Examining Primary Teacher Expertise and Agency in the Collaborative Design of Project-Based Learning Innovations

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Abstract: Developing curriculum innovations aligned to research-based design principles and education reforms poses a daunting design challenge requiring substantial expertise. This study examines how prioritizing the agency of primary school teachers, engaged with researchers in the collaborative design of curriculum innovations, may allow for teachers to develop and productively leverage expertise. Using data from teacher surveys, interviews, and artifacts, our analysis has centered on what expertise teachers may develop around project-based learning and national science education reforms and what agency teachers have to influence the design of curriculum. We found evidence (1) teachers increased their understanding of project-based learning but showed fewer gains in understanding key ideas in science education reforms and (2) teachers significantly influenced the design of curriculum innovations. This study has implications for teacher learning and the design of curriculum innovations aligned to research-based design principles and national education reforms.

Major issues addressed

Successfully implementing innovative education reforms will require equally innovative materials. In science education, novel science curricula should embody the vision of reform (National Research Council, 2012). Developing science curriculum innovations, however, that faithfully reflect reforms and draw on research-based design principles has proven a daunting design challenge (Roseman, Fortus, Krajcik, & Reiser, 2015). Efforts to develop more innovative solutions to complex challenges may benefit from the presence of multiple or varied forms of expertise (Engeström, Engeström, & Kärkkäinen, 1995). Traditionally, researchers have dominated the process of developing innovations like curriculum to support reforms, often relegating teachers to merely the enactors of others' designs (Ormel, Pareja Roblin, McKenney, Voogt, & Pieters, 2012). Such approaches to the design of innovations fail to adequately develop or leverage teachers' expertise to support reforms.

We posit that positioning teachers to have the agency to develop and leverage expertise during curriculum design could serve to develop not only teachers' expertise in research-based design approaches, like project-based learning (PBL; Krajcik & Shin, 2014), and science education reforms but also support the development of needed curriculum. Working within a large-scale curriculum development effort at the primary school level where we instituted a collaborative design framework, we explore the following research questions:

(1) What expertise did primary teachers develop or leverage during the collaborative design process?

(2) What agency did primary teachers have to productively shape the design of curricular innovations within the collaborative design process?

Significance

This study coheres with established precedents in the learning sciences and design-based research, particularly in using design to explore learning in real-world settings and in leveraging multiple forms of expertise to develop education innovations (Collins, Joseph, & Bielaczyc, 2004). In addition, this study reflects design research efforts that promote more equitable arrangements of expertise through the use of collaborative design (co-design; see Penuel, Roschelle, & Shechtman, 2007). While some recent co-design work has focused on developing curriculum, these efforts have occurred exclusively at the secondary level (see Severance, Penuel, Sumner, & Leary, 2016). This study is unique in its focus on the co-design of curriculum innovations and the role of agency at the primary level. Moreover, few studies posit, as this study does, that co-design alone can promote deep teacher learning (see Voogt et al., 2015). Relatedly, few studies have examined using co-design to develop teacher expertise in the Next Generation Science Standards (NGSS) or other national science reforms (see Severance et al., 2016), and no study has used co-design to promote teachers' learning of key ideas in PBL.

Theoretical framework

Given this study's emphasis on examining transformations in activity (i.e., developing new curriculum to achieve reforms), learning within social and collective settings (i.e., co-design activity), as well as agency (i.e., opportunities to leverage expertise to affect a design), we utilize a theoretical framework informed by

sociocultural and cultural-historical activity theory (CHAT; Cole & Engeström, 2007). We subscribe to the idea of "learning by expanding" wherein individuals work in collective activity systems to develop new forms of desired activity leading to desired outcomes (Engeström & Sannino, 2010). When designers achieve new forms of activity (e.g. artifacts, practices etc.) during a design process we take this as potential evidence of learning.

In sociocultural theory and CHAT, *agency*, defined as the capacity to produce an effect or a desired change in the world (Engeström & Sannino, 2010), proves essential for how people transform their activity and achieve new learning or expertise. In design work, individuals ideally share a common desired object (i.e., the goal of designing curriculum innovations), and must exercise agency to pursue and achieve the object and bring about desired outcomes. Achieving lasting transformative changes in activity requires a shared transformative agency (Virkkunen, 2006), as well as attending to historical contradictions—such as teachers having little say in curriculum—that can manifest as tensions (Engeström & Sannino, 2010). We posit unresolved tensions may serve as evidence of a lack of agency in collaborative design, whereas observing desired changes in activity and shared artifacts (i.e., shape of curriculum) serves as evidence of designers exercising agency.

