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GUEST EDITORIAL



Infrastructuring Teacher Learning about Equitable Science Instruction

Philip Bell 

College of Education, University of Washington, Seattle, Washington, USA

How might we continue to promote educational transformation in support of social justice in an era of educational standards implementation and broad political turmoil? Can we use the platform of collective teacher learning associated with standards implementation to even promote liberatory goals? In the context of my editorial, I draw inspiration from Vossoughi and Gutiérrez (2016) who want to focus our attention on the possibilities for nondominant communities presented by the creative practice of pedagogy toward liberatory ends. They build on Freirian perspectives where students develop critical consciousness about inequities and injustices and become agentic transformers of those worlds. If we can do such work through educational standards implementation projects, what forms might such work take—and what resources might help educators engage in such work? This is the focus of this editorial using the context of recent work in my research group and professional network to provide some insight.

I recently helped moderate an unconference for science teachers who were focused on implementing the Next Generation Science Standards.¹ An unconference meeting is a professional engagement model where participants largely determine how to focus and arrange the shared time together. Early on the first day I asked each participant to name their top 10 areas of expertise so we could get a sense of the knowledge in the room. There was an awkward moment of silence after I made my request. Some participants admitted to feeling uncomfortable naming specific areas of expertise. Others questioned whether they had 10 areas of expertise. Ultimately, participants all listed their areas of deep knowledge on stickies, and we built an impressive “wall of participant expertise” in the room by thematically clumping and naming various domains. It became a resource as people navigated their personal and group learning and work agendas throughout the meeting. But, the palpable hesitation in the room made me reflect on the pervasive discourses we have in U.S. society that unjustly and problematically continue to deprofessionalize PreK-12 teaching. My point of departure in this editorial is that broad scale educational improvement hinges upon leveraging, extending, and sharing the expert knowledge of teachers. A theme you will see throughout is that we collectively need to disrupt the discourses that deprofessionalize teaching and to reinforce asset-based frames related to teacher knowledge, judgment, and potential.

CONTACT Philip Bell  pbell@uw.edu  University of Washington, College of Education, 312 Miller Hall, Box 353600, Seattle, WA 98195.

Color versions of one or more of the figures in the article can be found online at www.tandfonline.com/uste.

¹This was an inspiring experience that I co-hosted with Dr. Cindy Kern and the QeST Learning Center in Connecticut. See the following Twitter thread to learn more: <https://twitter.com/i/moments/1161589725972574208>.

The need to work the liminal spaces between teaching, research, and community

We need to develop scaled and sustained models of supporting cumulative progress toward equitable and just science instruction. I see this work involving the building of communities that focus on collaborative, ongoing improvement working at multiple levels in and out of the formal educational system centered on progress toward social imaginaries that promote justice. The knowledge needed to guide ongoing transformation of educational systems resides substantively in teaching practice itself and in communities—as well as in academic traditions. We need to promote cross-sector collaborations and educational development efforts that live between the boundaries of these social groups. We need to develop boundary spanners that broker network connections and weave together relevant knowledge. We need to focus this liminal work on developing professional learning experiences and associated learning resources that can provide a foundation for educators as they refine their practice. These resources need to fit the pragmatic contours of their professional practice as it is constituted within largely under-resourced systems. It needs to fit their exigencies while support their sustained development along multi-decadal timescales of expertise development.

This kind of resource development work is productively understood as infrastructure development—building the system of substrates that support desired practices within a community (Star, 1999). Infrastructures are fundamentally relational and importantly can embody standards that link with desired conventions of practice (Bowker & Star, 1999). Infrastructuring as a shared collaborative design practice is inherently a contested and complicated endeavor, but it has a strong potential for productively working toward equity across networks of teachers, community members, and researchers.

The STEM teaching tools initiative: professional learning resources to support equitable science instruction

With support from the National Science Foundation,² a collaborative team worked to transcend the problematic and colonial research-to-practice model of academic knowledge dissemination. Our Research + Practice Collaboratory developed and studied different models of collaboration between researchers and practitioners—and more recently with communities—focused on equitable educational improvement. Within that effort, my research team launched an initiative in the fall of 2014 called STEM Teaching Tools (<http://stemteachingtools.org>) with the idea of collaboratively designing professional learning resources for science educators working to enact the vision represented in *A Framework for K-12 Science Education* (National Research Council [NRC], 2012). The design strategy hinged upon the realization that the educational sector already had *research briefs* and *policy briefs* to inform conversations about education and guide improvement—but we lacked what we came to refer to as *practice briefs* authored for

²Primary funding for the STEM Teaching Tools initiative has come from National Science Foundation grants DRL-1238253 (A Research+Practice Collaboratory, <http://researchandpractice.org>) and DRL-1561300 (Advancing Coherent and Equitable Systems of Science Education, ACESSE, <https://twitter.com/AcesseProject>). Additional funding provided by the Shauna C. Larson Endowment in the Learning Sciences at the University of Washington.

