Editorial

Biology Education Research 2.0

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Earlier this year, I was enjoying dinner with an influential colleague at an education conference. As would be expected given the venue, this colleague was interested in good teaching. I assumed she would be familiar with the abundance of research on the effectiveness of active learning (e.g., Hake, 1998; Prince, 2004; Ruiz-Primo *et al.*, 2011; Freeman *et al.*, 2014). After listening to one of our tablemates describe an active-learning strategy he had used, my companion turned to me and asked, "But how do we know that it works?" Her question caught me by surprise. Hadn't this question been answered time and time again?

This moment of disconnect between research on effective instruction and the many instructors and other decision makers who are not yet familiar with this body of knowledge got me thinking about the power of the *CBE—Life Sciences Education* (*LSE*) community. Since the inception of the journal, *LSE* editors, authors, and readers have been called on to serve as translators between what is known about teaching and learning and how teaching is practiced. *LSE* has put this translational role into practice in a number of ways, such as the *Approaches to Biology Teaching and Learning* and *Current Insights* features and the *Research Methods* essays.

These, along with many other articles and essays published in *LSE*, have described or cited the guiding principles for teaching that promotes active learning: engaging students, aiming for an outcome or objective, providing structure and opportunities for practice, giving feedback, encouraging interaction and reflection, expecting higher-level thinking, informing instructional decisions with evidence of student learning and development, and incorporating well-motivated and well-timed explanations from reading or mini-lectures (Bransford *et al.*, 1999; Singer *et al.*, 2012; Dolan and Collins, 2015; Kober, 2015). We know this type of teaching works when deployed well (Freeman *et al.*, 2014),

and that it works especially well for students who have been traditionally underserved (e.g., Eddy and Hogan, 2014).

Imagine for a moment that teaching using active learning is a construction project, and the goal is to construct student learning. The construction tools (e.g., screwdriver, hammer) are the instructional materials (e.g., assignments, clicker questions, exams), and how the tools are used is the instructional strategy. At this point in understanding teaching and learning, we know how to design the screwdriver and the hammer. We also know how a screwdriver and a hammer should be used, and that some aspects of construction will require a screwdriver, while others will require a hammer.

A person who is new to construction may not know that the hammer, rather than the handle of the screwdriver, is a better tool to drive in a nail. He or she may not know that a particular screw requires the use of a Phillips-head instead of a flathead screwdriver. This does not mean we need to redemonstrate that a screwdriver or hammer works. Rather, we need to figure out ways to help all involved in construction to learn how useful the tools are, how to select the right tools for the job, how to use the tools, and what latitude there is for using a range of tools.

This is the direction in which we need to head with the study of biology education. We need to know what is happening during active learning that makes it work—at the levels of the student, instructor, discipline, department, and institution. We need to understand what working means, for whom, and in what contexts (Tanner, 2011). This will require a different kind of research—what some are calling the next generation of biology education research (BER), or BER 2.0.

Excitingly, the *LSE* community is already making progress in this direction. Several recent articles in the journal have aimed at demonstrating what makes "flipped instruction" work (Gross *et al.*, 2015; Jensen *et al.*, 2015) and what "working" means (van Vliet *et al.*, 2015). To continue to make progress in this direction, we need to look to other fields for theory and methods, including cognitive science, psychology, sociology, and anthropology, while keeping in mind our important role in translating the work in these fields, so it is comprehensible to a much broader audience. We need to think creatively about how to bring life sciences research methods—such as those used to study physiological systems, to model ecological processes across scales, and to analyze metabolic networks—to bear on the study of teaching and learning. We need to examine research from such diverse environments as K–12 education and corporate settings and to envision how it might help us understand biology education at other levels and in other settings.

We have embraced concept inventories to measure student learning, which has been an important driver of deeper consideration of how we assess our students' learning. Now we need to explore other ways of thinking about student cognition (Pellegrino *et al.*, 2001), such as threshold concepts (Meyer, 2008; Meyer and Land, 2006; Loertscher *et al.*, 2014); learning progressions (Alonzo and Gotwals, 2012); and schema, phenomenological primitives, and cognitive construals (diSessa, 1988, 1993; Hammer, 1996; Coley and Tanner, 2015). We need to examine other ways biology learners develop, for example, in their identities as scientists; their sense of belonging to science; or their abilities to reflect, self-regulate, and embrace a growth mind-set (Duckworth and Yeager, 2015). We need to balance our need to use common instruments to compare results across studies with our need to develop new and better ways to measure important outcomes that will help us improve the experience of learning biology (e.g., Pellegrino *et al.*, 2001; Yeager *et al.*, 2013).

We need to study instructional change beyond single classrooms or institutions. For example, how do faculty develop knowledge and skills important for teaching research courses (Auchincloss *et al.*, 2014), supporting all students in learning, or guiding students in learning particular domains of life science? What lessons learned from professional development in other disciplines and K–12 settings apply to understanding experiences of biology faculty? In what ways do our institutions differ in their teaching climates, cultures, operations, and incentive systems, and how do these differences support or constrain faculty members in improving their teaching? Again, we can inform our research in these areas by exploring other fields, such as industrial and organizational psychology, improvement science, and health systems research (Campbell *et al.*, 2000; World Health Organization, 2015).

BER 2.0—moving beyond answering the question of whether it works—will be best positioned to thrive if we continue to embrace our role in translating what is known about teaching and learning so that it can both inform our work and serve a broader audience of biology educators. This has been priority and a defining feature of *LSE* since its inception and will be the focus of a new phase of development of the journal in 2016. Stay tuned!

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