DEVELOPMENT AND USE OF A CONJECTURE MAP FOR ONLINE PROFESSIONAL DEVELOPMENT MODEL

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In this paper we discuss our development and use of a conjecture map for a large research project on the design and implementation of an online professional development model. Following Sandoval's (2014) model, we built the conjecture map to reflect our high-level conjectures (overarching goals of the project), the embodiment of the learning design, the mediating processes, and the outcomes. After roughly half a dozen iterations to ensure that we accurately and fully captured the features of the learning environment and the mediating processes, we used the conjecture map as an anchor for a number of our data analysis activities, particularly of our online course modules, and for initiating theory-building processes. We also found that it was an expedient way to communicate internally and externally the core assumptions and learning principles of our multifaceted online professional development model.

The project described in this paper involves a three-part model whose primary goal is to transition multi-faceted face-to-face professional development experiences to online environments in order to provide rural teachers access to high-quality professional development experiences. For example, the Teaching Lab lessons (similar to Lesson Study) have traditionally been conducted entirely face-to-face; we subsequently redesigned these experiences so teachers from disparate rural environments can participate without having to travel great distances. Moving face-to-face experiences to online environments is not straightforward and requires an iterative process to understand and respond to the logistic, technological, and theoretical challenges that arise. Consequently, we conceptualized our project as design research in that we planned to use lessons gained from our initial attempts to inform subsequent revisions to the original designs and sequencing of the components of the model. We turned to Sandoval's (2014) description of *conjecture maps* to guide our efforts to unpack the assumptions and theories on which we operated as we designed and redesigned the components.

In this conceptual paper, we discuss the development and use of a conjecture map (Sandoval, 2014) to help us reflect on and better understand our own assumptions regarding the overall conjectures for the project, the design of the learning environment, and the processes that mediate between the learning environment and the outcomes related to our high-level conjectures. Wozniak (2015) used a conjecture map for a project involving online learning and noted that the refinements made through design research due to the conjecture map enhanced their "theoretical understanding about transitioning to online distance learning" (p. 608). In considering the relevance of this model to our own context, we asked ourselves the following questions:

1. To what extent do the conjecture maps have face validity to the actual processes engaged by our participants?

2. How have the conjecture maps informed both the revisions of the professional development model and the data analysis?

Frameworks

Design Research

We follow a design-based research model (Barab & Squire, 2004; Cobb, Confrey, diSessa, Lehrer, & Schauble, 2003; Edelson, 2002; The Design-Based Research Collective, 2003) to guide our research. Design research is intended to engineer learning environments, study the impact of that learning environment on desired outcomes, and revise the learning environment as needed, with the goal of testing and building theory. The goal of design research is to be able to explain learning that occurs and what supports that learning by systematically and iteratively studying the design and the impact of the design (Cobb et al.).

Design research departs from naturalistic research in that it purposefully engineers features in the learning environment, though it retains some of the messy complexity found in naturalistic settings. This type of research departs from experimental design and other research done in highly controlled, even contrived, settings in that it seeks to understand the role of context and the situated nature of activity to explain learning. Design research operates at an intermediate level of theory, to produce useful explanations that extend beyond the context in which the study is situated, but not to pose universal theories of learning (Cobb et al., 2003). Additionally, the design research process purposefully facilitates (engineers) particular interactions in order to produce useful explanations (Barab & Squire, 2004).

In this paper, we describe a model of online mathematics professional development for teachers in rural contexts, the hypothesis and conjectures we developed and are testing, and the way in which we articulated and operationalized features of the design experiment we are conducting. Our goal is to not only understand how our model works with our participants, but how it may inform broader efforts to conduct high-quality professional development online, how to engage rural mathematics teachers in such experiences, and how it leads to theory-building.