teachers, educators, and educational leaders. Over the past five years, we have worked with a growing network of researchers and practitioners to develop over 60 practice briefs on a broad variety of topics related to equitable science instruction (see Figure 1). Each practice brief acts as an idea and resource funnel for the practitioner around problems and opportunities in educational practice. They were designed to help share key knowledge and tools developed through teaching, research, and community life—and for this reason they are typically coauthored and reviewed by individuals with expertise spanning these social groups. We have since co-designed and shared teacher professional development resources through STEM Teaching Tools—through a tiered collaboration first with school districts (in Seattle and Renton in Washington with my group and in Denver in Colorado with Bill Penuel's group) and then with the Council of State Science Supervisors (CSSS, <http://cosss.org>) to study and co-design more generally useful educational resources in a project called Advancing Coherent and Equitable Systems of Science Education



Figure 1. Examples of four different PreK-12 practice briefs (page 2 shown only for the first example).

(ACESSE). Generally, STEM Teaching Tools are published as open educational resources (OER) through Creative Commons licensing—as a way to resource broad networks of educators and their collaborators around key shifts tied to the vision in the NRC Framework.

It has also been key to develop strategic alliances with professional associations representing and serving science teachers during the current *Framework* and standards implementation time period (Bevan, et al., 2018). In addition to CSSS, we have worked closely with the National Science Teaching Association (NSTA), Achieve Inc., and numerous state science teacher associations in order to directly bridge between fields of research and practice in support of equity-focused improvement. These organizations have used their communication channels and sponsored events to distribute the STEM Teaching Tools resources to the affiliated teacher communities. For example, many state science supervisors from CSSS and their immediate colleagues helped co-design professional development resources that they then brought back and used with their state implementation teams and across their states. For these reasons, we conceptualize our work as being a "network of networks" improvement community effort.

Our web analytics show that the STEM Teaching Tools resources have been conservatively accessed over two million times in the past five years—and our OER PD modules (focused on classroom formative assessment) have been accessed over 40,000 times since January 2017. Surveys show that 80% of users are practitioners—primarily classroom teachers, professional development providers, and educational leaders at different levels of system. We were designing the resources to be relevant, timely, and useful—as a conjectured way to productively support improvement, and we have studied the use of the practice briefs and PD resources in our implementation contexts. People find the practice briefs to be unique resources that fill a need—and a powerful way to start conversations among educators (e.g., during a professional learning experience or teacher education course). We have intentionally designed many of them to serve as productive ways to launch equity discussions specifically. Their modular format allows them to be easily used alongside other resources—and the embedded links make them extensible resources that can be explored in significant depth. People find them to be clear, well-organized, and succinct. The PD resources are similarly received although they tend to be strongly adapted to fit local contexts of professional learning in which they are used. Using the analytical framework from Weiss and Bucuvalas (1980) used by Penuel et al. (2017), we have documented *instrumental uses* (in service of a decision or design), *conceptual uses* (to change a person's perspective on the situation), and *symbolic uses* (in order to validate a preference or justify a decision) of our resources. We believe all three uses serve important functions in the work of improvement and transformation. In other words, the resources can guide the design of professional learning experiences, shift the perspective of those designing or engaging in professional learning, or give backing to people needing to justify staying the course in a specific way. Interestingly, many of the insights and tools shared through the resources that are found to be relevant come from educational efforts conducted many years before—so they are a way to hold onto important parts of our science education history and learning sciences history as well as to share more recent developments.

Attending to problems and opportunities in educational practice

I appreciate a substantive engagement with thorny problems of educational practice when it comes to efforts at improvement and transformation. For example, how can we build capacity toward equitable and meaningful sense-making of natural phenomena within and across educational experiences when we have many educational goals and our educational institutions are inequitably resourced? We do need to engage in sustained and collective problem identification and work toward improvements. However, I believe there is also significant progress to be made by crafting connections *between* existing structures and practices.

My first encounter with a problem frame for teacher learning—although importantly different—was from Lampert’s math education research where she focused opportunities for teacher learning and pedagogical refinement around pragmatic “problems in practice” (Lampert, 1985). I prefer this framing that problems occur *in* the context of practice—in the learning situation. Over the last decade or so, however, I frequently hear a focus on identifying and engaging with “problems of practice” in implementation efforts, teacher education discussions, and in efforts leveraging improvement science approaches. I think solely relying upon a problem-solving frame for teacher learning and educational improvement has some problematic consequences. First, it frames teacher knowledge and practice as being fundamentally problematic—and in inherent need of solving or fixing. That is, the unitary frame of “working on problems of practice” can serve to reinscribe a deficit logic about teacher knowledge that resonates too closely with prevailing and damaging narratives about broken public schools. I know that many who leverage the “problem of practice” frame to better focus teacher learning and improvement have a full appreciation of the expertise and insight of teachers in the work, but I still worry that there is collateral damage to the teaching profession through the routine signaling of only the problematic aspects of teaching.

