# Design Experiments and Laboratory Approaches to Learning: Steps Toward Collaborative Exchange

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This contribution explores how the emerging goals, approaches, and methodologies of design experiments might be productively combined with methods of inquiry common in more traditional laboratory science and considers the potential benefits of such a dialectic. The authors hope to promote a constructive dialogue to help formulate an infrastructure for the science of education that synthesizes theoretical insights supported by a wide array of investigational methodologies (Posner & McCandliss, 1993).

Recent congressional and U.S. Department of Education policy statements mark a radical shift in the shaping of future educational research methodology, calling for randomized controlled trials as the primary source of "scientific evidence" relevant to improving practice (see Shavelson, Phillips, Towne, & Feuer, this issue). Although traditional laboratory methods can play a valuable role within a comprehensive approach to educational research, such policy statements could prove to be counterproductive if they undermine support for methodologies—such as design research—that play a productive role in formulating the very questions and conjectures that serve as targets for randomized controlled studies. There is a basic tension between the types of methods and frameworks advanced in these recent calls for evidence-based practice and those that have proven to be useful in the leading models for design experiments—a tension that could be resolved by re-investing in a critical component of Ann Brown's (1992) research vision.

Brown envisioned a dynamic relationship between classroom-based and laboratory-based research, and her work provided specific examples of observations, conjectures, and artifacts that might realistically be transported across these two research contexts. Brown saw such exchange as bi-directional, supporting a mutually beneficial cross-fertilization of two very different research contexts. Unfortunately, many of the dominant design experiment approaches (e.g., Kelly & Lesh, 2000; Collins, 1999; Cobb, Confrey, diSessa, Lehrer, & Schauble, this issue; Design-Based Research Collective, this issue) have provided little or no provision for intellectual exchange with laboratory science methods.

Significantly, the central organizational model for the National Science Foundation's Research on Learning and Education program (see www.nsf.gov) rests on a view of research that incorporates bi-directional flow of insights and agendas across research contexts. In this model, investigations of brain systems and cognitive systems are seen as lying on a continuum with studies of social aspects of learning and learning in complex educational contexts. Finding ways to bridge these worlds of research is advanced as a national research priority that impacts research on learning both at the level of design experiments and research centered on causal hypothesis testing. This framework provides a potential infrastructure for promoting productive exchange across these very different types of investigation (Hamilton, Kelly, & Sloane, 2002).

But how does one combine the strengths of these research contexts in a mutually beneficial way, given the fundamental contrasts on methods, goals, and approaches that are so often cited in the design experiment literature? How might researchers identify the subset of conjectures that might be usefully transported from one research context to the other? How can key ideas that are central to a design's success be abstracted from its particular situation and studied in a different context? In considering these questions, we draw upon three examples from our collective experiences and provide some preliminary thoughts on how such an exchange might be approached.

### The Causal Connection: Three Examples of Collaboration

In the early 1980s, Bradley, an educational practitioner, and Bryant, a laboratory-based cognitive researcher, began a collaboration based on an observation from educational practice that poor readers also tended to be poor at classroom rhyming activities. This observation led them to the conjecture that poor rhyming skills caused difficulties in reading. Bradley created and refined a pedagogical technique for boosting rhyming skills in preschoolers that used engaging materials and spanned multiple sessions. Bryant designed a randomized experiment which contributed a control condition that focused children's attention on a complementary set of cognitive codes—semantics instead of phonology—while still using the same materials and very similar activities.

Bradley and Bryant systematically contrasted the impact of these two interventions on reading measures collected later in development. The resulting article on the causal role of preschool phonology skills on early reading development (Bradley & Bryant, 1983) is a citation classic within both educational and psychological literatures. It has contributed to the co-evolution of innovative curriculum design work in schools and a line of laboratory-based discoveries establishing children's ability to attend to phonological codes as a critical mechanism in the acquisition of literacy (National Reading Panel, 2000). When conjectures that make

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claims about the causes of success can be constructed so as to hold meaning within the context of a design experiment and a laboratory context, results from both causal testing and integration into an educational context can significantly advance theory and practice. Identifying, contextualizing, and testing factors that are thought to be critical for success may help to mitigate against the development of "fatal mutations" (Brown, 1992) in new situations and may have a profound impact on the diffusion of an innovation throughout the community of potential adopters (Rogers, 1995).

