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A Commentary on Design Research

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The call for design research, design-based research, or design experiments arose from the recognition of the complexity of classroom interventions and dissatisfaction with existing methodologies for exploring the outcomes from such interventions. The goal of the proposed design research was to describe how interventions worked and was less about documenting that they worked. The concerns voiced are not new, and the emergence of proposals for alternatives was a natural outgrowth of trends in the field of educational psychology. Advances are only beginning to be made in the articulation of a design research methodology, and some of the criticism and recommendations for progress are described. The articles in this issue provide examples of design research and point to some issues that still require attention. Among these are the need to clarify the nature of design research and the role of context in such research.

The articles in this special issue of *Educational Psychologist* all address issues related to design-based research. This article provides a brief background on design research and some of the challenges faced by proponents of design research as a research methodology that can produce credible evidence. I then consider some of the considerations about design research that are stimulated by the five articles in this issue and how the articles collectively contribute to an increased understanding of both the potential and limitations of design research.

The difficulty of studying complex human functioning, such as might be found in classrooms, was recognized almost a century ago. Thorndike (1910) noted that the "extreme complexity and intimate mixture with habits in the case of human instincts prevents studies of them, even when made with great care, from giving entirely unambiguous and elegant results" (p. 10). Concerns about the appropriate methods for studying complex cognition are also not new. Thorndike made the following observations about the appropriate dispositions and methods for conducting research:

> But the educational theorist or practitioner who should conclude that his casual observations of children in homes and schools needs no reinforcement from the researches of psychologists would be making the same sort of, though not so great, an error as the pathologist or physician who should neglect the scientific studies of bacteria and protozoa. Also the psychologist who condemns these studies in toto because they lack the precision and surety of his own studies of the sensations and perceptual judgments is equally narrow, though from a better motive. (pp. 10–11)

Thorndike was aware of the important contribution of practice and naturalistic contexts to the study of psychology, but he was also committed to the scientific study of phenomena. He believed in the importance of both laboratory- and school-based work, as is shown in the following quotation:

> The science of education can and will itself contribute abundantly to psychology. Not only do laws derived by psychology from simple, specially arranged experiments help us to interpret and control mental action under the conditions of school-room life. School-room life itself is a vast laboratory in which there are made thousands of experiments of the utmost interest to "pure" psychology. (p. 12)

Thorndike recognized the importance of classroom-based research, precise methodology, the contribution of other kinds of methods beyond those utilized in laboratories, and the importance of the relation between understanding of phenomena and action in the world. The limited methodologies available for the measurement of cognitive functions at the beginning of the 20th century made it difficult to realize the potential synergy between laboratory-based and classroom-based research. It was not until the World War II that significant developments in the measurement of mental abilities and performance occurred. The kind of research program described by Brown in her 1992 article that moved between

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classroom-based investigations and controlled laboratory investigations, "a cross-fertilization between settings" (Brown, 1992, p. 153), is perhaps the kind envisioned by Thorndike.

A number of developments resulted in a return to the kind of considerations envisioned by Thorndike (O'Donnell & Levin, 2001). The kind of learning studied in the 1970s (as represented in the *Journal of Educational Psychology*) was simpler and more readily measurable than the kind of learning that became more prevalent in the 1980s, which included higher order cognitive processes such as reasoning and metacognition (O'Donnell & Levin, 2001). The changing nature of theories of learning created a press for better methods to study higher order processes and instructional methods for how to promote such processes. In addition, there was increasing concern among researchers and others for research to be educationally relevant and to contribute to the improvement of education (Grinder, 1989; Klausmeier, 1988; Salomon, 1995) in addition to developing new understandings of complex learning and instruction. Criticisms were made about studying processes such as memory in a laboratory context with artificial materials when those contexts were so different from those in which students would actually use memory skills and with materials that were unlike those used in laboratories. Design experiments were introduced against the backdrop of these other developments in educational psychology.

Brown (1992) and Collins (1992) first introduced the term *design experiments*. Collins provided the following example of a hypothetical design experiment:

> Our first step would be to observe a number of teachers, and to choose two who are interested in trying out technology to teach students about the seasons, and who are comparably effective, but use different styles of teaching; for example, one might work with activity centers in the classroom and the other with the entire class at one time. Ideally, the teachers should have comparable populations of students … Assuming both teachers teach a number of classes, we would help the teacher design her own unit on the seasons using these various technologies, one that is carefully crafted to fit with her normal teaching style. (p. 19)

If differences in the outcomes from these contexts were found, it would be impossible to know to what these differences could be attributed. It is not clear in what sense this particular example can be described as an experiment. The term *experiment* has more recently given way to *design research* or *design-based research,* a change that removed some of the confusion associated with the name of the methodology.

