Mathematical Tasks as Boundary Objects in Design-Based Implementation Research

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Abstract: This paper describes a collaboration involving school district curriculum supervisors, mathematics teachers, university researchers, and web engineers engaged in design-based implementation research of the adaptation of an Algebra 1 curriculum to meet the demands of the Common Core State Standards for Mathematics. In this effort, mathematical tasks operated as a boundary object, acting to organize cooperative work despite a lack of consensus regarding their meaning or purpose. Exposing and understanding this lack of consensus during joint work at community boundaries provided opportunities for learning in the form of changed practice and activity. Evidence for learning through coordination is presented, such as the communication of curricular vision and the routinization of a task rating process. Where lack of consensus led to potential conflict, as in the case of task adaptation, evidence for learning in the form of new practices was less evident.

Major Issue

The adoption of the Common Core State Standards for Mathematics (CCSSM) has created a need for many teachers and school districts to consider changing their curricular materials. For the 44 U.S. States that have adopted these standards, they generally represent a more focused and demanding target than prior standards (Porter, McMaken, Hwang, & Yang, 2011). While some schools will purchase new curriculum materials that better align to the CCSSM, many others will attempt to modify and improve existing materials. This kind of adaptation can require considerable effort and expertise, and implementation strategies for the CCSSM are not yet well-developed (Cobb & Jackson, 2011). Collaboration with researchers can be a productive option for not only developing quality curriculum, but for better understanding the processes by which standards-based curriculum is designed and implemented.

A useful unit of mathematics curriculum is the *task*, which is sometimes defined as “a classroom activity, the purpose of which is to focus students’ attention on a particular mathematical idea” (Stein, Grover, & Henningsen, 1996, p. 460). As intended by the CCSSM, high-quality mathematical tasks are likely to be inquiry-based activities that engage learners in multiple Standards for Mathematical Practice (NGA Center/CCSSO, 2010). While adapting curricula to include such tasks may be a goal shared by teachers, district curriculum supervisors, researchers, and other reform agents, the meaning and significance of a mathematical task may vary depending on one's position and perspective. In this way, mathematical tasks are a potential *boundary object* (Star & Griesemer, 1989; Star, 2010). In this paper, we ask: How do mathematical tasks operate as boundary objects, and what do mechanisms for learning related to boundary objects and boundary crossing imply for collaborative efforts to adapt and implement new curricula?

Contextualization and Significance

Our research is an example of design-based implementation research (DBIR; Penuel, Fishman, Cheng, & Sabelli, 2011), an approach that expands classroom-based design research to consider perspectives of other stakeholders in an educational system. DBIR leverages iterative and collaborative development of processes and products to enhance a system's capacity to sustain and scale change related to persistent problems of practice.

Participants in this DBIR project represented four communities: university researchers, curriculum supervisors from an urban school district, high school algebra teachers from the district, and an engineering team coordinating with the researchers to develop a web-based catalog of curricular resources. The district supervisors selected teachers with the goal of representing varying levels of teaching experience and expertise with curriculum development. Approximately ten teachers participated at any one time on a Teacher Design Team (TDT), with some leaving and others being added as the project changed phases or as individual circumstances demanded. This project is significant not only in its purpose to support curricular change in response to the CCSSM standards, but in its DBIR approach and researcher access to both the district's teachers and their supervisors. The focus of this paper is the initial phase of the project, a period from July 2012 through the first TDT meeting in December of 2012, a full-day workshop involving all four communities. During this phase there were weekly meetings of the research team as well as weekly phone conferences between the researchers and the district supervisors. One member of the engineering team attended these weekly meetings in a significant liaison role.

Theoretical and Methodological Approaches

Boundary objects are so called because they exist at and cross the boundaries of social worlds, such as the boundaries between communities of teachers, researchers, and curriculum supervisors. Star and Griesemer (1989) described boundary objects as "objects which are both plastic enough to adapt to local needs and the constraints of the several parties employing them, yet robust enough to maintain a common identity across sites" (p. 393). In addition to an interpretive flexibility across social worlds, Star (2010) clarified that boundary objects allow groups to cooperate without a consensus regarding their meaning or use, and they have a dynamic between ill-defined and well-structured uses. For this paper, we are particularly interested in how boundary objects represent the "stuff of action" (Star, 2010, p. 603) being the thing around which work is organized.

