Running Head: EMERGENCE OF OBJECTS IN CO-DESIGN

The Emergence of New Objects in Co-Design:

A Cultural-Historical Activity Theoretical Analysis

William R. Penuel

Samuel Severance

Raymond Johnson

Heather Leary

Susan Miller

University of Colorado Boulder

DRAFT, June 2014

PLEASE DO NOT CITE OR QUOTE WITHOUT PERMISSION

Paper to be presented at the 11th International Conference of the Learning Sciences,

Boulder, CO, USA.

Introduction

Collaboration between researchers and practitioners is a hallmark of design research in the learning sciences (Cobb, Confrey, diSessa, Lehrer, & Schauble, 2003; Design-Based Research Collective, 2003). Sometimes, collaboration entails researchers assuming responsibility for teaching in a single classroom for a short period of time (e.g., Confrey & Lachance, 2000), while other projects involve teachers, educational leaders, and researchers working together to design efforts to improve teaching and learning across an entire school district (e.g., Cobb & Jackson, 2012). Still other design research studies involve multiple institutions who work together to bring about more robust learning ecologies that span formal and informal settings (e.g., Gutiérrez & Vossoughi, 2010).

Many design research projects in education entail the co-design of innovations. Co-design a highly-facilitated, team-based process in which educators, researchers, and developers work together in defined roles to design an educational innovation, realize the design in one or more prototypes, and evaluate each prototype's significance for addressing a concrete educational need (Penuel, Roschelle, & Shechtman, 2007). In contrast to some forms of design research, co-design begins with a *flexible curricular target,* in that the researchers do not specify fully ahead of time either the goals that designs are intended to support or their social and technical realizations. In this way, co-design allows for participants in the process—especially educators—to have not only a stake but also a say in design (Kensing & Greenbaum, 2013).

An important aspect of co-design is that *new objects* emerge through the process. By object here, we do not refer to the "innovation" that is being design; rather, we mean object as defined by Cultural-Historical Activity Theory (CHAT). Within CHAT, the

object is understood as a kind of "shared problem space," and as such, a site of intervention, transformation, and learning (Akkerman & Bakker, 2011; Engeström, 2011; Engeström & Sannino, 2010). With many other learning scientists, we employ co-design as a methodology principally for its potential to reveal new, transformative possibilities for practice that we could not have imagined at the outset of our work. At the same time, we also acknowledge the possibility for failures in co-design and the need to analyze failures as a key condition for developing design research as a methodology (O'Neill, 2012).

In this paper, we describe a method for empirically analyzing how new objects emerge within co-design. The method draws from Spinuzzi's (2011) approach to analyzing the emergence of new objects in inter-professional collaborations. Our particular method draws attention to how new objects emerge through boundary encounters, as well as how participants articulate new boundaries as they seek to recruit new participants to their project. We illustrate our method with analysis of episodes within an ongoing research-practice partnership (Coburn, Penuel, & Geil, 2013) focused on improving the quality of mathematics teaching in a large urban school district. Both the method and our illustration show how CHAT analyses can help us develop an understanding of the nature of the effects of co-design on the practices of educational systems.

The Need for Empirical Research on Co-Design

There is increasing interest in co-design within the learning sciences. Learning scientists have argued that co-design helps to ensure that models of learning developed by researchers are adapted with integrity to local contexts (Lui & Slotta, 2013). Others

have argued that co-design can help to "optimize technological and social change" (Dolonen & Ludvigsen, 2013, p. 248). A recent review (Ormel, Roblin, McKenney, Voogt, & Pieters, 2012) of 18 design research studies found that all of them reported significant levels of participation of practitioners in design, indicating that co-design is a common approach to organizing design research.

This same research review (Ormel et al., 2012) revealed two additional characteristics of design research that point to the need for more empirical research on co-design. The first is wide variation in how projects structure participation of educators, with some projects according significant roles to educators in multiple phases of design research and others more circumscribed roles. Developing a body of empirical research on co-design can benefit the learning sciences by showing the varieties of ways research and development projects can structure participation within co-design in ways that account for differing purposes and contexts of design (e.g., Penuel, Tatar, & Roschelle, 2004). Second, the review found little documentation of how the practical knowledge of educators informed design work or contributed to the development of knowledge and theory. This particular limitation in the research base underscores the way that co-design involves both mutual appropriation (Downing-Wilson, Lecusay, & Cole, 2011) and mutual learning on the part of researchers and practitioners is poorly understood within the learning sciences.

We also know little about how and when co-design helps participants collectively envision new possibilities for practice and develop practices that neither researchers nor practitioners could have imagined ahead of time. We need such knowledge, because co-design in education—as in other fields—is complex, messy, and slow moving

(Greenbaum & Loi, 2012). Participation may need to be structured in ways that accounts for both organizational dynamics peculiar to the context of design (e.g., Penuel et al., 2004), and historical patterns of exclusion and inequity (e.g., Bang, Medin, Washinawatok, & Chapman, 2010). Moreover, co-design does not lead inexorably to more usable designs, to expanded agency, or to more just social futures. It is an open question as to whether or not innovations that are co-designed—as compared to those that are designed by software engineers working closely with subject matter experts—spread more readily and have a greater impact.

Using CHAT to Analyze Co-Design

From our own perspective, Cultural-Historical Activity Theory (CHAT) offers a theory and methodology for intervention research suitable to the task of analyzing co-design. As we elaborate below, CHAT provides (1) a unit (the object-within-a-project) for bounding analysis of co-design, (2) a focal point (boundary crossing) for analysis of the process of co-design, and (3) a principle (transformative agency) for evaluating the effects of co-design.

Unit of Analysis: The Object-within-a-Project

The object is what helps us make sense of why individuals, groups, or organizations do what they do (Kaptelinin, 2005). It bounds analysis of activity systems and interactions between activity systems, serving as the reference point from which researchers develop claims about the organization and effects of activity (Spinuzzi, 2011). Of particular relevance to the phenomenon of co-design, where participants engage in joint work to intervene in a particular context, the object is also

often understood as a kind of "shared problem space" (Akkerman & Bakker, 2011; Engeström, 2011; Engeström & Sannino, 2010).

