of value-sensitive design (Friedman, Kahn, & Borning, 2003), namely to maximize control users have for determining access to sensitive content.

This particular solution does not resolve, however, the issue of staff who play a dual role of coach and supervisor. In addition, the team is concerned that as the tool becomes more widely accessible, demands for functionalities related to program-wide improvement will increase, because centers' continued funding from Head Start depends on documentation of improvements to teaching and learning. Our conjecture is that resolving these issues will require the team to attend more to designing the social aspect of the infrastructure of coaching. Authority for designing this aspect is likely to lie outside the design team.

Broad Access Versus Usability

In planning to develop the mobile application, we grappled with the choice of platform. We view this tension as one between the objective of providing a broadly accessible tool with the value of providing a tool that is easy to learn how to use. Android has larger market share in the United States at 53% for Android versus 34% for iOS as of September 2012 (ComScore, 2012). Android devices are cheaper than iOS devices, so more of our end users (teachers and coaches) may be able to afford them. Tests with Android tablets, however, indicated that compared to iOS devices (iPads), video capture and trimming functionality provided an inferior user experience. Because of limited bandwidth and server space, users would have to trim video prior to uploading it to the tool, so an easy-to-learn trimming function is critical.

As with the decision about what to design and develop first, the decision about platform involves ease of use and costs of development. The Android platform is an open source Java framework (vs. Objective C for iOS, which is closed source), and our programming team has expertise in Java. However, there are hundreds of Android devices, and variation in devices can be a significant headache for development, testing, and support, which would need to be restricted to a small subset of the Android devices on the market.

The team's decision was to develop an iOS app first, but we also have plans to explore whether there will be sufficient resources to develop an Android app afterward. Thus, as with the design tension related to individual versus program learning, we privileged user experience, largely on the grounds that the Head Start context is one in which many coaches and teachers are not regular users of technology in their work. A poor user experience would not sustain interest and commitment to use the tool.

Discussion and Conclusion

Over the course of the design and development of a tool to support instructional coaching in Head Start, our team encountered a number of design tensions. In this context, a need for broad access to the functions of the tool came into conflict with the desire for a portable tool that also provided an optimal user experience. Also, the demand that the tool align closely with the model of Practice-Based Coaching adopted by NCQTL came into

conflict with the need to make transparent the functions of the tool. Finally, the goals of promoting individual teacher learning and program-level learning could conflict as our tool goes to scale.

In addressing some of these tensions, recent research within computer-supported collaborative learning on classroom orchestration was an invaluable resource for the team's thinking. For example, Dillenbourg and colleagues' research (Dillenbourg, 2002; Dillenbourg et al., 2011) directed us to be wary of the risk of over-scripting workflows, lest we limit the range of situations in which coaches and teachers would find our tool useful. Thus, despite the need for the tool to help scaffold participation in the PBC model, we incorporated multiple entry points to using the tool that increased visibility of key functions. Likewise, we followed the key design principle of designing tools that are easy to use to support the coordination of "in-room" activities, particularly capturing and clipping video.

At the same time, our work also suggests the need within research on orchestration to create yet another "circle of usability" (Dillenbourg, et al., 2011). In addition to considering individual users' interactions with the system (first circle), teams' interactions (second circle), and classroom orchestration (third circle), there is a need for designs that support teachers' own learning to consider a fourth circle, namely the orchestration of uses of a tool across different settings. Instructional coaching takes place both inside and outside the classroom, and these spaces can have different kinds of constraints, which we have seen give rise to design tensions between accessibility and usability. Tools that support teachers' work in planning instruction and collaborating with other teachers to design or improve practices require attention to this fourth circle of usability as well (see, e.g., Sumner, Khoo, Recker, & Marlino, 2003).

In addition, classroom orchestration tools rightly privilege teacher control, given the teacher's responsibilities in classrooms. However, in coaching, the need for shared control gives rise to a set of design considerations within this new, "fourth" circle of usability. For one, CSCL design must take into account institutional arrangements, such as the roles of different actors and their stake in the uses of particular tools. Tools that teams design could exacerbate role conflicts that arise from institutional arrangements, as in our case. These institutional arrangements are important constraints on design.

Our case also foregrounds the need for teams designing tools to support orchestration to articulate tensions, compromises, and the privileging of particular values in design. Orchestration research makes explicit a number of values in design, but the design tensions framework we employed to analyze our team's decisions helped us to make explicit when values come into conflict. In most instances, values will come into conflict, and teams need to decide when and how to create compromises, as well as when to privilege certain values over others. We have sought to be explicit about our design choices and rationales here, as part of our ongoing effort to maximize participation in design and maintain accountability to multiple stakeholders.

Instructional coaching, a set of practices through which teachers learn to work more effectively with students, provides and interesting space for exploration of computer supported collaborative learning and computer supported cooperative work (CSCW). Especially at the preschool level, coaching has traditionally been characterized by high-touch, face-to-face working relationships. As the practice becomes more widespread and as technology use increases in this context, further CSCL research on designing infrastructures for instructional coaching will be needed.

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