Conjecture Maps

We follow Sandoval (2014) in developing and using conjecture maps to articulate our model, guide our research, and build theory. According to Sandoval, "*Conjecture mapping* is a means of specifying theoretically salient features of a learning environment design and mapping out how they are predicted to work together to produce desired outcomes" (p. 19) and is intended to reify the conjectures regarding the learning environment and how they interact to promote learning. There are four main elements to a conjecture map. The first element involves *high-level conjectures* about the learning context and it supports learning. Those conjectures are then operationalized in the *embodiment* of the learning design, which is the second element. In the third element, this embodiment in turn is intended to generate *mediating processes* that produce desired *outcomes*. The desired outcomes constitute the fourth and final element of the conjecture map. The conjectures about how the designed learning environment (the embodiment) results in the mediating processes—or the process from the second to third element—are called *design conjectures*, which take the form "if learners engage in this activity (task + participant) structure with these tools, through this discursive practice, then this mediating process will emerge" (p. 24). The conjectures about how those mediating processes produce desired outcomes—or the process from the third to final element—are *theoretical conjectures*, which take the form "if this mediating process occurs it will lead to this outcome" (p. 24).

High-level conjectures are the abstracted ideas about the learning principles evident in the design of the learning environment and are produced by an analysis of the needs evident in a certain context with respect to the desired outcomes. The embodiment of the learning design involves four elements, according to Sandoval (2014): tools and materials, task structures, participant structures, and discursive practices, described in further detail below. Mediating processes involve the kinds of observable interactions between participants and the design of the environment, though artifacts created through learning activities can be used as well. Observable interactions can show how the learning environment facilitates or mediates participants' interactions, particularly those conjectured as leading to desired outcomes. Analysis of artifacts can show how participants interpret designed activity structures and tools to explain their interactions and engagement. Mediating processes are intended to produce desired *outcomes*. Sandoval notes that different design research projects can utilize "a wide variety of outcomes and could take a wide variety of approaches to gathering evidence of those outcomes" (p. 23).

Online Learning Model

We designed a three part online professional development model with the goal of providing rural mathematics teachers access to high quality professional development. We chose to pursue an online model due to the difficulties for rural teachers to attend face to face professional development. The three components had been originally designed and implemented in face to face formats and were moved to fully online versions for the purposes of this project. Our project utilizes a series of synchronous online experiences, which departs from the typical asynchronous nature of much of the current online professional development, educational coursework, and virtual teacher communities. The three parts of the model include online course modules, Teaching Labs (akin to a lesson study approach), and online coaching. We based our model on research on teacher learning, described in more detail below, which informed our conjectures.

The online course modules were based on discourse practices that orient teachers toward high-leverage discourse practices that facilitate mathematically productive classroom discussions (Smith & Stein, 2011). These discourse practices are facilitated by five practices emphasized in the course, entitled *Orchestrating Mathematical Discussions (OMD)*, anticipating, monitoring, selecting, sequencing, and connecting. The modules also emphasize key aspects of lesson planning, such as goal-setting, in addition to having teachers solve and discuss high-cognitive demand tasks. The modules are designed to develop awareness of specific teacher and student discourse moves that facilitate productive mathematical discussions, to understand the role of high cognitive demand tasks in eliciting a variety of approaches worthy of group discussions, and to further develop participants' mathematical knowledge, particularly the rich connections around big mathematical ideas that are helpful to teach with understanding (Ball, 1991; Ma, 1999). The modules involve a combination of synchronous and asynchronous work, in order to minimize the amount of time teachers must virtually meet together (Robinson, Kilgore, & Warren, 2017). This minimizes logistical challenges and maintains a high degree of teacher effort and attention due to the shortened synchronous time. Hrastinski (2008) found that the combination of synchronous and asynchronous complement each other by offering opportunities for cognitive participation (asynchronous) and personal participation (synchronous). Cognitive participation allows for reflection on complex instruction, while personal participation involves collaborative opportunities for immediate feedback, community building, and collaborative learning.

The Teaching Labs follow a lesson study design, modified to decrease time commitments and, in our case, with the need to be physically present in the classroom of the target lesson. Research on lesson study (e.g., Amador & Carter, 2018; Stigler & Hiebert, 1999) has led to an emphasis on demonstration lessons where teams of teachers collectively plan, enact, and reflect on lessons in ways that make public the features of the lessons and teachers' instructional practices (Saphier & West, 2009). The benefits of lesson study are to help teachers incrementally expand their knowledge base, promote collective professional discussions, and to improve instructional practices (Choskshi & Fernandez, 2005; Stigler & Hiebert, 1999). Our work takes this traditionally in-person model and translates it into a synchronous and asynchronous online professional development opportunity.