Collins (Collins, 1999; Collins, Joseph, & Bielaczyc, 2004) contrasted seven aspects of experimental laboratory studies of learning and design research. Experimental studies were laboratory based and typically involved a single dependent measure. Researchers made all the decisions, sought to control variables, and used fixed procedures. Participants in the research were generally socially isolated, and the research involved testing hypotheses. Design experiments, in contrast, involved messy situations that were difficult to characterize. Researchers used multiple dependent measures and attempted to characterize the situation while acting in the role of coparticipants. The participants in design research are almost always engaged in social interaction, and the goal of the researcher is to develop a profile of the design in operation. The primary goal of design research is to "investigate how different learning environment designs affect dependent variables in teaching and learning" (Collins et al., 2004, p. 17) .

Brown's thought provoking article in 1992 described the challenges she met in conducting research on complex interventions in classrooms and the methodological concerns provoked by the alternative research strategy involved in design research. She described her career as beginning with the study of children in laboratory settings and gradually shifting to the study of learning in classrooms. The classroom-based research began in "lab-like settings as pull-out time (for reading groups etc.), then in socially sanctioned settings in the classroom (reading groups), and finally, orchestrating, some might say disrupting, the entire classroom activity for at least one hour a day" (Brown, 1992, p. 152).

The shift to working in more naturalistic contexts raises many issues related to methodology when the researchers are also the designers of the educational environments in which the research is conducted. Winn (2003) noted that controlled experiments limit the intrusion of spurious variables that may affect outcomes by experimental control, whereas design research accomplishes this through an iterative process. Levin and colleagues identified four components of research that can produce credible evidence (Derry, Levin, Jones, Osana, & Peterson, 2000; Levin & O'Donnell, 1999). These four components together are referred to as "CAREful" intervention research: Comparison, Again and again, Relationship, and Eliminate. According to Levin and O'Donnell, evidence of an intervention is credible if the intervention is compared to an appropriate comparison group, the outcomes produced by the intervention can be replicated, a direct relation exists between the intervention and the outcome (i.e., the intervention actually produces the effect), and alternative explanations can be ruled out. The iterative nature of design research can contribute to the production of credible evidence, but there are clear limits to the researcher's ability to eliminate alternative explanations and limits to understanding what aspects of a design are necessary to an effective instructional intervention.

The efforts at objectivity that typically characterize experimental research are no longer possible in design research. Brown (1992) described a mixed methods approach in which she conducted standard pre- and posttest measures of student learning, analyzed these data using quantitative measures, and then developed a richer understanding of students' knowledge acquisition by more in-depth probing of a subset of students. One of the methodological concerns raised by Brown is what she termed the *Bartlett effect,* or a tendency to be selectively at-

tentive to data that conform to the researchers' expectations. According to Brown, this is "particularly acute when portions of edited transcripts or clinical interviews are selected to illustrate a theoretical point, or when descriptions of planning sessions, peer tutoring, or teacher coaching are culled from a vast array of potential examples" (p. 162). The problem is how to avoid misrepresenting the data. This problem is exacerbated by the amount of data that is collected as part of design research. Brown noted that she did not have room to store all her data, let alone score it. The problem of data selection continues to be a problem with design research (Dede, 2004). In his criticism of design research, Dede described it as underconceptualized and overmethodologized. His reason for describing many design research projects as overmethodologized is that only 5% of the huge amounts of data collected were needed to induce the findings.

Despite claims that design research is increasingly accepted as a research methodology, little was written about this methodology in the decade after Brown and Collins wrote their first commentaries on the subject, although descriptions of research were available. Suter (1999) included design research in his descriptions of research methods in mathematics and science. Explicit discussions of the methodology as a research methodology have only recently appeared. Special issues of *Educational Researcher* (Kelly, 2003) and *Journal of the Learning Sciences* (2004, Vol. 13, No. 1) highlighted this research methodology and have helped to make the discussion of this methodology more available to the larger community of scholars.