Work organized around boundary objects can represent learning in the form of changes in identity and/or participation. In their review of boundary crossing and boundary objects, Akkerman and Bakker (2011) identified in the literature four mechanisms of learning at boundaries: identification, coordination, reflection, and transformation. Akkerman and Bakker grouped identification and reflection together as mechanisms that reflected meaning-oriented learning processes with implications for people's identities and perspectives, and grouped coordination and transformation together as practice-oriented learning processes with implications for activity. In this DBIR project, mechanisms related to practice and activity are most relevant for discussing learning. *Coordination* involves communication, efforts of translation, boundary permeability, and routinization, all of which contribute to people or objects moving smoothly across boundaries. Alternatively, *transformation* typically involves confrontation, recognition of shared problem spaces, hybridization resulting in new cultural forms, and crystallization of routines or procedures that embody new learning and require continuous joint work at boundaries. The in-between practices that can emerge in transformation are often held as goals but tend to be difficult to achieve and sustain, while coordination maintains the nature of boundary objects in ways that avoid the disruption of power structures or organizational hierarchies.

The primary sources of data used in this analysis are field notes taken in meetings of the research team, the researcher-supervisor planning meetings, and the TDT meeting. Results from an end-of-year teacher survey were also considered. The analysis here focuses on meetings where boundaries were exposed, such as in researcher-supervisor meetings and the TDT meeting. Iterating over the meeting notes, we identified arcs of work (Strauss, 1985) related to mathematical tasks, then identified design tensions (Tatar, 2007) within each arc.

Arcs of Work in Design-Based Implementation Research

The project's initial arc of work established mathematical tasks as a potential boundary object. DBIR often begins with a search for an appropriate boundary object (Penuel, Coburn, & Gallagher, 2013) around which work can be organized. The object is not a "given" because the goals of a project emerge through collaboration. Though many of the participants in this project had collaborated before, identifying a common aim—and a new potential boundary object—was a key initial step in the work. The previous collaboration resulted in an online catalog of digital objects for supplementing a new science curriculum. The district supervisors' initial stance was to develop a similar website and set of resources for Algebra 1, while researchers focused more on issues of curriculum implementation aligned with current research agendas, rather than the curriculum itself. Researchers' early conversations suggested "productive adaptation" of curriculum (meeting notes, July 23, 2012), curriculum adaptation and authoring tools for teachers (meeting notes, August 28, 2012), analyzing teachers' use of teacher-created materials (meeting notes, September 4, 2012), and a need for teachers to do task evaluation in a way that was simple but rooted in learning sciences research (meeting notes, August 28, 2012).

District supervisors pressed to pursue task evaluation and requested a selection of task rubrics, including rubrics for cognitive demand and language (meeting notes, September 17, 2012). The researchers suggested in the following meeting that the work focus primarily on learning trajectories, which was responded to by a supervisor with "Why not just use the curriculum guides we already have?" and "I don't want to sound too pedestrian, but I want us to help teachers identify and use tasks that extend our current program" (meeting notes, September 24, 2012). This request, combined with an underdeveloped research base for learning trajectories in high school algebra (Sztajn, Confrey, Wilson, & Edgington, 2012), led to organizing project work around mathematical tasks. The focus on tasks fulfilled the supervisors' desire for new, high-quality curricular materials, and the prospect of a task rating process would allow researchers to focus on productive curriculum adaptation and other aspects of teacher practice based in mathematics education and learning sciences research.

The second arc of work included the selection of task qualities teachers would use to rate tasks. Beginning with the supervisor-requested qualities of cognitive demand (Stein, Smith, Henningsen, & Silver, 2009) and language (Moschkovich, 2012), researchers assembled task evaluation guides and rubrics, attempting to consider what teachers actually do in implementing tasks (meeting notes, September 25, 2012). Additional potential rubrics and guides included alignment to standards and district learning goals, task "launch" (Jackson, Shahan, Gibbons, & Cobb, 2012), cultural relevance, and use of technology (meeting notes, October 9, 2012).

The main tensions in this arc of work centered on task adaptation and implementation support. The draft of the language rubric suggested task modifications for English learners, which raised concerns from a supervisor: "One thing I worry about is, how will a teacher know if a task is appropriate for modification? Or if it has no guide for modification?" (meeting notes, October 22, 2012). Rather than modify the task, the supervisors requested supporting materials for ELLs that could support all tasks, including those in the district-adopted textbook. It was agreed that the development of these and other supporting materials would be pursued in a future phase of the project and that task qualities would apply to tasks only as written. This decision was applied later in the meeting when discussing the evaluation of tasks for cultural relevance. This rubric was set aside, with one supervisor suggesting that cultural relevance was related to teacher planning, not task quality. A different supervisor agreed, stating, "If teachers determine it's a worthwhile task, there ought to be a place to make some notes about how that task is supported," which again suggested a future phase of work focused on supporting the implementation of tasks. At meeting's end, the list of task qualities to consider with the TDT were limited to the alignment with CCSSM and district goals, cognitive demand, language, and technology.