Coaching has a relatively short history in education, and online coaching is just now emerging as something that is beyond experimental. Coaching, as characterized by the interactions between coaches and practitioners, facilitates *deliberative practice* in that there are repeated opportunities to reflect on practice in principled and formative ways (Ericsson, Krampe, & Tesch-Romer, 2003). Over the last two decades, there has been an increasing focus on coaches to provide teachers with personalized and content focused professional development (Campbell & Malkus, 2011; Cobb & Jackson, 2011; Hartman, 2013), which is highly valued by the teacher (Chval et al., 2010). Common aspects of coaching include working with teachers to model instructional practices, reflect on observed instruction, study student work, and plan lessons (Batt, 2010; Matsumura, Garnier, & Spybrook, 2012). Research on the impact of coaching has found positive effects of content-focused coaching on teachers' instructional practices and student achievement in the area of literacy (Matsumura et al., 2012). Other research has shown that literacy coaches, when they collaborate closely with teachers around core instructional practices, can have positive impacts, though this impact was mediated by the roles of the coaches and the access of teachers to coaches with expertise in the instructional intervention (Coburn & Russell, 2008; Penuel, Riel, Krause, & Frank, 2009). Again, our work focuses on moving in-person coaching to an online context.

Methods

Development of the Conjecture Map

To develop the conjecture map, we first articulated the high-level conjecture and *desired* outcomes (Edelson, 2002), the bookends of the conjecture map. Our high-level conjecture was that *teachers transform their instructional practices by engaging in collegial interactions related to core instructional practices across multiple online contexts*. This conjecture captured aspects of the goal of transforming practice, the ways in which we were engineering opportunities for that to occur, the kinds of interactions we envisioned, the context in which the designed learning environment was going to be situated, and the theories we hoped to test and build. This conjecture reflected the core hypotheses of our online professional model.

We then articulated four desired outcomes related to our model. These outcomes were that teachers would become more adept at: (1) attending to student thinking in productive ways; (2) noticing key aspects of instructional practices; (3) engaging in high-leverage discursive practices with the goal of eliciting and refining student thinking; and (4) reflecting on one's own practices, using evidence from the classroom, leading to instructional change. The outcomes reflected our understanding of the kinds of instructional practices that result in vibrant and productive classroom learning environments (e.g. Jacobs, Lamb, & Philipp, 2010; Smith & Stein, 2011).

The next step was to describe the embodiment of our conjectures, the designed learning environment or what Cobb et al., (2003) term the *learning ecology*, which they describe as "a complex, interacting system involving multiple elements of different types and levels" (p. 9). Following Sandoval (2014) and Cobb et al., we focused on four features of the learning environment as: (1) tools and materials, (2) task structures, (3) participant structure, and (4) discursive practices. The tools and materials included the online platforms we used, the tools available within those platforms, and the protocols for structuring interactions, such as planning templates and the Noticings and Wonderings prompts for reflecting on mathematical tasks and episodes of instructional practice. The task structures included engaging with and reflecting on mathematical tasks, fictional and real accounts of instructional practices, and planning and reflecting on lessons. The participant structures included a range of whole group, small group, and one-on-one settings. Discursive practices included the type and tenor of interactions we intended to facilitate, such as collegial collective discussions and critical reflection on one's own practices. We identified these four features for each of the three components of the model. For example, for the Orchestrating Mathematical Discussion online model, we listed the Zoom environment (online based video conferencing software) and protocols for interaction as the Tools and Materials, the mathematical tasks and cases of classroom instruction as Task Structures, collective work in small and whole groups in an online space as the Participant Structures, and collegial discussions in which participants share their reflections on the learning activities as the Discursive Practices we were trying to engineer.

