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Design-Based Research: An Emerging Paradigm for Educational Inquiry

by The Design-Based Research Collective

The authors argue that design-based research, which blends empirical educational research with the theory-driven design of learning environments, is an important methodology for understanding how, when, and why educational innovations work in practice. Design-based researchers' innovations embody specific theoretical claims about teaching and learning, and help us understand the relationships among educational theory, designed artifact, and practice. Design is central in efforts to foster learning, create usable knowledge, and advance theories of learning and teaching in complex settings. Design-based research also may contribute to the growth of human capacity for subsequent educational reform.

Educational researchers, policymakers, and practitioners agree that educational research is often divorced from the problems and issues of everyday practice—a split that creates a need for new research approaches that speak directly to problems of practice (National Research Council [NRC], 2002) and that lead to the development of "usable knowledge" (Lagemann, 2002). Design-based research (Brown, 1992; Collins, 1992) is an emerging paradigm for the study of learning in context through the systematic design and study of instructional strategies and tools. We argue that design-based research can help create and extend knowledge about developing, enacting, and sustaining innovative learning environments.

Definitions of design experiments abound (see Bell, 2002a). We use the phrase *design-based research methods* deliberately (after Hoadley, 2002) to avoid invoking mistaken identification with experimental design, with studies of designers, or with trial teaching methods. We propose that good design-based research exhibits the following five characteristics: First, the central goals of designing learning environments and developing theories or "prototheories" of learning are intertwined. Second, development and research take place through continuous cycles of design, enactment, analysis, and redesign (Cobb, 2001; Collins, 1992). Third, research on designs must lead to sharable theories that help communicate relevant implications to practitioners and other educational designers (cf. Brophy, 2002). Fourth, research must account for how designs function in authentic settings. It must not only document success or failure but also focus on interactions that refine our understanding of the learning issues involved. Fifth, the development of such accounts relies on methods that can document and connect processes of enactment to outcomes of interest.

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Why We Need Design-Based Research: Challenges of Context, Design, and Enactment

The last few years have seen a renewed effort to close the "credibility gap" (Levin & O'Donnell, 1999) in educational research. Some see this gap as arising from unscientific research approaches (e.g., NRC, 2002), while others point to the detachment of research from practice (Lagemann & Shulman, 1999). Educational research that is detached from practice may not account for the influence of contexts, the emergent and complex nature of outcomes, and the incompleteness of knowledge about which factors are relevant for prediction (Robinson, 1998). Claiming success for an educational intervention is a tricky business. If success means being certain that an intervention caused learning, then we need to look carefully at the intervention in a particular setting. However, research in this model would be difficult to generalize to other settings. On the other hand, if success means being able to claim that an intervention could be effective in any setting, then we should study effects across a variety of settings in order to generalize. However, this kind of research leaves many questions unanswered about how any observed learning was caused by interactions between intervention and setting. To address these problems, we view educational interventions holistically—we see interventions as enacted through the interactions between materials, teachers, and learners. Because the intervention as enacted is a product of the context in which it is implemented, the intervention is the outcome (or at least an outcome) in an important sense.

In addition, the design of innovations enables us to create learning conditions that learning theory suggests are productive, but that are not commonly practiced or are not well understood. For example, the Jasper Series (Cognition and Technology Group at Vanderbilt, 1997) was one of the first learning environments that presented students with an opportunity to develop computational skills by grappling with real-world scenarios. This innovation allowed the testing of the tenets of "anchored instruction," which included the belief that learning should be contextualized, and of ideas that mathematics learning should be more closely tied to students' experience. Successive classroom trials with different versions of these series contributed to an understanding of the characteristics of an effective "anchor," clarified issues for the theoretical refinement of transfer, and showed how social interactions play a role in metacognition.

Illustrations of Design-Based Research

Design-based research methods focus on designing and exploring the whole range of designed innovations: artifacts as well as less

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concrete aspects such as activity structures, institutions, scaffolds, and curricula. Importantly, design-based research goes beyond merely designing and testing particular interventions. Interventions embody specific theoretical claims about teaching and learning, and reflect a commitment to understanding the relationships among theory, designed artifacts, and practice. At the same time, research on specific interventions can contribute to theories of learning and teaching.