As in other collective efforts to transform practice, the object as shared problem space in co-design is an emergent phenomenon that is—especially in the earliest phases of design—unstable and shifts as particular projects evolve. The problem spaces of co-design often have the character of "runaway objects," that is, objects held in common across multiple activities that take place across multiple settings and with different configurations of actors (Engeström, 2008). Collaborative design teams in education today take on such objects as "improving instruction at scale" (Cobb & Jackson, 2012) and "improving the success rate of community college students who place into developmental mathematics" (Dolle, Gomez, Russell, & Bryk, in press). As with other runaway objects, these are not in any single person, group, or organization's control, including participants in partnerships.

Another characteristic of co-design is that it is typically organized around specific projects (Midler, 1995; Penuel et al., 2007) or multiple projects linked by the same organizational partners (D'Amico, 2010). As such, the project is one aspect of an activity that helps to bound the problem space, that is, the objects that emerge from joint work (Blunden, 2009). Funders of co-design projects in education require some specification of the object ahead of time in proposals, and a common challenge to developing proposals that employ co-design is to assure funders and peer reviewers of the value of investing in a project with an initially ill-specified project (Gutiérrez & Penuel, 2014). Developing a research base on how teams can organize to successfully negotiate a focus for joint work and the conditions that are required

can help to build greater tolerance for risk taking among funders, if proposers can justify their own approaches to co-design in light of that research base. This research base can benefit from employing a common unit of analysis, which we call here, the *object-within-a-project.*

Focal Point for Analysis: Boundary Crossing

A CHAT perspective on boundaries begins with a premise that all activity must be analyzed as involving at a minimum the interaction of multiple activity systems (Engeström, 2001). Different activity systems each have different sets of actors, with distinct professional norms and professional cultures (Engeström, Engeström, & Karkkainen, 1995; Suchman, 1994). Different professions develop distinct repertoires of resources for action—forms of language, routines, artifacts, tools, and dispositions (Wenger, 1998). When actors from different activity systems meet to engage in joint work on a new project of some kind, they frequently encounter these differences as discontinuities in action—as obstacles to accomplishing what they thought they had set out to do together. Successful joint work depends on *boundary crossing* (Engeström et al., 1995), that is, navigating experiences of discontinuity by making use of differences as a resource for collective action.

Boundary crossing makes a particularly useful focus point for analysis of the activity of co-design for two key reasons. For one, co-design typically entails the intersection of activity systems of practitioners, researchers, and often also of developers of some kind (e.g., of software, of curriculum). Researchers have observed that they and educators work in different cultural worlds, with contrasting work practices, priorities, and institutional norms and incentives (Bickel & Hattrup, 1995; Brookhart & Loadman, 1992;

Gifford, 1986; Keating & Clark, 1988; Schlecty & Whitford, 1988). Where these worlds meet in co-design, we would expect experiences of discontinuity, and that has indeed been documented in research on co-design in the learning sciences (e.g., D'Amico, 2010; Penuel et al., 2007; Reiser et al., 2000). A second reason for making boundary crossing focal in analysis that is directly related to the likelihood of discontinuities in action in co-design is that there is a need for a better understanding of precisely how actors recruit differences to benefit design, that is, to document both the kinds of interactional moves that people make in design that make relevant expertise of participants visible that might otherwise be invisible (e.g., Kerosuo, 2004) and the organizational routines that support making productive use of difference a regular—rather than purely happenstance—occurrence (e.g., Hargadon & Sutton, 1997).

Boundary crossing often entails the development of a *boundary practice.* Boundary practices are "in-between" and hybrid activity systems that draw on cultural forms familiar to some of the actors but that are taken up in novel ways in the site of joint work (Gutiérrez, Baquedano-Lopez, & Tejada, 2000). Successful boundary practices are purposefully and collectively organized interactions that enable joint work and mutual learning (Kerosuo, 2001; Wenger, 2000). Joint work within the boundary practice is often facilitated by the construction of boundary objects (Star & Griesemer, 1989), that is, artifacts that link practices outside the site and in which each actor can see reflected their contribution. Learning is supported when difference is surfaced and made a resource for joint work and the emergence of new objects that no single actor could have anticipated ahead of time (Guile, 2011, 2012).

Co-design often involves the creation of boundary practices. For example, Penuel, Coburn, and Gallagher (2013) describe how one partnership comprised of researchers, district leaders, and teachers in science developed practices to support joint work to revise curriculum units to make them more "student-centered." The work initially had focused on a "curriculum audit" the district asked researchers to perform, but it was not until the group organized around re-design of curriculum units that an object emerged that sustained a long period of joint activity.

Of course, a shared problem space might not ever have emerged for this group, and so it is critical to consider not only successful instances of boundary crossing, but also failures of boundary crossing and instances where new boundaries emerge in the course of work. Co-design boundary practices sit within a nexus of other practices, so it is necessary to consider how an emergent practice is both linked to and separate from those other practices (Wenger, 1998). Of particular relevance to co-design is the social system that co-design teams seek to influence—other teachers and schools in a system who are not part of the design process, for example. As the co-design team seeks to expand beyond immediate participants, new boundaries are likely to emerge that present both new opportunities for boundary crossing and obstacles to transforming practice.

Principle for Evaluating Effects of Co-Design: Transformative Agency

CHAT intervention research focuses on transforming activity and expanding the agency of participants (e.g., Cole & Engeström, 2006; Engeström, 2005; Engeström & Sannino, 2010). Transformative agency is a collective phenomenon that entails both envisioning new possibilities for and making changes to work activity (Engeström, Sannino, & Virkkunen, 2014; Heikkila & Seppänen, 2014). Agency emerges from direct

engagement with the contradictions embedded in practice, in particular through both individual and collective sensemaking about the object of activity (Engeström & Sannino, 2010; Heikkila & Seppänen, 2014). Out of this analysis can emerge a "novel concept" (Engeström, 2011), that is, a new form of activity that draws on resources and ideas from the existing activity system but that in some ways also breaks away from it.

