Researchers and Practitioners Co-Designing for Expansive Science Learning and Educational Equity

Philip Bell
pbell@uw.edu
University of Washington

Samuel Severance, William R. Penuel, Tamara Sumner, Wagma Mommandi, David Quigley, Katie Van Horne, and Raymond Johnson
samuel.severance@colorado.edu, william.penuel@colorado.edu,
tamara.sumner@colorado.edu,wagma.mommandi@colorado.edu, david.quigley@colorado.edu,
katie.vanhorne@colorado.edu, raymond.johnson@colorado.edu
University of Colorado, Boulder

Shelley Stromholt, Heena Lakhani, Katie Davis, Adam Bell, and Megan Bang
stromhos@uw.edu, hlakhani@uw.edu, kdavis78@uw.edu, abell42@uw.edu, mbang3@uw.edu
University of Washington

Abstract: This symposium addresses the design and enactment of learning environments in support of the new vision for K-12 science education (NRC, 2012) and the related collaborative co-design practices of research-practice partnerships (Coburn, Penuel & Geil, 2013) as we focus on how to promote and understand cognitively and culturally expansive learning experiences for youth from culturally and linguistically diverse communities. Each study in our symposium is focused on "developing and testing innovations that can improve the quality and equity of supports for implementation of reforms" in real-world contexts (Penuel & Fishman, 2012, p. 282). The research projects in this symposium document practices and findings of various research practice partnerships that allow participants to work together to imagine and bring about new possibilities for educational improvement that reflect new goals and arrangements for learning. Our aim is to explore responsive co-design methods for collaborative design teams of researchers, teachers, and teacher leaders accountable for transforming student learning.

Introduction

This symposium brings together threads of research related to the design and enactment of learning environments in support of the new vision for K-12 science education (NRC, 2012) and the collaborative co-design practices of research-practice partnerships (Coburn, Penuel & Geil, 2013) as we focus on how to promote and understand cognitively and culturally expansive learning experiences for youth from culturally and linguistically diverse communities. We approach this work from an ecological perspective on how people learn within and across social settings as a strategy related to promoting educational equity and social justice (Bell, 2012).

In ideal terms, educational standards can be viewed as an equity-focused policy strategy for changing the educational system to ensure that all students have access to a baseline level of rigorous academic learning goals related to educational achievement. In pragmatic terms, standards-based implementation leads quickly to complicated problems of educational practice that need to be better understood and attended to. At of the time of this writing, the Next Generation Science Standards (NGSS) have been adopted by 17 states and the District of Columbia—with almost 35% of U.S. youth living in states working to support this new vision for K-12 science education. The new vision includes strategies and perspectives associated with cultivating culturally expansive learning opportunities for youth. There is a significant opportunity associated with working to promote those ideas at broader scale. Our work supports human capacity-building and educational tool development in STEM content areas and supports teachers within disciplinary-specific communities of practice, enabling equitable implementation of the NGSS, as envisioned in the NRC *Framework for K-12 Science Education* (NRC, 2012).

The learning sciences have long embraced collaborative design as a feature of design research (Brown, 1992; Cobb, Confrey, diSessa, Lehrer, & Schauble, 2003; Voogt et al., 2015). Many of the NGSS implementation projects to be reported on are engaged in design-based implementation research (DBIR) with deep attention to systemic scaling and sustainability (Penuel et al., 2011), while others are engaged in traditional design-based research (DBR) to explore possibilities in specific settings (Bell, 2004). Collaborative design within research-practice partnerships presents both expanded possibilities and new challenges. Research-practice partnerships are long-term collaborations between practitioners and researchers that are organized to investigate problems of

practice and solutions for improving the outcomes of educational systems (Coburn, Penuel, & Geil, 2013). They have the potential for broader impacts, because designs aim to impact practice in larger systems and networks (Cobb, Jackson, Smith, Sorum, & Henrick, 2013). In addition, they have potential to develop important "context theories" related to learning (Cobb et al., 2003), focused specifically on the conditions for broad and equitable implementation of innovations. In addition, they require organizing partnerships to address concerns across multiple levels of systems and settings where differences of power and inequity deserve attention (Bang, Medin, Washinawatok, & Chapman, 2010). Our aim is to explore responsive co-design methods for collaborative design teams of researchers, teachers, and teacher leaders accountable for transforming student learning experiences.