One example is the BGuILE project (Reiser et al., 2001), a program of research to support inquiry learning in biology. The underlying innovative approach was the use of discipline-specific scaffolds for data analysis and explanation construction. Initial design efforts focused on developing software and activity structures to support student investigations of episodes of natural selection, followed by cycles of design, enactment, and analysis to successively refine the relationships between technological scaffolds for inquiry and social scaffolds to support scientific discourse. Besides improving the curriculum design, this project yielded concomitant findings concerning psychological aspects of students' understanding of scientific explanation and argumentation (Sandoval, 2003), as well as the role that artifacts and the social interactions around them play in such processes (Tabak & Reiser, 1997). Such findings provide insights into the complexity involved in developing knowledge and skills, and they help us understand the role that teachers play in capitalizing on the affordances of learning materials, but they could easily have gone unnoticed had the research focused solely on the summative effects of the intervention.

Importantly, design-based research goes beyond merely designing and testing particular interventions.

Design-based research methods respond to emergent features of the setting. For example, the Passion School Project (Joseph, 2002) articulated theoretical principles that should drive an interest-based curriculum, including the principle that students develop competencies in adult-defined learning objectives through engagement in authentic work in their area of interest. Micro-analyses of student interactions with activities based on that principle enabled redesign and refinement of activities, and ultimately refinement of the underlying interest-driven learning framework. Thus, emergent behaviors of students in response to activities drove development of the intervention and development of theory. These developments would have been unimaginable in the absence of real student choices.

Finally, in design-based research, practitioners and researchers work together to produce meaningful change in contexts of practice (e.g., classrooms, after-school programs, teacher on-line communities). Such collaboration means that goals and design constraints are drawn from the local context as well as the researcher's agenda, addressing one concern of many reform efforts (Robinson, 1998). Engaging such partnerships across multiple settings can uncover relationships between the numerous variables that come into play in classroom contexts and help refine the key components of an intervention. In particular, these partnerships can help us distinguish between a "lethal mutation" (Brown & Campione, 1996)—a reinterpretation that no longer captures the pedagogical essence of the innovation—from a productive adaptation—a reinterpretation that preserves this essence, but tailors the activity to the needs and characteristics of particular classrooms. For example, Baumgartner (1999) described how several teachers adopted different strategies to manage the tension between performance goals (e.g., building effective fishing rods) and explanatory goals (e.g., understanding why the rod works the way it does) in a science and engineering curriculum. The role that local interpretation plays in successful implementation became salient by examining the cases in which different teachers' strategies achieved similar instructional goals. Indeed, such reinterpretation is inevitable and necessary. Sustainable innovation requires understanding how and why an innovation works within a setting over time and across settings (Brown & Campione, 1996), and generating heuristics for those interested in enacting innovations in their own local contexts.

Relationships Between Design-Based Research and Other Methodologies

Design-based research has recently been described as a potentially fruitful methodology for generating causal accounts of learning and instruction that could form the basis for systematic, randomized clinical trials (Levin & O'Donnell, 1999; NRC, 2002). We see design-based research as raising important questions for research applied to practice and for research methods, generally. However, randomized trials are not necessarily the appropriate end goal of our research approach; we do not understand issues of context well enough yet to guarantee that randomized trials are the best means to answer the questions we care about. The use of randomized trials may hinder innovation studies by prematurely judging the efficacy of an intervention. Additionally, randomized trials may systematically fail to account for phenomena that violate this method's basic assumptions—that is, phenomena that are contextually dependent or those that result from the interaction of dozens, if not hundreds, of factors. Indeed, such phenomena are precisely what educational research most needs to account for in order to have application to educational practice. We would suggest, however, that design-based research can generate plausible causal accounts because of its focus on linking processes to outcomes in particular settings, and can productively be linked with controlled laboratory experiments or randomized clinical trials (cf. Brown, 1992) by assisting in the identification of relevant contextual factors, aiding in identification of mechanisms (not just relationships), and enriching our understanding of the nature of the intervention itself. For example, the CoMPASS

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project on computer-based conceptual representations in science learning illustrates one approach to linking design-based research and more traditional studies through "informing cycles" (Puntambekar, 2002). Though initial work showed learning effects of the conceptual representations, alternation between field-based implementation studies and controlled experimental work helped refine understanding of the important features that affect students' use of these representations.