Highlighting the principle of transformative agency within analyses of co-design links co-design to the participatory design tradition. Participatory design has always been understood as a form of democratic and emancipatory practice (Greenbaum & Loi, 2012; Kensing & Greenbaum, 2013), linked to traditions of workplace democracy in Scandinavia (Ehn, 1992). Thus, one does not engage in co-design simply to produce a more "usable" design for practitioners, regardless of whether that design is of value to them. Instead, a key yardstick by which the effects of co-design should be judged from a CHAT perspective is whether, how, and when co-design helps practitioners to envision new possibilities for action that overcome tensions, contradictions, or "double binds" of their practice.

Interventionists can and do support the envisioning of new possibilities for action through the intentional introduction of explicit tools or mediational means (Wertsch, 2007) for fostering reflection on practice in co-design. In a Change Laboratory, a method of CHAT Intervention research, the model of an activity system ("triangles") is such a tool. An intervention team generates the content of the model collectively and iteratively as a support for identifying contradictions in their local activity system. Other kinds of mediational means learning scientists have introduced into co-design to support envisioning new possibilities for action include ethnographic accounts of current practice

(Barab, Thomas, Dodge, Squire, & Newell, 2004; Roschelle, Penuel, Yarnall, & Shechtman, 2005), use scenarios (DiGiano et al., 2003), personas (Lundh, Cheng, Penuel, Joshi, & Lesk, 2010), and models for organizing instructional sequences (Morozov et al., in press). A key task for an analyst of co-design within a specific project is to investigate how these tools are taken up, ignored, critiqued, or even resisted within activity and with what effects on participants' imagined possibilities for action and practice.

Illustrative CHAT Analysis of a Co-Design Project

In the remainder of this paper, we present an illustrative analysis of a single project's co-design activities. Following earlier CHAT analyses of how objects emerge in joint work, boundary crossing, and agency, we draw upon a mix of field notes, video recordings, and audio recordings of meetings. As other scholars have pointed out, meetings are not simply a coincidental setting for joint work: they are complex cultural event where groups negotiate collective goals, power and authority, devise action strategies, and carry out action (Schwartzmann, 1989; Sprain & Boromisza-Habashi, 2012). Also as earlier CHAT analyses have done, we focus on evidence from *discourse* in these meetings, drawing on past analyses of agency and boundary crossing within change laboratories (e.g., Engeström, Engeström, & Kerosuo, 2003; Haapasaari, Engeström, & Kerosuo, 2014; Kerosuo, 2004) for guidance as to relevant features of discourse to analyze.

As in many design research studies, we find ourselves in the position of generating a "first person" account of co-design. The authors of this paper are all researchers who are participants in this particular project. Moreover, each has had to play multiple roles in the project—facilitator of design activity, classroom observer, and analyst. Because of our

position, and because we believe it is as important to highlight failures in design as successes, we have chosen to include a number of examples of difficulties encountered in negotiating the object of work, unresolved tensions, and new boundaries that have emerged within our work.

Spinuzzi (2011) offers an approach to researchers seeking to bound the study of objects and their transformation within a CHAT perspective. The first step is to provisionally bound the case, focusing on persons in a defined organization or network and representations that these persons recognize as what they do. Once the case is bounded, researchers should identify one or more material objects (e.g., a grant proposal, a curriculum) around which joint work is coordinated, which is then formulated as a *claim* as to what (for that moment) participants are up to. Then, it is critical to identify the multiplicity of outcomes that participants hope that their work will accomplish. Fourth, the analyst "re-bounds" the case, considering actual participants in activity, their contributions, and changes to outcomes that emerge for participants as they undertake joint work. Finally, the analyst describes the tools, rules, divisions of labor, and community stakeholders that are relevant to a *qualified claim,* that is, a claim that Spinuzzi (2011) describes as more "collaborative, multiperspectival, often multidisciplinary" (p. 28).

Provisional Boundary for the Case

As a provisional boundary for the current task, we consider a project funded by the National Science Foundation, the Inquiry Hub. The project provides a useful provisional boundary, because participants are named in the proposal and have some external accountability to the funder for their involvement, and because the proposal lays out a

statement about what the developers of the proposal think they are about. Though written by researchers, the proposal development process involved several meetings with the principal partner organizations—a research university, a school district, and a research non-profit organization—to develop its ideas. As stated in the proposal, the goal was to provide districts and teachers with the cyberlearning tools they need to shift towards adaptive and responsive *learner-centered teaching* with digital science and mathematics curricula. Of note is that the initial bounds of the case did not include multiple districts, nor were any teachers participants in developing the proposal. However, the plan called for expansion of tools developed in the partner district to other districts, as well as involvement of teachers in co-designing tools. The proposal called out several external "drivers" that the team said was influencing its direction, including the new Common Core State Standards in Mathematics and an increased demand for open access, digital curriculum materials.

Finding a Common Representational Object

The proposal process, which took place in spring 2011, included a large number of people from partner organizations. In addition, the proposal outlined a number of possible tools that the project team might develop, including formative assessment tools for teachers and a data query tool for district administrators to use to analyze digital curriculum use. As is typical, several months passed between the development of the proposal and the time when a decision to fund the project was made. At this point, a smaller group comprised of three district curriculum leaders (of whom one was their supervisor), a non-profit center director and program developer, and two faculty members, two graduate students, and a postdoctoral researcher at the university convened

to decide how to organize their work together. The supervisor from the district proposed a focus that was different from what the group anticipated. She saw a need to focus more attention on developing understanding of new Common Core standards in algebra and the kinds of tasks that embodied the new standards. She told the group, "I don't want to sound too pedestrian, but I want us to help teachers identify and use tasks that extend our current program."

