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COMMENTARY

Design Research: What We Learn When We Engage in Design

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Educational researchers are increasingly using design as a means of advancing their understanding. Historically design in educational research has served as a way to implement theories for testing. The emerging design research paradigm treats design as a strategy for developing and refining theories. In this article, I discuss the lessons that can be learned from design. Starting from a model that characterizes designs in terms of problem analyses, design solutions, and design processes, I describe 3 types of theories that can be developed through design research: domain theories, design frameworks, and design methodologies. I present examples from a design research program investigating software supports for reflective inquiry. I argue for design research as form of educational research because (a) design offers opportunities to learn unique lessons, (b) design research yields practical lessons that can be directly applied, and (c) design research engages researchers in the direct improvement of educational practice.

As educational researchers renew their commitment to research that influences practice, researchers are increasingly choosing to incorporate design into their research activities. In doing so, they are able to have a direct impact on education, but they are also taking advantage of the opportunity that design provides to advance their understanding. The focus of these design efforts varies as dra-

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matically as the interests of the educational research community. These design efforts include design of curriculum, software, professional development, school organizations, and school–community collaborations. This new wave of research, characterized by iterative design and formative research in complex real world settings, has been variously called design experiments (Brown, 1992; Collins, 1992), design research (Cobb, 2001), and development research (Richey & Nelson, 1996; van den Akker, 1999). These new efforts pose important challenges for researchers, not because design is entirely new to educational research, but because the relationship between the design and the research is changing, and because the complexity of the designs and their settings present challenges for traditional research methodologies.

The conventional role of design in educational research has been as a strategy for testing theories. Cobb (2001) described this theory testing as a four-step sequence:

1. The development of a theory.
2. The derivation of principles for design from the theory.
3. The translation of the principles into concrete designs.
4. The assessment of the designs to test whether they work as anticipated.

While Cobb questioned whether or not this neat process is ever realized in practice, he argued that it is held up as the ideal in research discourse. As described by this ideal, the role of design in research is to implement a theory so the theory can be evaluated and, if necessary, refined. This role assumes a fully developed theory that maps directly into design.

In the recent literature on design experiments and design research, researchers present a different picture of the role of design in their research (Brown, 1992; Kelly & Lesh, 2000; Richey & Nelson, 1996; van den Akker, 1999). They describe a process in which design plays a critical role in the development of theories, not just their evaluation. In this theory development approach, the design researchers begin with a set of hypotheses and principles that they use to guide a design process. Importantly, these hypotheses and principles are not detailed enough to determine every design decision. In addition, these guiding principles are not followed slavishly if accumulated evidence, specific circumstances, or informed intuition lead the designers to believe they do not apply. In this way, the design researchers proceed through iterative cycles of design and implementation, using each implementation as an opportunity to collect data to inform subsequent design. Through a parallel and retrospective process of reflection upon the design and its outcomes, the design researchers elaborate upon their initial hypotheses and principles, refining, adding, and discarding—gradually knitting together a coherent theory that reflects their understanding of the design experience. Confrey and Lachance (2000) described this process in the following way: “At points in its evolution, the conjecture should feel more like a grand scheme beginning to emerge from many, previously disparate pieces" (p. 235).

Numerous examples of this iterative design research have been reported in recent years representing a wide range of design domains and research questions. The domains include design of learning activities (Brown & Campione, 1994; Cognition & Technology Group at Vanderbilt, 1997; Hmelo, Holton, & Kolodner, 2000; Palincsar & Brown, 1984; Penner, Giles, Lehrer, & Schauble, 1997), software design (Bell, Davis, & Linn, 1995; Guzdial, Turns, Rappin, & Carlson, 1995; Hancock, Kaput, & Goldsmith, 1992; Jackson, Stratford, Krajcik, & Soloway, 1996; Scardamalia et al., 1992; White & Frederiksen, 1998), and professional development (Schifter, 1996; Sherin, 1998). This research has led to both applied (design-oriented) theories and basic theories on topics such as cognition, motivation, and social context.