We do not claim that there is a single design-based research method, but the overarching, explicit concern in design-based research for using methods that link processes of enactment to outcomes has power to generate knowledge that directly applies to educational practice. The value of attending to context is not simply that it produces a better understanding of an intervention, but also that it can lead to improved theoretical accounts of teaching and learning. In this sense, design-based research differs from evaluation research in the ways context and interventions are problematized.

In traditional evaluation, an "intervention"—an instructional program, a textbook, or a policy—is measured against a set of standards (Worthen, Sanders, & Fitzpatrick, 1996). During formative evaluation, iterative cycles of development, implementation, and study allow the designer to gather information about how an intervention is or is not succeeding in ways that might lead to better design. Then the intervention is "frozen," and the rigorous summative evaluation begins. Evaluators often conceptualize context as a set of factors that are independent of the intervention itself but that may influence its effects. Like formative evaluation, design-based research uses mixed methods to analyze an intervention's outcomes and refine the intervention. Unlike evaluation research, design-based research views a successful innovation as a joint product of the designed intervention and the context. Hence, design-based research goes beyond perfecting a particular product. The intention of design-based research in education is to inquire more broadly into the nature of learning in a complex system and to refine generative or predictive theories of learning. Models of successful innovation can be generated through such work—models, rather than particular artifacts or programs, are the goal (cf. Brown & Campione, 1996).

Challenges Faced by Design-Based Research Methods

The commitment to using theory-driven design to generate complex interventions that can be improved through empirical study and that can contribute to more basic understanding of the underlying theory raises significant challenges. Objectivity, reliability, and validity are all necessary to make design-based research a scientifically sound enterprise, but these qualities are managed in noticeably different ways than in controlled experimentation (e.g., Barab & Kirshner, 2001). Design-based research relies on techniques used in other research paradigms, like thick descriptive datasets, systematic analysis of data with carefully defined measures, and consensus building within the field around interpretations of data.

By trying to promote objectivity while attempting to facilitate the intervention, design-based researchers regularly find themselves in the dual intellectual roles of advocate and critic. Although there are no simple solutions to what we see as a necessary tension arising from the coupling of empirical research to design, it is possible to employ specific research methods to question the designer-researcher's tacitly held assumptions. In particular, design-based research typically triangulates multiple sources and kinds of data to connect intended and unintended outcomes to processes of enactment. In our view, methods that document processes of enactment provide critical evidence to establish warrants for claims about why outcomes occurred.

Complications arise from sustained intervention in messy settings. A single, complex intervention (e.g., a 4-week curriculum sequence) might involve hundreds, if not thousands, of discrete designer, researcher, and teacher decisions—hopefully working in concert—in an attempt to promote innovative practice. In these situations, causality can be difficult to decipher and disambiguate; all possible factors cannot logistically be equally pursued; precise replication of an intervention is largely impossible; and emergent phenomena regularly lead to new lines of inquiry informed by current theories or models of the phenomena. Reliability of findings and measures can be promoted through triangulation from multiple data sources, repetition of analyses across cycles of enactment, and use (or creation) of standardized measures or instruments.

Validity of findings is often addressed by the partnerships and iteration typical of design-based research, which result in increasing alignment of theory, design, practice, and measurement over time. For instance, Hoadley (2002) described how a design-based approach to studying mechanisms for learning via on-line discussions led to a fundamental rethinking of the theoretical notion of social inclusiveness and, with the help of local participants and teachers, its operationalization in the research program. This shift avoided a misinterpretation of data and produced an improved learning environment besides.

A logistical challenge for design-based researchers involves maintaining a productive collaborative partnership with participants in the research context. Because a single line of research often investigates multiple cycles of design, enactment, and study, the work can span years and touch on closely held commitments of the researchers and teachers. Indeed, successful examples of design-based research often are conducted within a single setting over a long time (e.g., Linn & Hsi, 2000), and the success of the innovation and the knowledge gained from its study depend in part on being able to sustain the partnership between researchers and teachers. There is a trade-off here between the refinement of a particular innovation to maximize its success, and the generalization of findings from an ultimately highly refined enactment. The challenge for design-based research is in flexibly developing research trajectories that meet our dual goals of refining locally valuable innovations and developing more globally usable knowledge for the field.