Scholarly significance of the symposium

Co-design with teachers is intended to support cycles of expansive learning that transform the collective agency of teachers (Voogt et al., 2015). Working from an educational equity perspective, Guitiérrez and Vossoughi (2010) recently outlined an important new model of design-based research focused on exploring what is possible in learning environments using a grammar of hope, possibility, and resilience. In expansive learning, participants learn collectively by creating something that does not yet exist (Engeström & Sannino, 2010). Participants imagine and bring about new possibilities for action that reflect new goals and arrangements for learning. When they are able to "break away" from the give frame of action and take initiative to change it, their collective agency becomes transformative (Virkkunen, 2006, p. 49). To this end, we will take up social justice perspectives as we explore the co-design efforts of researchers and practitioners working to implement these NGSS-related projects.

Co-designing with teachers for student agency in science

Samuel Severance, William R. Penuel, Tamara Sumner, Wagma Mommandi, David Quigley, Katie Van Horne and Raymond Johnson

Curriculum materials that expand student agency can positively influence student affect, interests, and learning. Past research has found that units foregrounding student agency yield more positive affective responses from students (Morozov et al., 2014). In the context of long-term partnerships among researchers, educational leaders, and teachers, engaging teachers in the co-design of curriculum materials aims to transform the historical relationships of authority for curriculum while expanding student agency and learning opportunities (Penuel, 2014). When teachers co-design with researchers, however, student voices may be left out, and the team can miss opportunities to expand student agency in the design and implementation process. We elaborate on three strategies for soliciting student input into curriculum design and foregrounding student agency during co-design processes.

Teacher and student sample

Study data comes from 783 students of 13 teachers from 8 schools in a large urban school district in the Midwestern United States. Data were collected during the co-design of curriculum for high school biology. In this curriculum, 8-week project-based units are organized around a design challenge. These units are intended to embody the principles of the Framework (NRC, 2012) and address the performance expectations of the NGSS.

Strategies tested for promoting student agency in design and implementation

We employed three strategies to expand student agency within co-design processes and implementation: (1) linking the unit to larger community initiatives; (2) eliciting student interests in exploring different phenomena; and (3) using data on student perspectives on the design challenge and their classroom experiences.

Linking design challenges to larger community initiatives

We sought to enhance the likelihood that students would experience science as contributing to community by linking design challenges that anchored units to larger community initiatives. For the ecosystems unit, the challenge was to select and plant a tree that contributed to the biodiversity of the tree canopy and the life it supports in the city. This effort was linked to the city's tree planting initiative, which provided the recommended trees for the students to plant in collaboration with park department personnel. We assessed student interests and engagement with this design challenge using weekly mini-surveys administered throughout the 8-week unit implementation. For the majority of days in this unit, 65% of days (n = 1,225), students reported that the class' lesson was "relevant to their community," while 29% said the lesson was personally relevant to them.

Eliciting student ideas about phenomena

Project-based science units that embody the vision of the *Framework* need to be anchored in explaining phenomena in the natural world (Krajcik, Codere, Dahsah, Bayer, & Mun, 2014). Not all phenomena are likely to capture and sustain students' interest, however. We designed a survey that asked current ninth grade students to rate their interest in 10 potential phenomena to investigate in the unit; they could also suggest alternative phenomenon. Teams chose to develop the design challenge around students' first choice and to develop supporting strands in the unit around students' other top interests. Initial surveys suggest that students perceive the selected topics as meaningful and relevant: in responses from two classes piloting this unit (n=110), 72% of students report that the class' lesson was "relevant to their community," while 36% said the lesson was personally relevant.

Using data of student perspectives
We gather evidence on a weekly basis on students' experiences of the challenge. This "practical measure" (Yeager et al., 2013) provides information to inform our iterative process of improving the intra-unit coherence of lessons. But the data we collect do more than hold us to account for coherence; they also include items about students' affective response to the unit, their judgment about whether what they learned that day was useful, and the personal relevance for lessons. Evidence shows we can still improve excitement and the perceived utility value of lessons, as 65% said what they learned on a given day was useful.

Implications
Student voice is challenging to integrate into collaborative design with teachers, but a concern with expanding student agency demands that we discover ways to incorporate student ideas into curriculum. We do so by connecting design challenges to community endeavors, eliciting student ideas about projects, and collecting data on student experiences of units that inform the design. These different strategies revealed a pattern of variation in student responses to curriculum but enabled the design team to strengthen efforts to expand student agency.