An important characteristic of design research is that it eliminates the boundary between design and research. In the traditional theory-testing paradigm, design and research are distinct processes that happen sequentially. Design takes place first as the implementation of the theory, followed by the evaluation-oriented research. The design process is not regarded as an opportunity for learning. In contrast, design research explicitly exploits the design process as an opportunity to advance the researchers understanding of teaching, learning, and educational systems. Design research may still incorporate the same types of outcome-based evaluation that characterize traditional theory testing, however, it recognizes design as an important approach to research in its own right.

In recent years, a number of discussions of design research have been published (e.g., Brown, 1992; Kelly & Lesh, 2000; Richey & Nelson, 1996; van den Akker, 1999). These have provided justifications for design in research, definitions of design research, explorations of methodological issues, and reports of results. In this article, I focus on a different question: What kinds of lessons can we learn from the design process in design research? In doing so, I argue that design provides an opportunity to learn unique lessons, and I describe a process by which those opportunities can be exploited. Several of the earlier design research discussions have also explored the question of what can be learned from design research (Cobb, 2001; Richey & Nelson, 1996; van den Akker, 1999). These discussions have tended to contrast the descriptive findings of traditional empirical research with the prescriptive findings of design research. In this article, I describe both descriptive and prescriptive lessons that can be learned through design research. I begin, in the following section, by looking at the design process in general and describing the lessons that any designer learns in the course of constructing a design. In the two subsequent sections, I describe the types of theories that these lessons can inform and the methods by which these lessons can be extracted from design through a process of design research. In the final section, I argue for the importance of design research in order to influence educational practice.

WHAT WE LEARN WHEN WE ENGAGE IN DESIGN

Opportunities to learn arise in the course of any design process. These opportunities for learning are the direct result of the specific decisions that must be made in the course of a design. In this section, I describe these decisions and the lessons that they offer.

The process of design is complex. Its open-endedness and reliance on creativity have made it a challenge for researchers to characterize and explain. Simons (1971) view of design as systematic search through a solution space has been influential in contemporary views of design, although Schon (1990) argued convincingly that the description of design advanced by Simon and operations researchers is overly rational and incomplete to explain complex design as it plays out in many situations. For the purposes of this article, it is not necessary to resolve the issues raised by Schon or to construct a comprehensive model of the design process. In the argument here, I use a simple description of the design process that is consistent with both Simon's and Schon's perspectives.

Design is a sequence of decisions made to balance goals and constraints. In the course of any design, the design team makes three sets of decisions that determine the results of the process. These are decisions about (a) how the design process will proceed, (b) what needs and opportunities the design will address, and (c) what form the resulting design will take. In the case of routine design, these decisions are straightforward, requiring little or no meaningful learning by the designers. On the other hand, in challenging or innovative design, these decisions can be complex, and as Schon pointed out, interdependent, requiring extensive investigation, experimentation, and iterative refinement on the part of the designers. In these cases, the designers inevitably acquire substantial new understanding.

These three decisions must be made in every design, although in practice they may not be explicit, conscious, or formally articulated. Nevertheless, at any point in time, any design process can be characterized by the decisions that have been made. I refer to the three collections of decisions that determine a design outcome: the *design procedure,* the *problem analysis,* and the *design solution.*

Design procedure. The design procedure specifies the processes and the people that are involved in the development of a design. Design can be astonishingly complex, requiring a wide range of expertise and a systematic process that insures that goals are met and constraints are observed. Designers must often develop a specialized set of processes to respond to a particular design challenge or the context in which a design is being constructed. These processes must address the needs for planning and preparation, development, implementation and evaluation, and revision and refinement. To account for the complexity of design, the designers must also assemble a team that includes the relevant forms of expertise. For any particular design, the expertise and process that are required are determined by the goals and constraints of the design.

Problem analysis. The problem analysis characterizes the goals, need, or opportunity that a design is intended to address together with the challenges, constraints, and opportunities presented by the design context. As such, the problem analysis incorporates what is frequently called a needs assessment. The problem analysis also includes a description of the goals they want the design to achieve. This characterization of challenges, constraints, opportunities, and goals lays out the design space within which the designers must weigh tradeoffs and select alternatives as they construct the design solution. A problem analysis typically evolves over the course of a design process incorporating information from a variety of sources. A design process often begins with a perceived problem or opportunity and an idea for how to respond to it. This initial hunch is typically elaborated through a combination of analytic processes, such as needs assessment and system modeling, and empirical processes of implementation and evaluation.