Given the multifaceted nature of the enterprise, a further challenge for design-based research is ensuring that knowledge claims are used appropriately. We have suggested ways in which design-based research can generate usable knowledge about educational practice, but even usable knowledge will not make complex educational problems simple. Ongoing methodological development is needed to enhance rigor while respecting the importance of local context. More importantly, we stress that design-based research should not become a euphemism for "anything goes" research or oversimplified interventions.

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Prospects for Design-Based Research in Education

We suggest that the value of design-based research should be measured by its ability to improve educational practice. We see four areas where design-based research methods provide the most promise: (a) exploring possibilities for creating novel learning and teaching environments, (b) developing theories of learning and instruction that are contextually based, (c) advancing and consolidating design knowledge, and (d) increasing our capacity for educational innovation. We have seen progress in the area of developing new insights concerning novel pedagogy in classroom contexts (e.g., Linn & Hsi, 2000). We should make concerted efforts to accumulate the usable knowledge we produce and to cultivate long-term partnerships and infrastructure for systemic change.

Exploring Possibilities for Novel Learning and Teaching Environments

Efforts to design, use, and do research on educational tools and materials in real settings can promote the adoption of innovations. They can help researchers and designers understand the real-world demands placed on designs and on adopters of designs. In addition, pursuing development and enactment through close collaboration with teachers places them in direct ownership of designs. Although design-based research is positioned to address these issues, sustaining innovations hinges on our ability to articulate the mechanisms that underlie their success.

Developing Contextualized Theories of Learning and Teaching

We have argued that design-based research methods are of value in addressing research questions related to the enactment of interventions in varying contexts. As a field, educational research must develop better theories of the elements of context that matter for the nature of learning and for the implications of policy for local educational practices. Design-based research can contribute to such theories through rich accounts of instructional interventions and their effects across multiple settings and in multiple areas of instruction.

Constructing Cumulative Design Knowledge

Design-based research can lead to an understanding of relevant design knowledge and practices as they apply to naturalistic settings. In design-oriented fields, design knowledge is often characterized by common examples, patterns, and principles, and by the expertise required to apply these generalities in specific settings. Currently, design-based research communicates this knowledge in many forms, including narratives of planned and enacted instruction (Hoadley, 2002; Linn & Hsi, 2000), design principles connecting enacted designs to educational outcomes of interest (Bell, 2002b), and design patterns abstracted from one or more settings describing how a designed innovation interacts with settings and evolves (Orrill, 2001). We hope for a scholarship of design in education that adopts common communicative approaches and links theory to local applied understandings, similar to research in architecture or engineering.

Increasing Human Capacity for Innovation

Design-based research provides numerous opportunities for the exchange of expertise across disciplinary boundaries. Interactions between partners reveal crucial practices that lead to insights about what occurs when we orchestrate complex interventions in messy settings (Cobb, 2001). As a natural entailment of design research partnerships, the participants frequently learn about the phenomena under study, encounter new theoretical lenses, and acquire experience in conducting and interpreting new analytical techniques (Barab & Kirshner, 2001; Edelson, 2002). The need for innovation in education is ongoing, as theories of learning and teaching lead to usable knowledge about and reform of instructional practice. Therefore, the development of people who can apply this knowledge (teachers, administrators, policymakers, and researchers) and who understand and can orchestrate educational change in context should more explicitly drive design-based research partnerships.

Summary

We have argued that design-based research methods can compose a coherent methodology that bridges theoretical research and educational practice. Viewing both the design of an intervention and its specific enactments as objects of research can produce robust explanations of innovative practice and provide principles that can be localized for others to apply to new settings. Design-based research, by grounding itself in the needs, constraints, and interactions of local practice, can provide a lens for understanding how theoretical claims about teaching and learning can be transformed into effective learning in educational settings.

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