Following the October 22 meeting, a district supervisor sent researchers four tasks selected from the Mathematics Assessment Project (http://map.mathshell.org). The tasks had been scheduled into the Algebra 1 pacing guide for teachers to use at specific points in the curriculum. Each tasks represented a full lesson and included supports developed by the Mathematics Assessment Project such as student materials, slides, and discussion guidance. The district supervisors had added a cover sheet to each task that outlined a lesson plan and aligned the task to district content and language standards, but the task itself was unmodified from the original.

A third arc of work involved the design of a process for rating tasks within a group professional development activity. The researchers recognized there would be a "need [for] tasks for [teachers] to analyze using the draft rubric" (meeting notes, September 25, 2012) with sufficient practice with each rubric for teachers to have a "calibrated/shared understanding on that area of the rubric" (meeting notes, October 9, 2012).

Negotiations over plans for the TDT meeting surfaced tensions related to aims for tasks and relevant task qualities. In a November 5th meeting with supervisors, the researchers suggested structuring activities so that teachers "directly address their own questions about aligning to the goals of the CCSSM," which was met with a supervisor concern that the conversation could devolve into irresolvable details of practice that might distract from the goals of the activity. Instead, the supervisor expressed a broader vision: "It would be nice to see a task that truly represents the kind of task that students should be capable of after three years of high school math." A researcher altered the TDT agenda to reflect this vision of an "ultimate goal." A supervisor also wanted teachers to work with the rubrics enough to be comfortable with both CCSSM alignment and cognitive demand, stating, "A task might have great cognitive demand, but if it doesn't align to the standards, it doesn't serve much of a purpose for us." In a November 13th meeting, the liaison from the engineering team presented plans to show the TDT the curriculum website, how rated tasks might eventually be presented, and how other digital library resources were being algorithmically brought in to align with the district scope and sequence.

Teachers voiced their own perspectives at the TDT meeting, asking to consider their perceptions of students' capabilities to engage in the task. For example, when discussing cognitive demand, teachers indicated their ratings depended on where in the curriculum they might use the task, or if the task was to be used with a relatively higher- or lower-ability group of Algebra 1 students. Seeking consistency in the rating process and consensus amongst raters, the researchers encouraged teachers to evaluate the tasks only as written and their "qualities independent of the particular groups of students" (meeting notes, December 1, 2012). This tension over task adaptation to classroom contexts persisted to the year-end teacher survey. When asked what factors influenced their use of tasks *not* captured in the rubrics, answers included "individual student abilities," "the needs of my students," "whether the task will be engaging/interesting to my students," and "level of engagement from the students." When asked how they would design PD around the CCSSM, responses included:

> Teacher 2: "I would want a focus on how these resources can be used in my unique situation"
> Teacher 7: "I really just wanted to focus on creating better tasks … I don't really care too much about the rubric"
> Teacher 11: "[I would give] teachers resources that would enable them to create their own tasks"

Discussion

Figure 1 summarizes how each community interpreted mathematical tasks. For supervisors, tasks were a vehicle to add cognitive demand into the intended curriculum. The data shows the supervisors' resistance to encourage teacher modification of tasks, preferring instead to identify high-demand tasks and to support their use. Teachers, by showing a desire for selection and adaptation of tasks, were grounded in their daily need to use or adapt available resources in the written curriculum meet students' particular needs. For the researchers, tasks represented opportunities to engage teachers in using the rubrics. The particular task was somewhat unimportant, as the higher goal was to instill teachers with a set of curriculum design principles to apply to all tasks in the transformation between the written and intended curriculum. Lastly, for the web engineers, tasks were interpreted as a digital resource in a collection of resources that comprised a written curriculum.