Design solution. The design solution describes the resulting design. It is the result of the designers' efforts to address the challenges, satisfy the constraints, exploit the opportunities, and balance the tradeoffs that were identified in the problem analysis. Solution construction requires a different, complementary form of analysis from problem analysis. In solution construction, designers often decompose a complex design problem into manageable components. The simplified, rational view of design holds that solution construction is a process of generating alternative solutions and weighing their costs and benefits, although real design is more complex (Schon, 1990). As with the other elements of design, the design solution typically evolves over the course of the design process as the designers deepen their understanding of the design context through analysis and formative evaluation.

Although these descriptions of design procedures, problem analyses, and design solutions may give the impression that they are concrete artifacts, I do not mean to imply that they exist as such in any actual design nor that design is a neat, rational process of making these decisions (Schon, 1990). My characterization of design in terms of these components is not intended as a process theory of design at all. Rather, it is a way of characterizing the state of a design at any point of time, a type of snapshot, that characterizes the decisions, be they implicit or explicit that the designers have made up to that point. In the messiness of real world design, these components may only exist implicitly in the actions of the designers. To the extent that they are explicit, they are likely to be in constant flux. In some forms of design, the design procedure may be clearly articulated and followed, but many effective design processes are flexible and dynamic, meaning that the entire procedure cannot even be described until the design process is complete. Similarly, the problem analysis may not be constructed before the design solution, as an idealized view might suggest, but may be developed hand-in-hand. In fact, the problem analysis may never be recognizable as a complete entity, and only exist in the form of individual design challenges that are identified and addressed one at a time. Nevertheless, it is useful to describe these elements as discrete entities because the decisions that they characterize encode the designers understanding of the design context. As designers learn lessons that enable them to construct designs, their lessons are reflected in the design procedure, problem analysis, and design solution.

In the following paragraphs I present an example of these decisions from my own design research on software, curriculum, and professional development activities for inquiry based science learning. Since 1995, my colleagues and I on the Supportive Inquiry-Based Learning (SIBLE) Project at Northwestern University have been investigating the design and use of software to foster reflection in extended computer-supported inquiry activities (Loh et al., 2001). This research was founded on the observation that when students engage in extended inquiry activities on the computer, they often fail to plan or execute plans effectively, forget what they have done, or are unable to make coherent sense of their experiences. There have been two types of design products from this research. The first is a software environment called the Progress Portfolio. The Portfolio is a database that allows students to record the process and intermediate products of an investigation, and to annotate, organize, and create presentations from those records. The second design product is a set of curriculum units that incorporate the Progress Portfolio as a support for extended investigations involving computer-based inquiry tools. In the following paragraphs, I provide a brief description of the design procedure, problem analysis, and design product in this research effort to date. This discussion is not intended as a comprehensive report of the research, but as an illustrative example to draw on throughout the article.

Design procedure. The design process began with the observations cited above about students' failure to engage in the metacognitive activities required by extended scientific investigations, particularly in computer-supported inquiry activities involving large quantities of data and data representations. These observations led to the first set of design activities, which were conducted in three interwoven strands: a review of the relevant literature on metacognition and students inquiry strategies, a set of classroom observations of students use of metacognitive strategies in extended inquiry activities, and the rapid prototyping of a tool (the Progress Portfolio) that would allow students to capture and store text and graphics from other programs. The participants in the first stage were academic researchers with backgrounds in cognitive science, computer science, and learning environment design. In the next stage of the process, we entered an iterative cycle of design and implementation in which the initial team (a) worked with three teachers on the design of curriculum units that incorporated the Progress Portfolio; (b) extended the Portfolios functionality in response to the demands of those units; (c) observed the curriculum units implemented in classrooms; and (d) refined the curricula and software in response to observed problems, needs, or opportunities. This stage of the process is ongoing. Overall, the design process has involved design team members representing a wide range of expertise including cognitive psychology, observational research methods, human–computer interaction, software development, curriculum development, and teaching practices. We have found the voice of teachers in this design process to be particularly valuable.