Co-designing a digital badge system: Supporting learners' science identities through participatory design

Katie Davis and Adam Bell

This study employed participatory design (PD) to develop a digital badge system that recognizes the skills and achievements of a diverse group of high school students who participate in an out-of-school science education program. Documentation of the design sessions illustrates the benefits of engaging students, program supervisors, and researchers in co-design activities aimed at articulating the learning pathways available to students in the program. By providing students with opportunities to reflect on their learning experiences, these co-design activities supported their developing science identities. This work offers best practices for directly engaging learners and supervisors in the design of a technology-based learning management system.

Conceptual framework and project design
This study is grounded in situated theories of learning, which emphasize the social, contextualized nature of learning. According to this perspective, learning is an inherently relational process that takes place as people negotiate meaning in specific social contexts (Lave & Wenger, 1991). Evidence of one's learning is similarly negotiated among actors who are embedded in distinct social systems, each with its own set of norms, values, artifacts, and practices. When new artifacts are introduced into a social system, there is an opportunity to call attention to existing practices and possibly alter them.

In the current study, students, program supervisors and researchers worked together to design a specific type of new artifact—digital badges—to recognize the learning that takes place in an out-of-school science education program. We employed a sociotechnological participatory design (PD) approach (Pazmino et al., 2015) that leveraged the expertise of the program supervisors and the researchers in order to focus student ideation for creating a digital badge system. Each design session incorporated one or more PD techniques informed by existing practice (e.g., rapport building, mixing ideas, stickies, layered elaboration) (Druin, 2002).

All PD sessions were recorded using a digital video camera and microphone. During the design sessions, researchers collected field notes that were later used for analysis (Merriam, 2009). Each session yielded design artifacts (photographed in situ). The analysis of the design sessions was completed in four phases: (1) after each design session, a researcher produced a narrative summary using a grounded theory approach (Merriam, 2009); (2) the researchers reviewed the summaries to identify critical events that occurred during each session (Derry, et al., 2010); (3) the researchers independently reviewed the video data corresponding to the critical events (Landis & Koch, 1977); and (4) the researchers viewed the critical events together for discussion and analysis (Bell, 2004).

Findings

By employing PD to create a digital badge system, students: *(1) articulated science knowledge* by displaying an understanding of science-related phenomena; *(2) constructed learning pathways* by mapping the structure of science domains; *(3) analyzed work practices* by stabilizing expectations for workplace success; and *(4) developed science identities* by embodying the epistemological orientation of science experts.

Implications of developing digital badges to promote STEM identities

This research offers evidence of successful sociotechnological participatory design with students as a method for designing a digital badge system and encouraging student reflection on their learning experiences. We show how PD techniques can be used to support the values and goals of an out-of-school, science-based learning environment. This project identifies the unique benefits of a digital badge system as a mode for wide-ranging

The co-design of professional learning experiences for teachers through a research-practice partnership

Philip Bell

In this design-based implementation research (DBIR) project (Penuel, et al., 2011), researchers partnered with staff from two urban school districts to support implementation of the vision of the NGSS and the underlying Framework (NRC, 2012). The partnership is focused on supporting approximately 100 teachers per year from these districts as they adapt, test, and refine existing instructional materials. I propose a model of design-focused research-practice partnerships (RPPs) called *lines of partnering*—and present an analysis of the co-design practices of researchers and practitioners conceptualizing, designing, delivering, analyzing, and refining professional learning experiences for this network of teachers.

Conceptual framework and study design

The partnership is engaging teachers in the adaptation of existing curriculum materials as the strategy for supporting teacher learning aspects of the new vision. This paper focuses on the co-design work of professional learning experiences for the teachers. We use the 'theory of persons' perspective to interpret human behavior as happening within a nexus of impinging structures of sociomaterial practice across places and over time (Dreier, 2009; Bell, et al., 2012). Partnering across practice communities is conceptualized as laying down and bringing *lines of action* into correspondence through the enactment of various sympathies (Ingold, 2015)—which are identified through empathetic investigations. In Design-RPPs, people interweave lines of activity related to the shared endeavor in the context of prevailing and generated forces from the nexus of social practices at play.

Six researchers partnered with six district staff and two staff from a science industry non-profit to engage in this work. Over three years the partnership has worked with 200 teachers from these urban districts to negotiate problems of practice associated with implementing the NGSS through curriculum adaptation. Ethnographic fieldnotes, audiorecordings, artifacts, and surveys were analyzed across multiple levels of the partnership (management, program design, program implementation, classroom).