Second, I think “problems of practice” is too narrow of a frame to reference the possibilities for improvement within contexts where there is significant social and institutional capital that can be mobilized within teacher networks and educational institutions. Do educators, educational leaders, and researchers only share problems? Of course not. We also share opportunities for learning and improvement within the contextual circumstances we find ourselves. Teachers at a school can recognize that colleagues at a nearby school have developed deep expertise on designing more fair assessments for emergent multilingual students—and they can see how they might collaborate with these colleagues to build their own assessment design capacity and an assessment infrastructure that is more just and useful. This seems to be an *opportunity for teacher learning and educational improvement*—in that it allows for identifying and mobilizing potential alignments between existing resources, practices, policies and goals for equitable instruction.

Some might say that this critique is a rhetorical game that doesn’t really matter—that the “opportunity of practice” I have outlined above (and others) can be productively viewed from a “problem of practice” frame. I would agree that opportunities tend to relate to felt problems or latent possibilities. However, my experience has been that framing professional learning and educational improvement around a combined and expanded focus on “problems and opportunities in practice” is more likely to get people to stop and look for synergies within existing practices, knowledge, and policies as they engage in

learning and improvement. It makes the aspect of the work of crafting coherence and building capacity for equity *through alignments of aspects of the infrastructure* more focal to our discussions and our social dreaming. This shift also more clearly highlights the productive capacities that reside within our educational contexts as assets that can be leveraged. Teaching involves incredibly rich intellectual work; it is as complex as any other profession. We should do what we can to frame it as creative, challenging, and collective work that is cumulative and improving.

Educational standards as liberatory technology: a paradoxical strategy

Is it possible to broadly promote counter-racist pedagogies through the implementation of educational standards? What is the role of science curriculum in decolonizing education and supporting the resurgence of Indigenous lifeways? Can we work to disrupt ableism through the intentional design of classroom formative assessments that have historically helped (re)produce it? Can we center educational purposes on the local cultural interests of non-dominant communities—and work in resistance to neoliberal economic logics—as we engage students in standards aligned-science and engineering investigations? Or to put it another way, can the very tools of colonial school structure (standards, curriculum, assessment, shared aims) be used to promote the liberation of non-dominant communities with a meaningful degree of fidelity to associated ethical and moral goals?

These and other equity and justice projects associated with liberatory aims for education are frequently in the discussions I have about educational improvement through implementation of the *Next Generation Science Standards*. They are certainly not yet a mainstream aspect of standards implementation projects as I encounter them, and we do not yet know how to facilitate that level of spread and organizing. However, these equity-focused efforts are not entirely absent from the field of implementation and there is great promise in the cultural and community-centered equity focus in *A Framework for K-12 Science Education* (NRC, 2012) that has been used to guide educational standards development in 44 states at the time of this writing. We have intentionally made equity and justice work central to our STEM Teaching Tools initiative—by centering a focus on relevant aspects within each resource and by developing specific resources in the collection about specific equity topics. Our team has decided to not participate in standards-focused implementation projects that do not keep equity central, and I find our collective conversations in science education writ large about equity to be deepening over the years. We are committed to exploring if (and how) educational standards implementation can be a venue for transforming educational systems by promoting rightful presence for all students across the scales of justice (Calabrese Barton & Tan, 2019), by desettling inequitable systems of science education through critical historical analysis of educational practice (Bang, Warren, Rosebery, & Medin, 2012), and by promoting expansive learning and cultural resurgence for non-dominant communities (Bell, Tzou, Bricker, & Baines, 2012; Stromholt & Bell, 2017; Tzou et al., 2019).

In working to accomplish this vision we have to engage in other important work throughout implementation. First, we need to *resist uniformity in educational systems and practices*—a common logic centered on sameness in educational improvement efforts—since it tends to reinforce socially dominant perspectives in how uniform structures are

Table 1. Proposed equity and justice projects for PreK-12 science education.