Initial problem analysis.[1] The problem that this design set out to address initially was students' difficulty with successfully sustaining effective inquiry strategies as the length of an investigation or the quantity of data exceeded a threshold. Our initial analysis of the problem was that as the size of students' investigations exceeded their memory capacity, they became unable to monitor and manage their investigations effectively.

Initial design solution. The initial problem analysis led to the first prototype of the Progress Portfolio, a tool intended to allow students to offload the memory demands of tracking an extended investigation to an external resource. This prototype (and all subsequent versions) consisted of a "Data Camera" that allows users to snapshot images of their computer screen and a "Portfolio" where students can store these records, organize them in Portfolio folders and pages, and annotate them with text and graphics.

Intermediate[2] *problem analysis.* Following the introduction of the Progress Portfolio, we have continued to observe that students either lack or fail to apply inquiry strategies that would allow them to take advantage of the storage, annotation, and organizational tools that we provided. For example, they did not necessarily employ effective strategies for deciding what to record or they failed to look for previously stored resources when they might have helped them.

[1]For the purposes of exposition, it is easier to divide the problem analysis and design solutions into stages because each changes in response to the other with every design iteration. However, as I define them, the problem analysis and design solution at any point in a design process represent the cumulative set of decisions that have been made up to that point.

[2]As this work is ongoing, there is no final problem analysis or design solution.

Intermediate design solution. We have pursued two strategies to address this issue. The first is to add a capability for teachers to create page templates within the Progress Portfolio. These templates give teachers the capability to place blank fields on pages that students can place specific types of information (text or images) in, and they also give them the ability to write explicit text prompts describing the information that they want students to record. The second is to develop curricula that include activity sequences and discussions that have the explicit goal of helping students learn to make decisions about what to record and to refer to those records when appropriate.

Although this example of our research on the Progress Portfolio and reflective inquiry has specific elements that reflect the particular goals of the design research program, it is characteristic of design research in general. The research was undertaken with the twin goals of understanding the process of reflective inquiry and developing software tools with practical utility for supporting that process. It is informed by prior research, but it started with only a partial theory and has proceeded with the explicit goal of elaborating that theory before attempting any summary evaluation. The lessons that are emerging from this effort are being shaped by the concrete, practical work of design. In the following section, I describe the types of lessons that we can learn from design research in general and then return to this specific example to describe the theories that we are developing from it.

THEORIES FROM DESIGN RESEARCH

Design procedures, problem analyses, and design solutions represent collections of decisions that designers must make in any design process. The goal of design is to make these decisions in the best possible way given the constraints of the design context. These decisions represent opportunities for learning, because the more informed the designers are in making these decisions, the better their decisions will be. For example, in the case of instructional design, making these decisions leads designers to learn about teaching, learning, and the educational context. Except in the most routine of design processes, designers learn in the process of making these decisions and observing their consequences.

However, the lessons of any individual design effort are ordinarily restricted to the particular design and the individuals involved in it. That is, the goal of ordinary design is to use the lessons embodied in a design procedure, problem analysis, and design solution to create a successful design product. Design research retains that goal but adds an additional one, the goal of developing useful, generalizable theories. The opportunity that design offers for theory development is the possibility of using the lessons learned in constructing design procedures, problem analyses, and design solutions to develop useful theories. For each of these three elements of design, there is a corresponding type of theory that design research can develop. I call these three types of theories *domain theories*, *design frameworks*, and *design methodologies*. In the discussion that follows, I describe these three types of theories in more detail and provide examples from our ongoing design research on the Progress Portfolio and reflective inquiry.