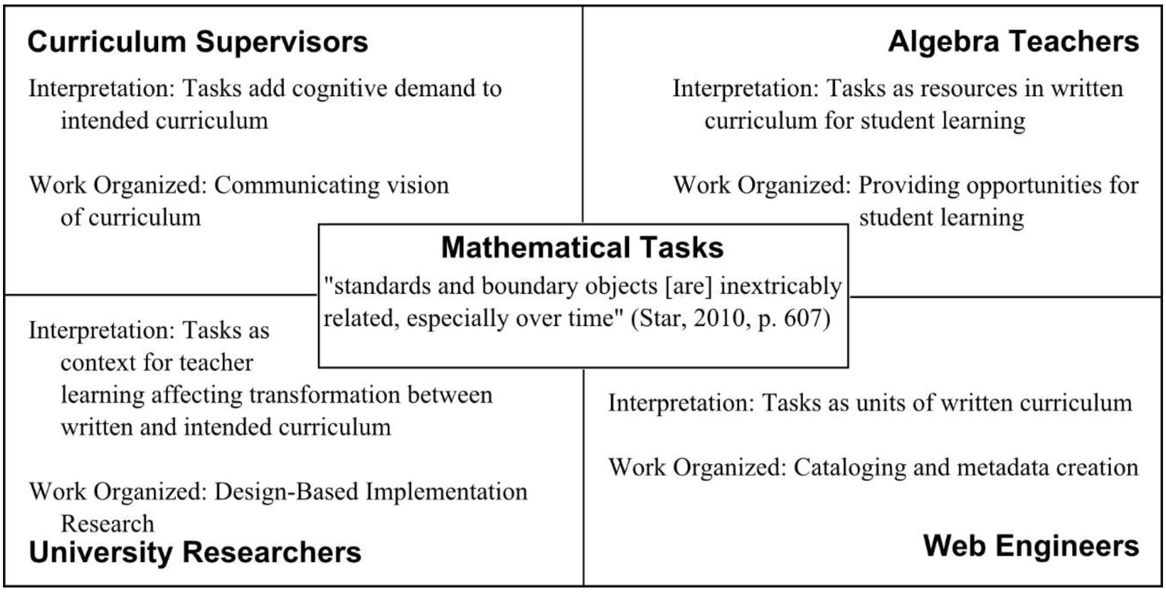

Figure 1. Mathematical tasks as a boundary object

It is also useful to consider how mathematical tasks organized work *within* each community in ways Star (2010) described as "invisible" or "back stage" work. The typically unseen work of the curriculum supervisor is the coordination of content and professional development to sculpt their vision for curriculum and instruction. Carefully chosen tasks are one way for supervisors to communicate that vision. For teachers, task-oriented back stage work includes how the unique demands of each classroom drives the search for tasks wherever they might be found, or the creation of new tasks when necessary. These unique demands are a reason why fidelity-based approaches to curriculum implementation tend to be problematic, despite supervisors' and curriculum designers' attempts to anticipate the needs of teachers. For DBIR researchers, invisible work includes collecting data of task analysis and enactment, as well as theorizing from patterns in that data. In this study, this invisible work would sometimes manifest itself in the form of a researcher-designed process to address a problem (e.g., "here's a recommended strategy for encouraging teachers to participate in a webinar about task use") when supervisors had more direct solutions available (e.g., "just tell us who needs to participate and we'll call people we trust to see that it gets taken care of"). For the web engineers, the back stage work with tasks was the meticulous cataloging of the tasks and the creation of metadata records to describe their location in the curriculum, their alignment to standards, and how they were rated.

Akkerman and Bakker (2011) identified coordination and transformation as practice-oriented mechanisms for learning at boundaries. The evidence presented in this paper primarily describes mechanisms of coordination, as the arcs of work consisted largely of communication and translation between communities rather than confrontation and shared recognition of problem spaces. Continued research in this DBIR project should yield evidence of whether the supervisors' vision for curriculum establishes a *communicative connection* across all spaces, if researchers' *efforts of translation* of the scholarly literature impacts perceptions of tasks, or if task rating can become a *routinized* teacher practice in individual lesson planning and in teachers' professional communities. Nine of 11 teachers reported in the year-end survey that their experience had a positive impact on their practice, with several indicating an influence of the task rating process into their daily selection and use of mathematical tasks. While this is a promising sign, more work at the boundary is required to understand how teachers' participation is changing, and how change can be made scalable and sustainable.

There are opportunities for learning to occur as transformation in this project, particularly where confrontation persists around mathematical tasks. Task adaptation is one such area, but the existence of *hybridization* or *crystallization* is unclear as conflict was largely avoided or postponed. New forms of participation are tempered by histories and structures that exist across and within communities, such as teachers' experiences with professional development and the roles of building administrators. Transformation may require a greater "coevolution" of teacher participation across contexts (Kazemi & Hubbard, 2008) and new theorizations within DBIR for addressing issues of power within educational systems. Transformation in this project could evolve as the crystallization of a task rating process that overcomes tensions between (a) teachers' need to situate tasks in their classrooms, (b) supervisors' need to provide curricular vision, (c) researchers' need for scalability and sustainability of processes, and (d) web engineers' need to classify and catalog tasks.

Conclusion

Collaborations between school districts, teachers, researchers, and other reform agents in design-based implementation research is a promising approach for building scalable and sustainable change in educational systems. This paper described how one such collaborative partnership organized their mathematics curriculum reform work around mathematical tasks. As a boundary object, mathematical tasks facilitated coordination despite a lack of consensus regarding their meaning. The lack of consensus exposed during joint work at the boundary of communities revealed opportunities for and achievement of learning, evidenced by changed practice and activity made possible mostly through the mechanism of coordination. In the case of task adaptation, a lack of consensus became a point of conflict. Successful confrontation of this conflict in the cooperative design process could yield new hybridized or crystalized task adaptation practices that, while difficult to achieve, have sustainable impact.

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