Our design conjecture was that the designed learning environment would facilitate the development of four mediating processes. These four mediating processes were: (1) reflection on one's own engagement in mathematical processes, discursive processes, and task characteristics; (2) discussion of core instructional practices in relation to attention to student thinking; (3) collective observation and non-evaluative reflection on concrete instances of practice; and (4) supported observation and reflection on one's own practices. These mediating processes constituted a progression of a sort, in that we felt that participants needed to discuss instructional practices in the abstract initially, discuss how those practices helped to lead to increased attention on student thinking, reflect on instances of actual practice collectively observed, and then reflect on their own practice. We saw these as requiring increased capacity as well as development of non-evaluative norms for noticing and discussing practice.

These mediating processes were the practices in which we hoped to productively engage the participants and which we viewed as essential if we were to realize the outcomes we had identified. While we imagined that we would need to revise the design of the learning environment to better facilitate these mediating processes, we saw the mediating processes as stable features of the overall design and conjectures, and which would be revised only after considerable discussion of the design and systematic analysis of data. We indicate the conjectured contribution of each component of the learning environment to the development of the mediating processes by the arrows shown in the conjecture map (See Figure 1). The width of the arrow indicates the strength of contribution for a particular component to the development of a mediating process. Our theoretical conjecture was that these mediating processes collectively would lead to the desired outcomes noted above.

Results

Below, we first present the conjecture map we constructed and then describe how we use the map to guide our analytic and design processes. The conjecture map is seen in Figure 1.