Domain Theories

A domain theory is the generalization of some portion of a problem analysis. Thus, a domain theory might be about learners and how they learn, teachers and how they teach, or learning environments and how they influence teaching and learning. For example, a curriculum designer might develop a domain theory about the needs of learners or the challenges of implementing a type of learning activity in certain settings. Even though a domain theory in design research is developed through a design process, it is a theory about the world, not a theory about design per se. As such, it is descriptive, not prescriptive. Design research can contribute to two types of domain theories, *context theories* and *outcomes theories.*

A context theory characterizes the challenges and opportunities presented by a class of design contexts. For example, in the Progress Portfolio research, we have been developing a context theory that describes the challenges facing students who are engaging in extended scientific investigations for the first time. The challenges we have observed for middle school students include students' inability to recognize when they need to keep records, failure to plan and monitor their progress effectively, and difficulty reconciling conflicting evidence. In another example, Soloway, Guzdial, and Hay (1994) developed a domain theory that describes the specific challenges of designing software for learners. Their theory of *learner-centered design* describes three issues that software for learners must address. These are the need to motivate learners, the need to adapt to changes in learners as they learn, and the need to accommodate the inevitable diversity among learners.

An outcomes theory characterizes a set of outcomes associated with some intervention. An outcomes theory is a natural outgrowth from a problem analysis because the problem analysis must characterize, not just the challenges, but also the outcomes of implementing the design. In the case of design research, there is one class of outcome of particular interest, desired outcomes. Understanding the desired outcomes and the transitions that can bring it about is essential to successful design. Therefore, the problem analysis must either explicitly or implicitly characterize desired outcomes and ways to achieve them. On the other hand, the problems exposed through formative evaluation or the eventual failure of a design effort can contribute important information about undesirable outcomes, which can also contribute to an outcomes theory. In the Progress Portfolio research, we use the term *reflective inquiry* to describe our desired outcome. Specifically, we are interested in helping students learn to monitor and guide their open-ended investigations in order to develop conclusions that are supported by evidence. To achieve this goal, we are developing a model of reflective inquiry. This model describes the metacognitive strategies that learners must possess in order to develop questions, collect and interpret data, formulate hypotheses, evaluate evidence, and report results in data-rich investigation environments. We are continuing to elaborate the model as the research continues, but the current version breaks the skills of reflective inquiry into three key components (Loh et al., 2001): creating a record of progress, monitoring progress, and communicating process and results to others. When it is completed, the model will be an outcomes theory describing the components of reflective inquiry. In his discussion of his own design research in mathematics, Cobb (2001) described the development of an outcomes theory. It begins in the designers' minds as a "possible learning route or trajectory that aims at significant mathematical ideas" (p. 456). Then, after a sequence of design and implementation cycles, it emerges as a "demonstrated learning route that culminates with the emergence of significant mathematical ideas" (p. 459).

Design Frameworks

A design framework is a generalized design solution. Although domain theories are descriptive, design frameworks are prescriptive. They describe the characteristics that a designed artifact must have to achieve a particular set of goals in a particular context. A design framework is a collection of coherent design guidelines for a particular class of design challenge. Van den Akker (1999) also described design frameworks, which he called *substantive design principles*, as a distinguishing characteristic of design research. Some prominent examples of design frameworks include: anchored instruction (Cognition & Technology Group at Vanderbilt, 1997), for creating meaningful problem contexts for extended problem solving; concept-oriented reading instruction (Guthrie & Alao, 1997), for motivating reading instruction through interest; for conducting embedded performance assessments (Sloane, Wilson, & Samson, 1996); and goal-based scenarios (Schank, Fano, Bell, & Jona, 1993/1994), for creating learning-by-doing software and in-person learning environments.

In the Progress Portfolio research, we envision creating design frameworks for both elements of the design effort, one for software tools and one for inquiry-based curriculum units. The software design framework will describe the features required to support reflective inquiry. For example, reflective inquiry requires a mechanism for storing and reviewing intermediate products from an investigation, so that students may have access to them as objects for reflection. Our design and implementation experiences with the Portfolio have demonstrated the importance of implementing this mechanism in specific ways. For example, it is critical that students be able to store these objects for reflection without interrupting the flow of their work in the investigation environment. It is also essential that they be able to annotate the records of their work. The second framework will be for curricula that help students develop effective inquiry strategies. This framework will provide guidelines for sequencing activities that will develop reflective inquiry skills and for designing page templates with appropriate prompts for scaffolding these inquiry processes. Developing and sharing design frameworks like these serves twin goals. It will enable designers to develop tools to support metacognition in similar ways in other contexts, and it will enable researchers to extend our understanding of the requirements of metacognition.