Methodology

Design methodology

This study takes place within a large-scale, multi-year curriculum design effort. Charged with developing 8-week PBL science units at the primary school level, this effort recently adopted a co-design approach for two units. The co-design team under study includes three researchers, and three primary school teachers: Frank, Jill, and Michelle. Co-design activity took place across in-person and online settings over the course of six months (see Figure 1). After an initial two-hour researcher-led session introducing key features of PBL and the NGSS, teachers, on average, participated in 30 hours of synchronous in-person design collaborations and 12 hours of synchronous online videoconferences. Our approach sought to position teachers in agentic design roles, from seeking teachers' expertise to negotiate initial unit storylines to having teachers lead the writing of actual lessons. Through mini-presentations and as-needed discussions, researchers sought to support teachers' understanding and application of key ideas in the NGSS, chiefly that students should use knowledge in the context of science and engineering practices, a *knowledge-in-use* approach. Researchers also sought to support teachers in internalizing and leveraging certain PBL design principles: students (1) "figure out" (are not told the science of) phenomena, (2) build ideas coherently following a storyline over time, (3) continually engage with driving questions, (4) have choice in meeting learning goals (no one right way to build understanding).

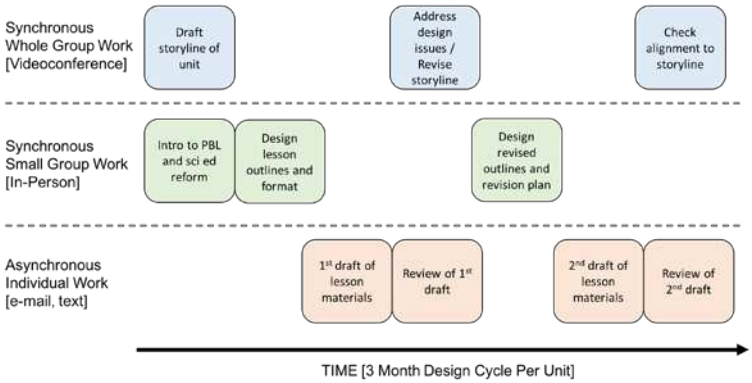

Figure 1. Activity of teachers (with researchers) in collaborative design over time.

Research methodology

Data collection and analysis for this case study occurred over six months. Sources of data for all teachers included pre-, mid-, and post-design process surveys assessing teachers' understanding of PBL and key ideas from the NGSS; semi-structured exit interviews examining teachers design expertise and beliefs about teaching; and artifacts created by teachers during the design process, primarily snapshots of lesson development. Data underwent deductive, theoretically-driven coding and inductive, bottom-up coding. Code co-occurrence highlighted data for finer-grained interpretive analysis to identify patterns of evidence for defensible claims.

Findings

We make two claims based on patterns of evidence observed that respond to our research questions: (1) teachers increased their understanding of PBL but showed fewer gains in understanding key science education reform concepts (i.e., *knowledge-in-use*) and (2) teachers significantly influenced the design of curriculum innovations.

Claim 1: Increased understanding of PBL (but not key tenets of reform)

Data for the three primary teachers indicates internalization of several PBL ideas. For example, Frank's survey responses show evidence he strongly internalized the idea, among others, of *driving questions* (see Table 1), a notion supported by his unprompted insertion of driving question discussions into his lessons. Patterns across Jill's interview and survey data indicates she connected most strongly with the idea of student *choice*, whereas Michelle showed she came to understand how PBL lessons move towards "a purpose" or have *coherence*.

Table 1: Teachers' responses describing PBL (Key PBL tenets in bold)

Teacher	Pre-Design Process Survey	Post-Design Process Survey
Frank	I would start by explaining the idea of teacher as **facilitator**, and how they will need to guide the students through the activities, and **allow the students** to take risks, even when you may feel that they will fail, it is often through that failure that success can be found.	**Kids looking at phenomena**, asking questions, experiencing and performing trials dealing with possible explanations, discussing and analyzing results, retesting and modifying when necessary, making a claim supported by evidence, and finally providing scientific reasoning to **explain or answer the original question/s**.
Jill	Materials! Prep time! Inquiry! Organization! **Loosening of control**!	I would describe it as giving the students powerful learning experiences where they have to **discover for themselves** the principles behind the **phenomena**. **There is room** for questioning, discussion, errors and all kinds of formative student ideas as they **figure it out**.
Michelle	...[A]llows for students to "discover" scientific ideas and theories **without being told** outright by their educator. The teachers role is that of mindful observer and travel guide. The educator may point out little clues by asking mindful questions but never spoons feeds students the answers...	PBL is an approach that puts students in the drivers seat. It allows students to **take control of their learning** and feel that their **learning has a purpose**. PBL allows the educator to play the role of a **coach**, one that fosters learning through guidance and mindful questioning.