Within the course of the first two to three months of planning for the project in fall 2012, finding high quality tasks became a focus of this team's work, but the ways that participants imagined teachers interacting with tasks expanded. The team of district leaders, researchers, and program developer met weekly for two months to plan a daylong workshop with teachers. At an early meeting, the district supervisor noted the team had been working with a framework developed by the University of Pittsburgh for analyzing the cognitive demand of tasks (Henningsen & Stein, 1997) and suggested that *task analysis* might be a fruitful way to organize the TAB's work. Recognizing that the Common Core State Standards were an important orienting "driver" for the project, the project team developed a plan to have teachers rate alignment as part of the analysis work. The team also decided upon rating tasks for their use of academic language, a key district priority, given the large numbers of English learners, and technology, specifically to identify tasks that might give students practice with new Common Core assessments. Throughout this initial planning period, district leaders largely decided upon the dimensions of analysis, while researchers drafted and revised specific *rubrics* for use in analyzing or rating tasks. When researchers did suggest a dimension that had not been

offered by district leaders—one on cultural relevance of tasks—a district leader

questioned whether analyzing tasks along this dimension would "add much value."

The team brought on board a group of 10 teachers to serve as a Teacher Advisory

Board (TAB) in December 2012. Their role in the proposal was to help support

development of content within the project's digital platform, the Curriculum

Customization Service. The first meeting of this board—an all-day Saturday meeting—

consisted of introducing TAB members to the process of what had come to be called *task

rating* using an initial set of rubrics.

Over the course of the next three months, the practice of preparing for and engaging

teachers in task rating became increasingly crystallized (Akkerman & Bakker, 2011) as a

kind of boundary practice constituted within the project around a set of focal routines and

artifacts. A graduate student in mathematics searched for tasks in an upcoming unit—

usually one to be taught within weeks of a TAB meeting—and these were reviewed by

the district supervisor to make a judgment as to whether they would be acceptable for

teachers to rate. Teachers rated tasks in a hybrid Google Site/Form that presented tasks to

be rated and rubrics for each as part of a paid "homework" (as it came to be known and

discussed) between TAB meetings. During TAB meetings, after seeing the distribution

for each dimension for a particular task from their colleagues, the researchers facilitated a

discussion of the ratings, offering their own perspectives occasionally on the ratings they

would assign to a particular task.

During this first year of the project, several things shifted both between and during

TAB meetings, which often became focal points for discussion. For one, the language of

the rubric dimensions was revised on multiple occasions, both in light of feedback from

district leaders and teachers and on the basis of observed patterns of difficulties teachers had "calibrating" their ratings. Second, during leadership tier meetings, researchers and district staff adjusted the amount of work they expected teachers to do, on the basis of how much rating was completed during meetings. This process involved a lot of guesswork and tweaking also of the composition and location of specific TAB meetings. To accommodate the fact that teachers came from across the district, the team met mostly online, in a teleconference format, for most of its spring meetings, which took place every three weeks. And, to lessen the time commitment, TAB members met for alternate TAB meetings. Each meeting had between two and four teachers typically, rather than the full ten.

Throughout meetings of the leadership tier and TAB, several representations became focal that were external to the partnership and presented challenges to the team. For example, the district had not yet updated its guidance documents to teachers about the sequence for algebra to reflect Common Core Standards when planning for the TAB began. This presented significant challenges for alignment, as well as extended deliberations about what topics should be the focus of researchers' task identification activities. In addition, throughout the year, the team struggled with ambiguities in the definitions of the Standards for Mathematical Practice in the Common Core. Though important to both district leaders and researchers as a dimension of tasks to rate, teachers struggled to come to as high levels of agreement on their ratings as for other rubric dimensions. In meetings of the leadership tier, researchers and district leaders both referenced efforts to bring in additional conceptual tools to help them wrestle with the Standards for Mathematical Practice.

By the conclusion of the spring of the first year, then, a defensible *claim* about their joint work was that it was about *task identification and rating,* work that was organized across multiple arenas of participation, with different configurations of actors, and around two loosely coupled technological infrastructures—a task rating web site and a password-protected platform for sharing curriculum resources. At the same time, the initial boundaries of the partnership had shifted around a smaller group of leaders from partner organizations but a new group of teachers. In addition, the team's attempts to orient to larger systems and resources for Common Core created tensions within the leadership tier and difficulties in helping teachers develop an understanding of the new standards.

Participants' Hoped for Outcomes

For different participants in the project, both tasks and task ratings took on different significance. By and large, the hoped-for outcomes varied by role group, with teachers, district leaders, university researchers, and the research non-profit representatives comprising three distinct role groups. Sometimes these hoped-for outcomes came into conflict with one another, especially toward the end of the first year, as the group began to develop plans for the second year.

As Johnson and colleagues (Johnson, Severance, Leary, & Miller, 2014) elaborate in their analysis of the first year of the project, the value of mathematical *tasks* was different for different role groups. For teachers in the TAB, the value of tasks was that they helped fill specific gaps in curriculum created by shifts in content for the Common Core. The team rated a number of tasks related to statistics and probability, tasks that would have been difficult to find in the district-adopted textbook. For district leaders, tasks presented *models* for what demanding, student-centered teaching should look like that were

Common-Core aligned. In other words, they were in an important sense educative and served the goal of building the capacity of teachers in the district to meet the demands of Common Core. As one district leader put it, "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." For researchers charged with finding tasks, a good outcome was finding tasks that would likely rate high on different dimensions of the rubric, so that they could meet district leaders' expectations. And for the program manager for the Curriculum Customization Service, a high-quality task represents a key resource within a digital infrastructure that fits within an ontology tied to the district's own "infrastructure" of curriculum documents (e.g., learning goals, pacing guides, sections of the district-adopted textbook). To the extent that there is an abundance of such tasks within the infrastructure, that infrastructure is likely to be seen as a valuable resource to teachers.

The value of *task rating* was much less clear for teachers than for district leaders and researchers on the team. Where district leaders expressed multiple benefits of task rating for teacher and coach professional development, and researchers concurred with this value, they were not oriented toward outcomes related to task rating. For teachers, the value of the task as a resource for instruction was primary, at least in the first year of the project. Though teachers were willing to rate and discuss tasks, and task discussion included extended deliberation about how to rate tasks, the leadership tier's repeated adjustments of "homework" assignment reflected the fact that work agreed to in TAB meetings was not consistently completed. The team interpreted this as a kind of resistance to this aspect of the work, but it may have been a misreading of teachers' needs. A survey conducted of TAB members revealed that to them, what they most needed to implement

Common Core were tasks. For example, one teacher said, "I need more performance-based tasks that include the scaffolding for students who are significantly below grade level and for English Language Learners." Another wrote, "Tasks that are rich, engaging, and meet the level of rigor expected in the new standards." Where teachers used the word "analysis" in surveys was in reference to an analysis of what was "missing from the textbook," not a detailed analysis of task rating.