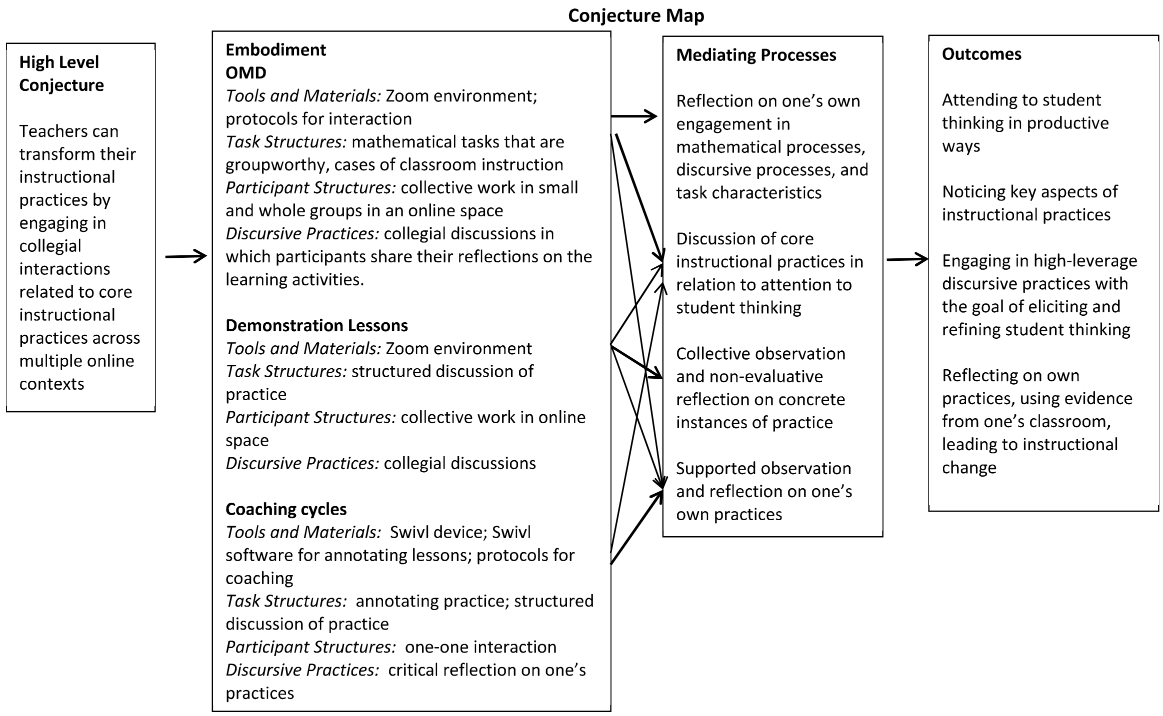

Figure 1. Conjecture Map for the Project

Conjecture Map as Reification of Our Model

Developing the conjecture map helped to reify our core conjectures about the design of the learning environment and the relationship between the design of the model, the intermediate processes we needed to develop, and our desired outcomes. Constructing the model engendered clarifying discussion about the learning environment and what each component was intended to accomplish. In our group, there is a distinction between the design and research teams, with several people dedicated entirely to the design and implementation of the learning environment, and several people dedicated to research, though there is some overlap between the groups. The researchers have focused primarily on the design conjecture at this point in the project: they have focused on how the learning environment facilitates the development of the mediating processes. Developing the map was one way for the design and research teams to come into greater contact with each other. The map provides an explicit articulation of the design and intended impact of the model as well as the conjectures and hypotheses on which we are basing our work.

Conjecture Map Guides Research Activities

The conjecture map has served as an anchor artifact in the discussions around data analysis activities. The map has focused the research team discussions on the design conjectures: we make sure we are documenting the design and we explore the affordances and constraints in the online learning environment; and we explore the impact of the learning environment on the development of the mediating processes. When we find a feature of the learning environment missing from the map, we revise the map to more accurately reflect our observations, and we check back in with the design team to verify the revised map. We develop our data analysis activities keeping in mind that they must speak directly to the nature of the learning environment, the relation between the learning environment and mediating processes, and the nature of the mediating processes in terms of our observations of the participants.

Conjecture Map Guides Documentation and Revision of Model

We use the conjecture map to anchor discussions about whether our designed learning environment facilitates the desire mediating processes and, if not, what needs to be revised within the learning environment. We recognized that it was crucial to fully document the enacted design at key intervals, to note the changes made to the learning environment, and to ensure that those changes are reflected in any revision of the conjecture map. This process has also identified unanticipated processes that have influenced the design of the project. For example, working in rural environments requires much more flexibility on our part in terms of the timing of classes and meetings, and the lack of internet infrastructure in some cases has led to complications. As a result, our design team has made changes on the fly without the benefit of using analysis derived from the research team, who have typically lagged six months behind in terms of processing and analyzing data. Thus, in documenting our design processes, we have audio-recorded and transcribed the design team meetings to understand the motivations behind the changes in the learning environment. Ultimately, however, the design and research teams are accountable to the conjecture map, and thus the teams will collectively revise the map to account for realizations and evidence gleaned through the practical contingencies of implementing a complex online model in rural environments and through systematic data analysis.

Role of Conjecture Map in Theory Building

The work in the project thus far has focused on our design conjectures (the link between the learning environment and mediating processes). However, as we wrap up the initial cohort at the end of the current project year, we will begin testing and revising the theoretical conjectures (the relationship between the mediating processes and outcomes). Ultimately, we will refine our high-level conjecture as we seek to generalize our findings beyond the context of the project, to address broader claims of learning, and, in particular, professional learning in online contexts.

Discussion and Implications

In this conceptual paper, we describe an ongoing design experiment that demonstrates the dynamic nature of the development and use of conjecture maps. Similar to Wozniak (2015), we found that our ongoing use of the conjecture map is strengthening the iterative nature of our design research project. As we regularly revisit the conjecture map and make modifications to our professional development design, we use the map as a framework for planning and evaluating the actual processes engaged by our professional development participants and the theoretical implications of the design. Through this process, the conjecture map is a key artifact for researchers engaging in design experiments (Sandoval, 2014; Wozniak, 2015). Developing and using a conjecture map holds us accountable to the assumptions of design experiments and to our own conjectures and hypotheses about improving classroom instruction of mathematics teachers in rural environments via an online professional development model. The map has anchored discussions about the design of the learning environment and how we research the design conjecture, specifically the data collected and the analysis process. Developing and using the map has helped us to identify misunderstandings between the design and research teams, to understand our lived processes with respect to revising the design of the learning environment, and to be more explicit about the specific mediating processes in which we seek to engage our participants. It has also helped us to be aware of key features of the design process, especially around the intended consequences of our work and the messiness of conducting research in naturalistic, if designed, environments. Ultimately, it will focus our theory-building discussions, especially as we explore the theoretical conjectures.

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