Design Methodologies

A design methodology is a general design procedure. Like a design framework, it is prescriptive. However, a design methodology provides guidelines for the process rather than the product. A design methodology describes (a) a process for achieving a class of designs, (b) the forms of expertise required, and (c) the roles to be played by the individuals representing those forms of expertise. Van den Akker (1999) uses the term *procedural design principles* to describe a design methodology. The creation of design methodologies is common in many design fields, including traditional instructional design (e.g., Gagné, Briggs, & Wager, 1992), as a mechanism for ensuring that the design process addresses all the essential issues, includes all of the necessary expertise, and progresses efficiently. A design methodology typically lays out a sequence of tasks, describing the objectives, processes, and participants for each step. For example, in the field of user-interface design in computer science, a number of different design methodologies have been created to make sure that data and feedback from users are obtained at appropriate intervals and incorporated into the design (e.g., Carroll, 1995; Kreitzberg, 1996; Muller, 1992).

In the Progress Portfolio research program, we are investigating a methodology for curriculum and software design that enables designers to benefit from the participation of teachers. This methodology specifies roles for teachers and classroom implementation at appropriate stages of the design process. In this methodology, collaborative teams of researchers, designers, and teachers, called *work circles*, carry a design through a three-phase design process from initial design through pilot and field-testing. This methodology is the focus of a broader program of design research in the Center for Learning Technologies in Urban Schools (LeTUS). During the first 2 years of LeTUS, 10 work circles involving researchers from Northwestern University and the University of Michigan and teachers from the Chicago and Detroit Public School systems have been created to develop and revise curriculum units. Data has been collected in each of these work circles about their procedures, participants, and products. These data are being used to identify challenges in the design process and strategies for using the different sources of expertise in the work circles for addressing them. When it is fully developed, this methodology will specify objectives and procedures for each stage of design and describe the roles of curriculum developers, teachers, and classroom evaluation in achieving those objectives.

FROM DESIGN TO DESIGN RESEARCH

Having looked at the lessons that designers learn and the theories to which they can give rise, I turn now to the question of how ordinary design efforts can be augmented to yield useful research results. To be useful, lessons from design must apply beyond the specific context in which they were learned, and they must serve an audience beyond the designers themselves. In the following, I describe four features that distinguish design research from simple design and their benefits for generating valuable research results.

Research driven. For a design research program to yield useful results, it must be informed by prior research and guided by research goals. In their discussion of how mathematics curriculum design can contribute to research, Battista and Clements (2000) argued that designers must connect their work both to research findings and research perspectives. Although the design process in design research is often guided by incomplete theories, that does not mean that the researchers resort to making things up as they go. Rather, effective researchers draw whenever possible on available theories and empirical results, are deliberate when they diverge from their guidance, and are aware when they are resorting to intuition or informal knowledge. In addition, their work is guided by an informed understanding of the gaps in current understanding in order to focus their effort in areas that will make a useful contribution to understanding. Being research driven enables a design research program to maximize the utility of its findings.

Systematic documentation. Although it is standard procedure in most engineering disciplines to keep comprehensive records of the design process, there are no such conventions in educational design. Therefore, for most educational designs the only record of the process available for analysis is the design itself. To support the retrospective analysis that is an essential element of design research, the design process must be thoroughly and systematically documented. According to Battista and Clements (2000),

> To take the first step toward becoming scientific, curriculum developers need to explicate their theoretical standpoints, judgments, purposes, and procedures, so that the development process is recorded, shared, and opened to critical reflection and discussion. (p. 747)

Engaging in design as a research process means taking the elements of design that typically remain implicit in a design and making them explicit. In design research, the designer–researcher documents the problem analysis, solution construction, and design process in a form that makes it an object for public reflection and discussion. Systematic documentation can be used to produce a *design case*, a rich description of a problem analysis, solution, and design procedure for a particular design experience. Maintaining systematic documentation ensures that a design research program will have data to support subsequent analysis.