Teachers also expressed a hope—and periodically sought during rating processes—for *task adaptation* to emerge as a focal activity within the project. Teachers frequently criticized tasks for issues related to accessibility of English learners and cognitive demand, often in their ratings discussion saying how they would modify the task if they were to implement it with their students. Though this occasionally surfaced in meetings of the leadership tier and was introduced at different times by both district leaders and researchers, it did not emerge as a focal activity within the first year of the project.

The differences encountered in the project echo past analyses that point to how differences in norms and forms of interaction create occasions for boundary encounters with sociocultural difference. But our own analyses suggest some different alliances, namely between researchers and district leaders in the partnership who orient toward runaway objects such as "capacity building," while teachers orient toward objects such as "filling in gaps in the curriculum I teach." The latter objects might to teachers seem both more tractable and immediate than researchers' and district leaders' goals, while researchers and curriculum leaders were quick in meetings to question whether teachers could fill in gaps without the insight they might gain from rating tasks.

The ambiguity of the object of "capacity building" and the available resources for making meaning of the Common Core, furthermore, occasioned significant moments of boundary crossing within the leadership tier. Multiple meetings were dedicated to collective sensemaking of TAB members' responses to activities in previous encounters, and an entire meeting was dedicated to mutual sharing of strategies other districts were attempting, strategies that one of the graduate students and the district supervisor learned about when attending the NCTM conference.

Re-bounding the Analysis: Shifting a Focus to Scaling

As often occurs within co-design projects, a new boundary emerged within the first year between insiders on the team and algebra teachers outside the team within the district. By April, teachers began to ask questions about what plans were for expanding access to the Inquiry Hub throughout the district. For researchers and the nonprofit program manager, the goal was clear: to make the Curriculum Customization Service accessible to all teachers in algebra. The technology infrastructure would include not only new district learning goals, pacing guides, and the existing adopted algebra textbook; it would also include the tasks and task ratings from the TAB. It would also include a new feature available to all teachers in the district, a "playlist" for bundling different resources together as part of instructional planning.

The playlist had not emerged as a focal problem space for co-design, however, nor had the Curriculum Customization Service been widely used by teachers in the TAB. Homework assignments to share resources there had not been completed, nor had teachers logged on very much during the year. Most of their activities to rate tasks had been supported by a kind of prototype infrastructure—a Google Form/Doc—that had

never been intended to serve as a long-term planning environment for teachers.

Unwittingly, perhaps, the research team had set up a disjuncture between teachers'

experience of the Inquiry Hub so far and where they wanted to take the project. As such,

teacher leaders in the TAB were not necessarily well positioned to serve as ambassadors

for the technology, so much as they might be advocates for specific tasks they found

valuable. Not surprisingly, when asked what direction the project should go in its second

year, the teachers advocated for finding more tasks.

Teachers also wanted to *develop* more tasks in the second year of the project. At an

end of year survey, they expressed a strong interest in moving beyond rating tasks that

the research team had identified for them. One teacher said, "I really just wanted to focus

on creating better tasks … I don't really care too much about the rubric." Another said

that what would benefit teachers the most would be to give "teachers resources that

would enable them to create their own tasks."

To the research team, the emerging problem space for district leaders was more

opaque at the end of the first year. On the one hand, they expressed in meetings accord

with the goal of encouraging use of the Curriculum Customization Service throughout the

district and use of the task rating process. But district leaders offered few concrete ideas

about venues where teachers could learn about the tool or experience the rating process.

The team had already begun to experiment with webinars open to any teacher, only to

have either no one or a small group of teachers attend. The district leaders introduced the

idea of organizing a professional development unit that would allow teachers to earn

credit by going through the task rating process, but this effort did not materialize. A small

window of opportunity was a New Educators' Institute, held for new teachers. Two of the

TAB members agreed to present the Curriculum Customization Service as a small "demo" within a large agenda. There were no district-wide professional development days to offer the team to support the process of scaling.

As a way forward, the team decided in fall of the second year to reconstitute the TAB—adding some new members, dropping some others—and focus the work around *building out the bank of rated tasks* within the Curriculum Customization Service. With few opportunities to "scale out," the team found a way forward in "scaling in," strengthening the potential longer-term value of the technology infrastructure as a resource for teachers in the future for finding tasks they can use that fill the gaps in their curriculum. Teachers in the TAB identified a set of chapters to prioritize where gaps were greatest. *Task rating* using the rubrics continued, but it was complemented with a new task intended to accommodate emerging goals for adaptation: *designing task implementation supports.*

The new focal problem spaces represent both new objects not anticipated initially within the project proposal and (limited) evidence of transformative agency within the project. The proposal had not envisioned a "scaling in" strategy as a necessary pre-condition for "scaling in," though the team began to imagine the possibility of this as well as the value of a richer bank of tasks for teachers to use in their classrooms as a way to strengthen their curriculum. The problematic object here became a source of new possibilities for the team (cf., Engeström, 2007). The new focus on designing task implementation supports expanded roles for teachers, and was a response to direct criticism, questioning, and efforts to redirect the work of the TAB toward more valued ends for teachers (cf., Sannino, 2010).

At the same time, in this second year of work—and after a year of shifting involvement in varied activities—the claim that what people are up to in co-design is *identifying and rating tasks* must be qualified in some important ways. For teachers, this activity is largely in the service of filling in gaps created by the Common Core grade-level content shifts, both for their own curriculum and that of other teachers in the district. For researchers, this task is in the service of "scaling in" or building a strong content base for future "scaling out" to the partner district and beyond. For program developers, the new problem space of *designing task implementation supports* provided an opportunity for a better integration of TAB activities with use of the Curriculum Customization Service, since the idea was to upload final versions of these supports and organize them using the "playlist" feature.