Dede (2004) and Kelly (2004) provided some important criticisms of the current state of design research. Dede criticized the absence of standards for identifying when a design should be abandoned or determined to be promising enough to warrant further exploration. Standards also need to be established for minimum criteria needed to actually begin an implementation. The possibility for endless revision of designs has important implications for classrooms, curricula, and students' time. Time in school is extremely limited (an average of about 180 days a year), and the school day is quite short. Students in poorer districts may not have the resources in the home or community to bolster and amplify the work that is done by children in the context of a school day. Thus, time in the classroom is a precious resource for these children. The use of this time for the purposes of research (either experimental or alternative types of research) must be utilized with great care, and criteria for identifying promising instructional interventions or interventions that are unworkable should be clearly in place. This caution is true for both experimental and design research, although the latter tends to be more time consuming because of its iterative nature.

Dede (2004) also criticized design research for being underconceptualized and without adequate theoretical basis. Furthermore, he criticized design research as suffering from the problems identified by Brown (1992) with respect to excess data and data selection for analysis. Kelly (2004) noted that design research is an emerging methodology and queries whether design studies are a set of methods or a single methodology. If design research is to be considered a research methodology, it must describe a set of procedures, a process, a set of steps to follow. According to Kelly, "design studies to date have been described primarily using a set of *process* descriptors" (p. 118).

There are problems for design research with generalizations across participants, as relatively few participants are typically involved in the kind of in-depth analyses that are characteristic of design research. It is also difficult to generalize over behaviors, as it is usually not possible to rule out alternative explanations. The very nature of design research in which adjustments can continually be made in the implementation of an instructional intervention make it very difficult to know what combination of features of the intervention actually contribute to its success. Generalizations are also difficult to make across contexts because of complexity involved in implementation and the confounds in identifying contributors to success. The context itself is not "natural," as it represents the joint efforts of researchers, teachers, students, and others who, in the normal life of a school, do not typically work so closely. To the extent that the researchers become integrally involved in the design, implementation, and revision of the intervention, their subsequent withdrawal from this involvement changes the context again.

The five primary articles in this issue all address issues related to design research. They describe work in different settings and focus on varied issues. They collectively describe examples of design research and attempt to respond to some of the kinds of criticisms leveled at such research. They engage issues related to aspects of the methodology of conducting design research and continue the discussions begun in special issues of *Educational Researcher* (2003) and the *Journal of the Learning Sciences* (2004).

DESIGN RESEARCH AND CONTEXT

The general feature of design research as articulated by Collins and his colleagues (Collins, 1999; Collins et al., 2004) are reiterated in a number of the articles in this issue and include the use of natural contexts in which flexible revisions are made to the design under consideration. Efforts are not made to control variables, and the research proceeds with the participation of teachers and students.

Single Method or Multiple Methods

Unlike Kelly (2004), who recommended the identification of a "design methodology," Bell (this issue) argues against seeking for a solitary definition of design-based research in education and points to many of the ways in which scholars disagree about theories of learning (universal laws of cognition, culturally bound cognition, or some interaction), design (what is be-

ing designed), and diffusion (how should an educational intervention be disseminated?). Instead, Bell argues for including a greater variety of research programs under the design experiment label. The lack of progress in describing a coherent design research methodology seems to stem from the lack of agreement about what constitutes the procedures involved in executing a design research project. Bell notes that it has been difficult to learn about design-based research approaches because the detailed practices of such research are communicated through the everyday activities of researchers involved in the work. Bell defines *design research* as the intentional design of objects (not necessarily concrete) along with empirical research and theorizing about what occurs in authentic contexts in which the designed objects are used. Bell describes how research framed from a disciplinary viewpoint (e.g., cognitive science) can include design research. Although the examples provided are intriguing, the proliferation of a variety of "families" of design research may actually work against the identification of standards for identifying when an intervention is promising or should be abandoned.

Examples of Design Research

Joseph (this issue) implements a form of design research that is quite different from those of others in that she worked as an individual teacher/designer/researcher. Kelly (2004) argued that one way to classify design research is by characterizing the outcomes or "products" of such research: "Design is not design without some form of designed artifact—even if the goal of the artifact is to advance a different outcomes such as new theory" (p. 116). Joseph's artifacts include both software and processes.

Joseph (this issue) notes that she needed to choose initially from a huge variety of questions that might be addressed in the research, but she does not describe how her initial decisions about which questions to address were made. She describes two separate studies related to her passion curriculum. The intent of this curriculum is to organize learning around expressed students' interests. In the first study, she used the topic of flight, which was considered to be of interest to students. The initial implementation relied on the use of goal-based scenarios (Schank, 1992; Schank, Fano, Jona, & Bell, 1993) and was based on cognitive apprenticeship. The initial implementation suggested that it was not, and the outcomes were disappointing. From this initial exploration, three possible explanations for the results were articulated: (a) the topic was not of interest, (b) the implementation schedule was not adequate, and (c) the activities did not support sustained motivation.