Findings

I conceptualize such efforts as engaging in four different dimensions of necessary work—two of which are most relevant to this analysis. The shared work associated with *lines of purpose* involves inquiring into and articulating overlapping and synergistic goals for the collaborative work from multiple perspectives in ongoing ways. *Lines of collaboration and cooperation* involves taking programmatic action within such shared endeavors, together and apart, as practice-focused groups (e.g., to engage in co-design). Cross-cutting dimensions involve: *mutualism* by identifying sympathies in the work through empathetic stances, *pragmatism* by working within systems to transform them, *equity* by focusing on the learning of learners from non-dominant communities and by positioning teachers as developing experts, and orienting to *historicity* in the practices, values, and priorities involved.

Based on an analysis of the co-design work focused on the professional learning experiences of teachers, a range of findings have resulted at different levels of the partnership. *First*, political considerations of the work sometimes need to trump epistemological goals. Districts need scarce professional development projects to be successful. Setting pedagogical learning goals too high can result in teachers opting out and threatening the success of the effort. *Second*, teacher agency and leadership in the work is promoted by positioning teachers as developing experts doing meaningful work in educational improvement projects. Teachers report how curriculum adaptation allowed them to engage in meaningful work and leverage and expand their expertise in ways that served their immediate instructional goals and the goals of the broader educational organization. *Third*, co-design work within

the partnership led to emergent problems of educational practice that require unanticipated research-related expertise that the research team needs to develop and leverage from their professional network—in addition to the existing expertise they hold. *Fourth*, sustained partnerships between researchers and practitioners—with growing levels of mutual trust—allow for an increased exploration of values and ethics that relate to the shared co-design work from an equity perspective (Bang et al., 2015). A growing interest in promoting culturally and linguistically diverse students participation in epistemic practices resulted in co-design work foregrounding pedagogical discourse strategies for linguistically minoritized students as a leading project-level activity.

Implications

Our field has often operated through research-practice partnerships, but we have not adequately theorized and studied how they operate and influence educational improvement. Design focused research-practice partnerships represent a promising approach for building equity-centered human capacity and developing theory about professional learning as large-scale implementation unfolds within complex educational systems. The proposed model for partnerships as it relates to the co-design work of partnerships allows us to understand and cultivate more work of this kind centered on improving promoting equity in education.

The development of practical measures for teachers to inform the co-design of educational improvement efforts

Shelley Stromholt, Heena Lakhani, and Philip Bell

Through an ongoing partnership of educational researchers, practitioners, and STEM professionals, our work is focused on collaboratively adapting curriculum and developing relevant strategies and tools to support both teachers' and students' learning of STEM through engagement in disciplinary practices. We take a responsive approach to practitioners' curricular and collaborative goals and learning needs using design-based implementation research methodology (Penuel, Fishman, Cheng, & Sabelli, 2011). In this context we explore how practical measures can "act as sensing mechanisms at the level at which work is carried out," producing rich opportunities for identifying improvement targets and continuous learning (Russell & Grunow, 2015).

This study examines an approach for the co-design and implementation of practical measures, those that can be "collected, analyzed, and used within the daily work lives of practitioners" (Russell & Grunow, 2015) relative to a theory of implementation for a shared vision of K-12 science education and inclusive participation structures (NRC, 2012). This paper presents a case study of an effort to develop emic accounts of the productive approaches, problems of practice, and resulting design implications for professional development as teachers shifted their teaching toward practice-focused instruction through curriculum adaptation in response to the NGSS.

Conceptual framework and study design

In the context of improvement research, Bryk et al. (2015) distinguish *measurement for improvement* from other forms of educational measurement traditionally focused on accountability or theory development. Measurement for improvement entails the frequent measuring of high leverage work processes in order to inform change efforts in everyday practice. We leveraged an experience sampling approach, in which participants respond to a short survey about their immediate activities *in the moment,* frequently over several days or weeks (Zirkel, Garcia, & Murphy, 2015). This approach allows access to settings and experiences otherwise inaccessible to researchers and generates frequent and timely data that can be triangulated with other data sources related to the processes targeted for improvement. Through iterative co-design we developed a "mini-survey" for teacher reflection on classroom instruction and student engagement in disciplinary practices as instruction unfolded over the school year. As part of our research practice partnership, we then use the results to convey outcomes to our partners which informed subsequent interventions through professional development.

Sources of data

Teachers were surveyed weekly for 12 weeks over the 2015-2016 school year. We conducted a thematic analysis of the teacher responses using open coding to identify productive approaches and problems of practice teachers encountered at various stages of implementation across the school year. These results were compared with fieldnotes and other data collected as part of the larger research project to develop claims and design implications for effective professional development related to equity-focused, practice-focused instruction (Erickson, 1986).