Analyzing the Activity System

As a final step in the analysis, we outline what we consider to be a set of working conjectures about the tools, rules, divisions of labor, and community stakeholders relevant to our emerging understanding of how different participant orient to the object, *identifying and rating tasks.* We emphasize these are working conjectures, intended to inform our ongoing design work in the project, across both the leadership tier and TAB tier of the partnership.

The most important *tools* from the standpoint of all the actors are the identified mathematical tasks themselves. Important qualities of those tools include the "latent" characteristics of tasks that are dimensions of the task rating rubric, as well as characteristics of importance to some but not all of the participants in the project. Some TAB participants, for example, have argued for the importance of considering "student

capabilities" when selecting tasks. Researchers, as noted above, suggested that cultural relevance and connecting to students' everyday experiences were important task qualities. Tasks have other qualities, too, that emerged as salient for all participants, namely the degree to which they "fill in" gaps in the existing curriculum.

The *rating process* links both a set of tools and rules that constitute the core of co-design. The rubric and task rating site are key tools used by all participants; over time, the language of the rubric has stabilized, but the task rating site has changed. There are now many more tasks that are embedded within it for rating, and there are more interactive features. One feature automatically emails a teacher's ratings back to them when they submit ratings, and another allows a teacher to facilitate their own rating process with colleagues. The rules for the rating process had stabilized by the end of the first year. Teachers are asked to apply rules for rating to task instructions as written, without consideration of their students' capabilities. Teachers rate independently, then discuss ratings with the distribution of the group's ratings projected before them. The discussions are not always predictable, nor are they facilitated consistently in practice, but justification of ratings is a kind of unwritten rule in all discussions.

The greatest shift of the project headed into its second year was with respect to the division of labor. At the outset of the project, roles for teachers in the process were more circumscribed, but beginning mid-spring, teachers began to lead discussions of the task rating process. And though the project has not—as part of its official joint work— allowed teachers to identify tasks for the group to rate, teachers have begun to take on a much more active role in shaping content through the development of implementation task supports.

The stakeholders in this activity system include not only participants in the project itself, but also the funder and policies to which participants in the work orient. These stakeholders outside the activity function as large constraints on the possibilities for action and the emergence of radically new objects. The Common Core prescribes certain subjects be taught at particular grade levels to all students, and new assessments will test the standards in ways that educators anticipate with varying degrees of fear and anxiety. Both drive the search for mathematical tasks, and they animate researchers' and district leaders' thinking about where to build teaching capacity through the project. Where signs of transformative agency are evident in the ways that teachers engaged with one another in challenging the value of particular tasks, providing input on rubrics, and suggesting directions for the project, this agency is circumscribed by this larger policy context. It is also circumscribed by competition among varied initiatives within the district for the time and attention of teachers and the absence of time set aside at the district level for professional development, which leadership team members saw as a necessary condition for scaling up as the initial proposal called for. The codesign team finds itself in a set of linked double binds: on the one hand, hoping to "bring to scale" the task identification and rating process to teachers throughout the district, but facing internal competition from other shared problem spaces articulated by other teams and actors outside the system.

Discussion and Conclusion

In this paper, we have presented an analysis of how the object emerges and transforms within a single project involving educational codesign. In the project, the object emerged within a constellation of settings, tools, and actors bound together by

mathematical tasks as objects and rules for rating tasks according to particular qualities judged to be valuable by researchers and district leaders. The object that emerged bound together participants with diverse hoped-for outcomes, though the shared problem space that the team created was filled with tension and created a new boundary between those inside the team and the actors in the district (other algebra teachers) they hoped their activities could reach.

Substantively, the analysis presented underscores the fact that all intervention research takes place within settings that are filled with tensions and contradiction, and it also creates new tensions. As Engeström (2011) writes,

> No terrain of activity, no matter how stable and resistant, is free of inner contradictions….When an activity system adopts a new element from the outside (e.g., a new technology or a new object), it often leads to an aggravated secondary contradiction where some old element (e.g., the rules or the division of labor) collides with the new one. (p. 609)

Interventions are contested spaces (Gutiérrez & Penuel, 2014), and co-design of the kind we have described here is not a single, planned-ahead-of-time process that makes research and development more efficient. Instead, the collaboration itself is subject to revision, disruptions, and contradictions (Gutiérrez & Vossoughi, 2010).

Methodologically, we have attempted here to show what an empirical analysis of codesign informed by Cultural-Historical Activity Theory can look like. No doubt, there are multiple versions of a CHAT-informed account we might have given—another that focuses more explicitly on microprocesses of boundary crossing or on transformative agency, for example. There are also multiple version of the story of our project that we

could tell. Ultimately, for us, the value of the account depends on its relevance to our ongoing design work. As a team, we seek insights that are too easily lost when we depend solely on intuition and individual sensemaking in guiding our work and move toward the next goal articulated in our research proposal. We do not yet know whether this analysis provides us with the kinds of conceptual tools or insights that we can use to support our team's ongoing work. Ultimately, we will judge our success against the principle of transformative agency: what new possibilities for action can we imagine together, having studied ourselves in the midst of a project?

Acknowledgments

References

Akkerman, S. F., & Bakker, A. (2011). Boundary crossing and boundary objects. *Review of Educational Research, 81*(2), 132-169.

Bang, M., Medin, D., Washinawatok, K., & Chapman, S. (2010). Innovations in culturally based science education through partnerships and community. In M. S. Khine & M. I. Saleh (Eds.), *New science of learning: Cognition, computers, and collaboration in education* (pp. 569-592). New York, NY: Springer.

Barab, S. A., Thomas, M. K., Dodge, T., Squire, K., & Newell, M. (2004). Critical design

    ethnography: Designing for change. *Anthropology and Education Quarterly,*

    35(2), 254-268.

Bickel, W. E., & Hattrup, R. A. (1995). Teachers and researchers in collaboration:

    Reflections on the process. *American Educational Research Journal, 32*(1), 35-

    62.