In a second iteration, Joseph (this issue) distinguishes between addressing these three issues "locally" or through more extensive research. In the context of design research, it seems that all questions are addressed locally. She selected a different theme for the second, informed by observations of children choosing activities and children's responses to surveys. It seems to me that this selection is also an element of the design. It is not clear how decisions about what are parts of the design or what are not are made.

Hoadley (this issue) identifies a key element of design research in noting that design-based researchers treat context as a fundamental construct. He further clarifies what is meant by design research by distinguishing between the enacted and the designed intervention. It is in this gap between the designed and enacted interventions that revisions are created. Hoadley also identifies some of the procedural elements of conducting design-based research. He notes that the relationship between researchers and teachers is often close and that this blurs the "objective" researcher–participant distinction. Tentative generalizations are made from initial implementations, although he does not consider the limitations to generalization articulated by Kelly (2004). New insights are pursued as they emerge, leading to changes in the intervention and the measurement as the research proceeds. This is a key feature of design research and one that may result in principled adjustments to procedures and measurement. It can also lead to reactive adjustments to local events that are not central to the overall implementation. Thus, one might lose sight of one's initial purpose, reconsider that purpose, and perhaps fail to align current action with redefined goals.

Hoadley (this issue) also addresses issues of rigor in relation to design research and the need for treatment validity and systemic validity in which studies inform theories that, in turn, should inform practice. He illustrates this process in his descriptions of research with the Multimedia Forum Kiosk and the SpeakEasy discussion tool. In describing some of the missteps along the way to the development of a workable discussion tool for online learning, Hoadley provides evidence for the importance of a prior conceptual base in decisions about design. The initial development of the discussion tool relied on a specific model of how collaboration promotes knowledge building (Scardamalia & Bereiter, 1994). The work described in Hoadley's article showed some of the surprising events that can occur in design research. In particular, the researchers' noted that girls expressed preferences for contributing anonymous comments to discussion threads, but, in fact, they did not contribute anonymously. Other unintended effects of design decisions included the realization that, when the designers seeded discussions by initiating commentary with anonymous comments, the students tended to add anonymous comments. Later, the designers realized that the anonymous comments were not read by other students. Redesign of the interface allowed students to elect to participate anonymously while not promoting the heavy use of that feature that had negatively impacted prior implementations.

The responsivity to changing conditions with respect to students' prior knowledge of computing was helpful in promoting computer-supported collaborative learning. What is missing from this account, however, is some cost–benefit analysis of whether the learning outcomes achieved were sufficient for the costs involved in terms of participants' and designers' time.

Design-Based Research Questions

Joseph (this issue) notes the myriad of questions possible that might frame her work. Hoadley (this issue) demonstrates how new questions arise in the execution of a research study. How do design-based researchers choose questions? The rather broad answer is that they identify questions that have a meaningful relation to student learning. What criteria are used to choose among questions?

Sandoval (this issue) introduces the concept of *embodied conjectures*. These are conjectures (rather than formal hypotheses, as might be articulated in experimental research) about learning within educational designs. In his article, Sandoval examines a specific conjecture embodied in a learning environment to support high school students' scientific inquiry. According to Sandoval, systematically designed interventions can contribute to developing theory "because designed learning environments embody *design conjectures* about how to support learning in a specific context, that are themselves based on *theoretical conjectures* about how learning occurs in particular domains." Two features of embodied conjectures are important: (a) conjectures are derived from existing knowledge in a particular domain; and (b) the empirical refinement can lead not only to improvement of a particular learning design, but also to refinements in learning theory itself. Embodied conjectures are embodied in multiple aspects of the learning design; they predict outcomes and interactions with their contexts of use.

Sandoval (this issue) illustrates his conceptualization of embodied conjectures using work conducted with the Biology Guided Inquiry Learning Environments (Reiser, Tabak, Sandoval, Smith, Steinmuller, & Leone, 2001) for inquiry in high school biology. The underlying conjecture was that conceptual and epistemic scaffolds for scientific inquiry should be integrated to help students understand the kind of knowledge they are trying to build while providing conceptual guidance. Consistent with the approach to design research as originally conceptualized by Brown (1992), the impetus for framing this particular conjecture comes from a deep analysis of the extant literature. The conjecture is embodied in the design environment by including specific features of the software tool, ExplanationConstructor, that explicitly attempt to instantiate the conjecture (see Sandoval for details). The software was intended for a specific context of use defined by participation structures.