Recently, McCandliss, a developmental cognitive neuroscientist, formed a collaboration with Beck, an educational researcher and former teacher who had developed an instructional procedure *Word Building* (Beck & Hamilton, 2000) which was designed to draw a child's attention to letter-sound combinations at all positions within written words. Incorporating insights from classroom experience with the procedure and cognitive research on literacy development, McCandliss and colleagues conducted a laboratory-based tutoring experiment to measure the impact of this intervention against a randomized control group. Results demonstrated improvements in the targeted cognitive operations, as well as improvements across more general skills such as phonological awareness and reading comprehension that could be causally linked to the intervention (McCandliss, Beck, Sandak, & Perfetti, 2003) and systematically compared to similar gains of the procedure as it is applied in classrooms. By taking learning to the lab, McCandliss and colleagues were able to examine the changes in brain activity associated with children's cognitive improvements (McCandliss et al., 2001). Such studies use functional magnetic resonance imaging to link changes in general cognitive strategies and specific mental operations to quantifiable increases in neural activity within particular regions of the brain associated with attention, phonology, and visual processing. Several projects of this kind are currently underway within several neuroimaging laboratories across the country, bridging investigations of brain mechanisms of learning, cognitive mechanisms of learning, and design principles for instructional intervention programs.

A third example of the benefits of lab-field collaborations in education comes from Kalchman, a former elementary school teacher who is now a mathematics educator and researcher. She and Case, a developmental cognitive psychologist and educational researcher, created and revised a theory-driven curriculum for enhancing understanding of mathematical functions, with a focus on the cognitive level of analysis. This work provides cross-sectional treatment–comparison classroom studies to test conjectures about curriculum-based changes in conceptual structures, which will lead to further investigations in laboratory settings (Kalchman, 2001; Kalchman, Moss, & Case, 2001).

## Steps Toward Productive Exchange

### *Identifying Common Ground Across Research Contexts*

The design experiment–laboratory science collaboration process is perhaps best conceived as a dialogue in search of common ground, rather than as a unidirectional transfer of information from "research-to-application" or as a request for a lab to test a specific hypothesis. As some laboratory investigations approach increasingly complex developmental learning questions—such as specialization of cognitive and brain mechanisms specific to reading (McCandliss et al., 2001) or the investigation of separate cognitive processes and brain networks involved in processing exact versus approximate calculations (Dehaene, Spelke, Pinel, Stanescu, & Tsivkin, 1999)—the overlap with the agenda and content matter of design studies grows. When common-ground issues are discovered, both groups become invigorated and see their research in new ways. Identifying common ground, however, can be a volatile process, with terms taking on different meaning in different contexts and groups talking past each other. Continued cross-disciplinary discussions are necessary to construct shared meaning across these two different contexts.

### *Converging on Measures of Success*

One useful activity is to establish shared understandings in the form of operational definitions of successful outcomes, thereby collaborating on artifacts that have currency in both communities of research. Although some measures are likely to be insensitive to many of the profound and subtle changes that a successful design experiment might engender within a classroom, operational definitions hold the distinct advantage of being highly transportable from the context of the design experiment to other contexts, such as laboratory investigations.

Some operational definitions of success can attempt to capture the *proximal* goals of an innovation—goals that are tightly related to the specific activities and cognitive processes in which children engage (e.g., boosting rhyming skills or increasing the frequency with which a strategy is used). Others might center on capturing more *distal* goals that address the proposed farther reaching impacts of an educational innovation, such as increasing the desire and ability to read and comprehend stories.

Focusing on how gains in proximal measures might translate into gains on distal measures helps embody conjectures about learning in a form that is accessible across research contexts and provides a framework that allows for contributions from multiple methodologies. For example, rich datasets of videotaped interactions that are common to many design experiments may provide unique opportunities for observing factors that mediate the relationship between improvements in proximal and distal measures—evidence that is not generally accessible via traditional laboratory methods (Cobb et al., this issue). Conversely, when collaborative efforts can identify meaningful applications of randomized controlled trials, a scenario emerges in which causal inferences can be directly tested and potentially warranted, and extended into meaningful education contexts. In our experience, the outcomes of such collaborations can have a cascading effect on theories of learning and the design of practice.

In general, collaboration on the selection or creation of proximal and distal measures may facilitate the discovery of a set of conjectures that might be meaningfully investigated across laboratory and realistic school contexts and may provide a concrete basis for cross-fertilization of insights and challenges encountered within each context. Such possibilities might further enhance the potential exchange between more traditional experimental approaches and emerging design experiment methodologies while addressing the needs of those who call for scientifically based evidence in education.

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