Blunden, A. (2009). An interdisciplinary concept of activity. *Outlines: Critical Practice*

    Studies, 11(1), 1-26.

Brookhart, S. M., & Loadman, W. E. (1992). School-university collaboration and

    perceived professional rewards. *Journal of Research in Education, 2*(1), 68-76.

Cobb, P. A., Confrey, J., diSessa, A. A., Lehrer, R., & Schauble, L. (2003). Design

    experiments in educational research. *Educational Researcher, 32*(1), 9-13.

Cobb, P. A., & Jackson, K. (2012). Analyzing educational policies: A learning design

    perspective. *Journal of the Learning Sciences, 21*, 487-521.

Coburn, C. E., Penuel, W. R., & Geil, K. (2013). Research-practice partnerships at the

    district level: A new strategy for leveraging research for educational

    improvement. Berkeley, CA and Boulder, CO: University of California and

    University of Colorado.

Cole, M., & Engeström, Y. (2006). Cultural-historical approaches to designing for

    development. In J. Valsiner & A. Rosa (Eds.), *The Cambridge handbook on*

    sociocultural psychology (pp. 484-507). New York: Cambridge University Press.

Confrey, J., & Lachance, A. (2000). Transformative teaching experiments through

    conjecture-driven research design. In A. E. Kelly & R. A. Lesh (Eds.), *Handbook*

of research design in mathematics and science education (pp. 231-266). Mahwah, NJ: Erlbaum.

D'Amico, L. (2010). The Center for Learning Technologies in Urban Schools: Evolving relationships in design-based research. In C. E. Coburn & M. K. Stein (Eds.), *Research and practice in education: Building alliances, bridging the divide* (pp. 37-53). Lanham, MD: Rowan & Littlefield.

Design-Based Research Collective. (2003). Design-based research: An emerging paradigm for educational inquiry. *Educational Researcher, 32*(1), 5-8.

DiGiano, C., Yarnall, L., Patton, C., Roschelle, J., Tatar, D., & Manley, M. (2003). Conceptual tools for planning for the wireless classroom. *Journal of Computer Assisted Learning, 19*(3), 284-297.

Dolle, J. R., Gomez, L. M., Russell, J. L., & Bryk, A. S. (in press). More than a network: Building professional communities for educational improvement. In B. J. Fishman, W. R. Penuel, A.-R. Allen & B. H. Cheng (Eds.), *Design-based implementation research: Theories, methods, and exemplars. National Society for the Study of Education Yearbook.* New York, NY: Teachers College Record.

Dolonen, J. A., & Ludvigsen, S. (2013). Analysing design suggestions and use of resources in co-design of educational software: A case study. *CoDesign, 9*(4), 247-265.

Downing-Wilson, D., Lecusay, R., & Cole, M. (2011). Design experimentation and mutual appropriation: Two strategies for university/collaborative after-school interventions. *Theory & Psychology, 21*(5), 656-680.

Ehn, P. (1992). Scandinavian design: On participation and skill. In P. S. Adler & T. A. Winograd (Eds.), *Usability: Turning technologies into tools* (pp. 96-132). New York: Oxford University Press.

Engeström, Y. (2001). Expansive learning at work: Toward an activity theoretical reconceptualization. *Journal of Education and Work, 14*(1), 133-156.

Engeström, Y. (2005). *Developmental work research: Expanding activity theory in practice*. Berlin, Germany: Lehmanns Media.

Engeström, Y. (2007). From stabilization knowledge to possibility knowledge in organizational learning. *Management Learning, 38*, 271-275.

Engeström, Y. (2008). *From teams to knots: Activity-theoretical studies of collaboration and learning at work*. Cambridge, UK: Cambridge University Press.

Engeström, Y. (2011). From design experiments to formative interventions. *Theory & Psychology, 21*(5), 598-628.

Engeström, Y., Engeström, R., & Karkkainen, M. (1995). Polycontextuality and boundary crossing in expert cognition: Learning and problem solving in complex work activities. *Learning and Instruction, 5*(4), 319-336.

Engeström, Y., Engeström, R., & Kerosuo, H. (2003). The discursive construction of collaborative care. *Applied Linguistics, 24*(3), 286-315.

Engeström, Y., & Sannino, A. (2010). Studies of expansive learning: Foundations, findings and future challenges. *Educational Research Review, 5*, 1-24.

Engeström, Y., Sannino, A., & Virkkunen, J. (2014). On the methodological demands of formative interventions. *Mind, Culture, and Activity, 21*(2), 118-128.

Gifford, B. R. (1986). The evolution of the school-university partnership for educational renewal. *Education and Urban Society, 19*(1), 77-106.

Greenbaum, J., & Loi, D. (2012). Participation, the camel and the elephant of design: an introduction. *CoDesign, 8*(2-3), 81-85.

Guile, D. (2011). Learning at the boundary: A commentary. *International Journal of Educational Research, 50*(1), 55-61.

Guile, D. (2012). Interprofessional learning: Reasons, judgment, and action. *Mind, Culture, and Activity, 18*, 342-364.

Gutiérrez, K. D., Baquedano-Lopez, P., & Tejada, C. (2000). Rethinking diversity: Hybridity and hybrid language practices in the third space. *Mind, Culture, and Activity, 6*(4), 286-303.

Gutiérrez, K. D., & Penuel, W. R. (2014). Relevance to practice as a criterion for rigor. *Educational Researcher, 43*(1), 19-23.

Gutiérrez, K. D., & Vossoughi, S. (2010). Lifting off the ground to return anew: Mediated praxis, transformative learning, and social design experiments. *Journal of Teacher Education, 61*(1-2), 100-117.

Haapasaari, A., Engeström, Y., & Kerosuo, H. (2014). The emergence of learners' transformative agency in a Change Laboratory intervention. *Journal of Education and Work*.

Hargadon, A., & Sutton, R. I. (1997). Technology brokering and innovation in a product development firm. *Administrative Science Quarterly, 42*(4), 716-749.