Initial evaluations of the use of the software showed that students acquired knowledge, engaged in explanation, used the explanation guides available, and monitored their progress. The explanation guides were used by students to suggest possible data to collect. Students, however, did not evaluate the explanations they constructed. Results supported the design conjecture to integrate epistemic and conceptual supports for inquiry, and further efforts refined the integration. One thing that emerged from the analyses was the discontinuity between how students perceived their own inquiry activity and how they viewed the practice of science. Students had "practical epistemologies" to guide their inquiry. New queries can be framed from the recognition of this disconnect.

Although Sandoval (this issue) notes that the conceptual analysis provided in his article is somewhat post hoc, he nevertheless provides an interesting illustration of how design questions are selected and how efforts at implementation provoke additional questions. Of key importance is that the framing of the original conjecture reflects a deep and thorough understanding of a research literature. In such circumstances, results that are predictable and those that are not can be recognized. The design environment represents a set of coherent relations among aspects of the environment.

Context

Many of those who write about design research emphasize the important role of context. Classrooms are occasionally described as complex contexts that cannot be studied by experimental methods because of the narrow focus on a limited number of measures. In contrast, design research is described as responsive to the contextual elements of the environment.

Anderman and Anderman (2000) edited a special issue of *Educational Psychologist* on the issue of context because of the increasing arguments for a focus on the context of the individual (Salomon, 1995), the role of culture in shaping students' cognitions (Pintrich, 1994), and the need to understand the social and interpersonal processes that constitute the social contexts of schooling (Goodenow, 1992). Difficulties in studying context include questions about what dimensions and levels of context should be measured and how, how contexts change, and how differing individuals experience contexts.

Brown (1992) expressed concern over data selection as a possible limitation of design research. Concerns may also be expressed about the features of particular contexts that receive attention and those that do not. What aspects of context are foregrounded, and which aspects fade to the background? Joseph (this issue) derives three potential explanations for outcomes from her initial implementation of her passion curriculum. What guided the identification of these aspects of the context (e.g., time allocation for the work at the end of the week) and not others? When contrasting design and laboratory research, an impression is created that design research is fully complete in responding to context. This does not seem plausible, as in every choice situation (what to measure, when to measure, what to use for measurement), a choice is always accompanied by a nonselection. How do we know when the most important (or least important) aspects of context are the subject of our consideration?

Tabak (this issue) specifically addresses issues related to the context and concludes that what constitutes context is "neither consistent nor uncontested." She distinguishes between exogenous and endogenous design. The former refers to the instructional materials, activity structures, and instruc-

tional strategies that were developed for the research. *Endogenous design* refers to the materials and practices already in place. The exogenous design is often given more attention and accorded more importance than the endogenous design, which is also a necessary part of the overall design. Tabak illustrates the relation between the exogenous and endogenous design through a case study and clearly conveys the complexity of defining, measuring, and understanding context.

In addressing the role of context in learning, we are faced with the problem of the "seen" and the "unseen." Students do not just exist as persons within a classroom, but bring their private lives, thoughts, and beliefs. Nor are all elements of the available context simultaneously salient to the student. The endogenous context can be much more complex than articulated by Tabak (this issue).

In other areas, efforts have been made to describe the role of context. For example, Anderson (1990) attempted to describe the structure of the environment or context relevant to the analysis of memory in terms of how different memories are needed in different situations. The basic premise was that, given a particular context, a memory structure A could be assigned a probability that it will be relevant to the current task. This probability was referred to as a need probability because it was the probability that the structure A would be needed for the particular task. Need probabilities are constantly recomputed as a result of frequency of use or cues inherent in the task. Memory structures with higher need probabilities are activated sooner than those with lower probabilities.

Context in a classroom is unlikely to exist as a global entity. The distinction made by Tabak (this issue) between endogenous and exogenous design is one method of differentiating elements of context. One fruitful area for advancing design research as a methodology might be to refine conceptions of context so that we can begin to understand why aspects of the general context become salient and interact with ongoing activity or are temporarily dismissed. Better descriptions of the nature and role of context and how it interfaces with individual (or group) characteristics will contribute to the advancement of the study of learning and the use of design research.

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