Engage in Culture-based Pedagogies: support expansive learning pathways for learners through culturally responsive, sustaining, and resurgent pedagogies
Support Diverse Sense-Making: build educator capacity and educational resources to leverage the diverse intellectual resources learners bring to educational environments (Rosebery, Warren, & Tucker-Raymond, 2015)
Disrupt Ableism: promote a cultural model of ability by leveraging and extending beyond universal design
Promote Place-based Learning & Ecological Caring: support science learning in outdoor settings and help people learn to engage in ecological caring practices in support of socio-ecological thriving and multi-species justice
Center Racial Justice: build capacity for counter-racist pedagogies; promote critical consciousness and responses around systemic racism (Mensah & Jackson, 2018)
Arrange for Cross-age, Family & Community Science Learning: dismantle the age segregation associated with settler-colonial schooling and normalize a focus on cross-age and cross-generational learning communities, leverage families as co-designers of education, make science education accountable to community goals
Design Course Sequences Using a Range of Meaningful Phenomena: design instruction where learners routinely investigate and act upon natural phenomena that have social gravity for them, their community, and society—including justice-centered phenomena (Morales-Doyle, 2017)

realized (aligned with White European and typically male values and the backgrounds of WEIRD populations [Henrich, Heine, & Norenzayan, 2010]).³ We need to promote educational standards without standardizing (Darling-Hammond, 1997). Second, we need to focus teacher learning and educational improvement on: (a) cultural and linguistic heterogeneity, (b) the geographic places where students and communities live (i.e., so students can regularly study phenomena in physical context), and (c) the historical knowledge and interests of local communities. This involves taking a strong objectivity perspective deeply into account in our educational design efforts—in the standpoint methodology sense (Harding, 2015). If educational approaches do not work for youth from non-dominant communities (e.g., if they do not find instructional materials compelling, if assessments do not fairly recognize their intellectual resources) then further development is needed before those approaches and resources are taken elsewhere throughout the education systems. This commitment also highlights the role of culture-based and place-based pedagogies in promoting powerful learning in relation to cultural and geographic specificities, and the importance of privileging heterogeneous sensemaking and multiple knowledge systems. Third, we need to disrupt power relations between the academy, educational practice, and communities such that the knowledge and interests of communities are central to guiding the work and that the expertise of practitioners is brought to bear in coordination with the knowledge from the academy. We need to collectively shift from a narrow focus on research-based approaches (e.g., in educational policy and educational funding) to a privileged role for approaches focused on participatory design (Bang & Vossoughi, 2016).

There are many efforts that have realized these goals and approaches within educational settings. We need to learn from these efforts, develop shared resources that can inform others, spread these approaches by developing collective understanding, and then adapt tools and practices to new contexts. I was recently asked by CSSS to consider the next 5–10 years of equity work in PreK-12 science education. Table 1 represents my sense of the directions where we might continue to advance our shared equity agenda in science education. I believe that working to collectively resource educators writ large

³The acronym signals that behavioral scientists have routinely published broad claims about human psychology and behavior based on samples drawn entirely from Western, Educated, Industrialized, Rich, and Democratic (WEIRD) societies—a far from globally representative cultural sample.

across these projects would allow us to develop networked justice improvement communities that have significant potential for systemic transformation.

Concluding thoughts: on the need to work together on a learning infrastructure for science teachers

I was attending a session at a recent research conference and colleague came up to me and bemoaned about how one of his most cherished ideas was not being taken up at this moment of standards implementation across the country. I suggested that he should package it up in a way that was available and usable and offered to have him and his collaborators author a STEM Teaching Tool to try and help networks of practitioners and educational leaders learn about the idea. Upon hearing the suggestion, he physically took a step back and said “But I’m a researcher” and waved off the opportunity—as if it was not his place, yet alone his ethical obligation, to share such knowledge with practitioners in a timely and usable way, or at least make the attempt. I have encountered similar stances among researchers with some frequency. I believe this is a short-sighted move that replicates the problematic separation of the academy from fields of practice and from community. That being said, many researchers do not hold this view and a collaborative stance is more common among newer generations of scholars which gives me great hope. We need to do our part to shift the norms of academic cultures to recognize and reward community-engaged forms of scholarly activity.

As I reflect on the possibilities associated with next decade of work in science education, I recognize that different research and practice communities working in science education have developed expertise and resources in specific topical areas related to equitable science instruction. I work from the perspective that coherent packages of knowledge and resources need to be used in ongoing ways to move educational systems toward equity and justice. I believe we need to develop models for aggregating and spreading this intellectual capital through networks of science educators so that it can be adapted for local contextual use. Our individual efforts are important and useful, but systemic transformation benefits from packaging collections of such work that can support longer timescales of multi-faceted capacity building within and across systems. We might decide to collaborate on developing networked justice improvement communities—social movements that use science teaching as a key lever for equity and justice.⁴ If we organize ourselves in this way, it would be beneficial to infrastructure these networked communities—to provide material and intellectual resources that can more easily support desired practices across disparate networks of collaborators. I believe that we could productively engage in such work together as a research community in close collaboration with networks of practitioners and guided by the participation of communities in support of cultural thriving and more equitable and just futures.

⁴The Science Educators for Equity, Diversity, and Social justice (SEEDS, <http://seedsweb.org>) community is an important development of just this kind.

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ORCID

Philip Bell  <http://orcid.org/0000-0001-9817-2457>

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