Heikkila, H., & Seppänen, L. (2014). Examining developmental dialogue: the emergence of transformative agency. *Outlines. Critical Practice Studies, 15*(2), 05-30.

Henningsen, M. A., & Stein, M. K. (1997). Mathematical tasks and student cognition: Classroom-based factors that support and inhibit high-level mathematical thinking and reasoning. *Journal for Research in Mathematics Education, 28*, 524-549.

Johnson, R., Severance, S., Leary, H., & Miller, S. (2014). *Mathematical tasks as boundary objects in design-based implementation research.* Paper presented at the 11th International Conference of the Learning Sciences, Boulder, CO.

Kaptelinin, V. (2005). The object of activity: Making sense of the sense-maker. *Mind, Culture, and Activity, 12*(1), 4-18.

Keating, P. J., & Clark, R. W. (1988). Accent on leadership: The Puget Sound Educational Consortium. In K. A. Sirotnik & J. I. Goodlad (Eds.), *School-university partnerships in action: Concepts, cases and concerns* (pp. 148-166). New York: Teachers College Press.

Kensing, F., & Greenbaum, J. (2013). Heritage: Having a say. In J. Simonsen & T. Robertson (Eds.), *Routledge International Handbook of Participatory Design*. London, UK: Routledge.

Kerosuo, H. (2001). Boundary encounters as place for learning and development at work. *Outlines: Critical Social Studies, 6*(1), 53-65.

Kerosuo, H. (2004). Examining boundaries in health care: Outline of a method for studying organizational boundaries in interaction. *Outlines: Critical Practice Studies, 6*(1), 35-60.

Lui, M., & Slotta, J. D. (2013). Immersive simulations for smart classrooms: exploring evolutionary concepts in secondary science. *Technology, Pedagogy and Education*(ahead-of-print), 1-24.

Lundh, P., Cheng, B., Penuel, W. R., Joshi, A., & Lesk, H. (2010, June). *Design personas for teachable agents: A qualitative tool for informing learning designs.* Paper presented at the 9th International Conference of the Learning Sciences, Chicago, IL.

Midler, C. (1995). Projectification of the firm: The Renault Case. *Scandinavian Management Journal, 11*(4), 363-375.

Morozov, A., Herrenkohl, L., Shutt, K., Thummaphan, P., Vye, N., Abbott, R. D., & Scalone, G. (in press). Emotional engagement in agentive science environments. In J. L. Polman, E. Kyza, K. O'Neill & I. Tabak (Eds.), *Proceedings of the 11th International Conference of the Learning Sciences*. Boulder, CO: International Society of the Learning Sciences.

O'Neill, D. K. (2012). Designs that fly: What the history of aeronautics tells us about the future of design-based research in education. *International Journal of Research & Method in Education, 35*(2), 119-140.

Ormel, B. J. B., Roblin, N. N. P., McKenney, S. E., Voogt, J. M., & Pieters, J. M. (2012). Research-practice interactions as reported in recent design studies: Still promising, still hazy. *Educational Technology Research and Development, 60*(6), 967-986.

Penuel, W. R., Coburn, C. E., & Gallagher, D. (2013). Negotiating problems of practice in research-practice partnerships focused on design. In B. J. Fishman, W. R. Penuel, A.-R. Allen & B. H. Cheng (Eds.), *Design-based implementation research: Theories, methods, and exemplars. National Society for the Study of Education Yearbook.* (pp. 237-255). New York, NY: Teachers College Record.

Penuel, W. R., Roschelle, J., & Shechtman, N. (2007). The WHIRL co-design process: Participant experiences. *Research and Practice in Technology Enhanced Learning, 2*(1), 51-74.

Penuel, W. R., Tatar, D., & Roschelle, J. (2004). The role of research on contexts of teaching practice in informing the design of handheld learning technologies. *Journal of Educational Computing Research, 30*(4), 331-348.

Reiser, B. J., Spillane, J. P., Steinmuler, F., Sorsa, D., Carney, K., & Kyza, E. (2000). Investigating the mutual adaptation process in teachers' design of technology-infused curricula. In B. Fishman & S. O'Connor-Divelbiss (Eds.), *Fourth International Conference of the Learning Sciences.* (pp. 342-349). Mahwah, NJ: Erlbaum.

Roschelle, J., Penuel, W. R., Yarnall, L., & Shechtman, N. (2005). Handheld tools that "informate" assessment of student learning in science: A requirements analysis. *Journal of Computer Assisted Learning, 21*(3), 190-203.

Sannino, A. (2010). Teachers' talk of experiencing: Conflict, resistance and agency. *Teaching and Teacher Education, 26*, 838-844.

Schlecty, P. C., & Whitford, B. L. (1988). Shared problems and shared vision: Organic collaboration. In K. A. Sirotnik & J. I. Goodlad (Eds.), *School-university partnerships in action: Concepts, cases and concerns*. New York: Teachers College Press.

Schwartzmann, H. (1989). *The meeting: Gatherings in organizations and communities*. New York, NY: Plenum.

Spinuzzi, C. (2011). Losing by expanding: Corralling the runaway object. *Journal of Business and Technical Communication, 25*(4), 449-486.

Sprain, L., & Boromisza-Habashi, D. (2012). Meetings: A cultural perspective. *Journal of Multicultural Discourses, 7*(2), 179-189.

Star, S. L., & Griesemer, J. R. (1989). Institutional ecology, "translations" and boundary objects: Amateurs and professionals in Berkeley's Museum of Vertebrate Zoology, 1907-1939. *Social Studies of Science, 19*(3), 387-420.

Suchman, L. A. (1994). Working relations of technology production and use. *Computer Supported Cooperative Work, 2*(1), 21-39.

Wenger, E. (1998). *Communities of practice: Learning, meanings, and identity*. New York: Cambridge University Press.

Wenger, E. (2000). Communities of practice and social learning systems. *Organization, 7*(2), 225-246.

Wertsch, J. V. (2007). Mediation. In H. Daniels, M. Cole & J. V. Wertsch (Eds.), *The Cambridge Companion to Vygotsky* (pp. 178-192). New York, NY: Cambridge University Press.