Teachers showed fewer gains in understanding the *knowledge-in-use* approach called for in the NGSS. When prompted at the end of the design process to describe instruction embodying the NGSS, only Frank discussed students integrating science and engineering practices with science knowledge: "Kids…asking questions…making a claim supported by evidence and finally providing scientific reasoning to explain or answer the original question/s." Conversely, Jill offered a practice-only approach where students "do various challenging tasks, like modeling principles" and Michelle noted only that students should have "control of their own learning and the educator plays the role of coach." Notably, all teachers could not write integrated learning performance statements for their lessons without researcher support, even at the end of the design process.

Claim 2: Teachers significantly influenced the design of curriculum innovations

Teachers had agency in the design process to make lasting contributions to the units that persisted even after external reviews and editing. For example, Frank and Jill proposed early on in the design process an idea for a final community-based artifact to end a unit. Though details surrounding the artifact shifted during months of design, the kernel of the teachers' idea remained focal in the unit. More tangibly, teachers' contributions to lessons they developed, in terms of scope and substance, remained intact (See Table 2). Of note, teachers developed the first set of lessons in each unit, which subsequent sets of lessons had to follow and cohere with.

Table 2: Teachers' lesson contributions by unit

Unit 1		
Teacher	Lessons	Present in Final Draft?
Frank	1.1	Yes
	1.2	Yes
	1.3	Yes
Jill	1.4	Yes
	1.5	Yes
	1.6	Yes

Unit 2		
Teacher	Lessons	Present in Final Draft?
Frank	1.1	Yes
	1.2	No
	1.3	Yes
	1.4	Yes
Michelle	1.5	No
	1.6	Yes
	1.7	Yes

While teachers did make significant contributions, survey and interview data revealed tensions when teachers felt researchers impinged upon their agency. On a pre-post survey item asking how much she felt valued in the design project, Jill decreased her 4-point Likert rating from *(4) extremely valued* to *(2) less valued*,

and remarked disappointment at the lack of adoption of her ideas: "I feel a key idea of the two-column lesson plan that I was told had been adopted has needlessly not been implemented." Although Frank did not change how much he felt valued *((3) more valued*), he expressed similar dissatisfaction during his interview with the lack of adoption of certain ideas, citing "too many cooks in the kitchen" as a possible cause. Michelle did not express dissatisfaction, saying in her post-survey she felt her "ideas are taken seriously."

Conclusions and implications

This study illustrates how prioritizing the agency of primary school teachers, engaged in the co-design of curriculum innovations with researchers, can allow for teachers to develop and productively leverage expertise. Moreover, this study shows how co-design approaches can potentially disrupt traditional design approaches to enacting reform—where reform has been done *to* teachers rather than *with* teachers. As seen in this study, purposefully supporting and leveraging the expertise of teachers through deeply inclusive co-design can support not only teachers' individual agency regarding reforms but supports a broader shared collective agency to enact reforms: teachers can develop expertise for innovative design (see Voogt et al. 2015), as well as bring about needed curriculum innovations. Notably, this study provides a strategy for science education reformers to consider when attempting to build capacity for the implementation of science reforms at the primary school level, the critical foundation for *all* students' future science education pursuits.

This study also highlights novel challenges in collaborative design work. While seeking to show how co-design can help address tensions stemming from the historical contradiction of teachers not having significant agency in reforms and curriculum, this study showed how new tensions can also arise. Primarily, this study demonstrates the potential double-edged nature of agency in design: promoting teacher agency allows the leveraging of needed expertise, but subsequently circumventing this newfound agency can create new tensions researchers must attend to or risk alienating design participants. Additionally, this study showed underwhelming learning gains for teachers in terms of their understanding of the idea of *knowledge-in-use* present in recent science education reforms. This points to the difficulty of developing teachers' understanding of key shifts called for in reforms while engaging in design. We encourage design researchers to engage with our process and results and to further explore the interplay of design, learning, agency, and reforms.

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