Implications

A growing focus in educational research on learning in and through practice necessitates a focus on measurement for improvement, but there are few accounts of how research practice partnerships have engaged in development and implementation of practical measures and the resulting improvements. This case study offers insights into practical measures as an approach for blending rapid, disciplined cycles of inquiry with traditional research activities to inform our understanding of educational improvement.

Axiological innovations in an ArtScience participatory design experiment
Megan Bang

As we continue to try to understand the complexity of learning and development in the evolving "thrown-togetherness" of life (Massey, 2005) - which she describes as politics of the event of place including the politics of difference, identity, affect, connectedness and relations -- creating interventions that contribute to just and sustainable change demands engagement across disciplinary fields both within and across the social and physical sciences to develop new designs, narratives, and possibilities of encounter and making relations (Aitken, 2010). This paper examines the ways in which designers engage in epistemic navigation in the context of an ArtScience project called Expansive Meanings and Makings in ArtScience (EMMAS). EMMAS is a participatory design research project investigating the untapped potential of an ArtScience approach to learning and teaching. EMMAS aimed to foster creative trajectories into meaningful STEM learning for Native American youth. The project engaged community members, artists, scientists, and learning scientists to develop learning environments for youth and their families that engage investigate complex ecological change, interpret artistic and scientific visualizations, and respond creatively to questions by integrating scientific and artistic concerns, materials and processes. An artscience repertoire (cultivating attention, making, critique, and exhibition) underlies the learning experience.

Conceptual framework and study design
Building on Lave & Wenger (1991), EMMAS frames learning as a social phenomenon constituted in the experienced, lived-in world, through participation in the ongoing practices of social communities. As a creative movement, artscience highlights commonalities in thinking and making practices across social communities (Brown et al., 2011; Heath, 1986). Artscience emphasizes coming to know phenomena deeply—a process of making and re-making relations with phenomena, tools, materials, histories, and people (Ingold, 2013).

Using participatory design methods, specifically community based design (Bang et al., 2010) narrative, cognitive, and discourse analytic methods, I study the conceptual ecologies, identity narratives, and artscience repertoires that youth and designers develop through their participation in EMMAS inquiries. Data sources include 12 hours of video and transcriptions of program implementation and especially group conversations about juxtaposed artistic and scientific visualizations focus on students engaged in making artistic responses, interviews with 15 students, and 15 design meetings. All of the data were transcribed. The design of these programs intended to cultivate attention across multiple epistemologies, scales, modalities, and perspectives, using protocols that facilitated sustained engagement across multiple interpretive pathways, openness to emergent and uncertain meanings, and knowing as movement (Ingold, 2013) particularly as they related to complex ecological systems and students' cultural ecologies. Further community members were very interested in supporting students' sense of identity and community throughout the programming. Transcripts were initially open coded to identify emergent themes (Creswell, 2007). Drawing from this initial thematic analysis, moments of navigation were identified and further coded using critical discourse analysis (Gee, 2011). As part of this analysis I analyze the ways in which epistemic navigation and ways of knowing are constructed. I focus on how these constructions are both around disciplinary boundaries and expansions as well as around western and indigenous ways of knowing.

Findings
The findings of this study expand recent work on axiological innovations in learning environments (Bang et al., 2015). I argue axiologies are reflected in the theories, practices, and structures of values, ethics, and aesthetics that shape current and possible meaning, meaning making, positioning and relations in cultural ecologies. In this paper I work to uncover the ways in which axiological normativity is inscribed in moments when settled and often incomplete notions of disciplines are employed in design decisions and in implementation. I juxtapose these moments with interactions that "desettled" expectations and resulted in the disruption of axiological normativity and produce what I call axiological innovations. I specifically examine how these interactions reflect an artscience pedagogy and epistemic navigation across cultural ecologies. I track how students interviews reflect more nuanced and sophisticated understandings of complex ecological systems connected to the activities that accomplished

these more expansive axiological innovations. Specifically, students reasoned through problems in ways that reflected awareness of Massey's thrown togetherness and the need to attend to a valuing of diversity of life.

Implications

These findings suggest that deliberate work to cultivate axiological innovations in the design and implementation of learning may support ore equitable and expansive learning environments – particularly in participatory design contexts that engage a range of perspectives and expertise. Further the forms of ecological reasoning and problem solving reflect a kind of sophistication that reflects the demands of the 21st century.

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