Formative evaluation. In principle, formative evaluation should be a part of all design, but like systematic documentation, it is often left out because of limited time or resources. Formative evaluation is critical in design research because it can identify inadequacies in the problem analysis, the solution, and the design procedure that cannot be exposed through analytical processes alone. In design research, as in good design, a tightly integrated process of design, evaluation, and revision can enable designer–researchers to identify problems or gaps in their understanding of the design context and to elaborate their analyses to account for them. Formative evaluation exposes issues that the design research program must address.

Generalization. The final element of design research is the process of generalization. In this process, the designer–researcher expands his or her focus beyond the current design context to look for generalizations to other contexts. Through a retrospective analysis, the designer–researcher treats the design problem, solution, and processes as instances of more general classes. In doing so, the researcher must be alert to elements of the design that can generalize to a useful range of situations. The generalization process draws on the other three elements of design research in an effort to reconcile partial theories from prior research, the detailed analyses from available design cases, and the issues raised in their formative evaluations. It is through the process of generalization that a design researcher takes the specific lessons of one or more design experiences and develops domain theories, design frameworks, and design methodologies.

CERTAINTY IN DESIGN RESEARCH

One commonly voiced concern about design research is the relative certainty of its findings in comparison to traditional empirical research. Unlike results from the theory-testing tradition, the form of design research I have described here does not lead to results with statistically determined confidence levels. This concern highlights two important contrasts between design research and experimental research.

The first is that the objective of design research is different from traditional empirical research. Therefore, they should not be judged by the same standards. The goal of design research is the generation of new, useful theories. Thus, two important evaluation metrics for design research are novelty and usefulness. A design research program should yield new theories that have utility for resolving important problems. The point of design research is to generate theories that could not be generated by either isolated analysis or traditional empirical approaches.

The second contrast between design research and traditional empirical research is their source of strength. Traditional empirical methods gain their strength from statistical sampling. As others have pointed out, the strength of theories developed through design research comes from their explanatory power and their grounding in specific experiences (Cobb, 2001; Steffe & Thompson, 2000). A design research theory is compelling to the extent that it is internally consistent and that it accounts for the issues raised during the design and evaluation process.

Finally, though the point of this article is to highlight their differences, design research is not, in fact, incompatible with traditional outcome-based evaluations. If the nature of any theory is such that a minimum level of certainty is required before it should be applied, then the theory should be evaluated empirically before it is applied, whether the theory was developed through design research or otherwise. My argument for the usefulness of this method of theory development is not intended to question the usefulness of theory-testing methods. Evaluation of theories is essential, particularly as Cobb (2001) pointed out, for convincing audiences such as administrators and policymakers. However, there are two risks for the educational research community of overemphasizing such evaluative research. First, the pressure to evaluate theories could lead to useful theories being discarded because they were evaluated and found wanting before they could be fully developed. Second, overvaluing evaluative research can lead us as a community to overlook the important contribution made by research approaches that develop, rather than evaluate, theories.

WHY DESIGN?

Design is difficult and costly, and there are other ways that researchers can develop or refine educational theories. Therefore, it is important to address the question, Why design? In this section I present three reasons why I believe educational researchers should engage in design research.

The first reason for engaging in design research is that it provides a productive perspective for theory development. Design provides a productive focus in three ways. First, the practical demands of design require that a theory be fully specified. If a theory is incompletely specified, it cannot meet the needs of designers. Second, the process of design reveals inconsistencies more effectively than analytical processes. The practical process of applying a theory to construct a design naturally exposes inconsistencies because the theory will provide the designer with conflicting guidance. Third, the goal-directed nature of design provides a natural focus for theory development. Where theoreticians often have little more than Occam's razor to guide their choice among alternative theories, designers have practical considerations such as resources, goals, and constraints to guide them. This can be critical in dealing with the complexity of educational challenges.

The second argument for design research is the usefulness of its results. At its heart, education is a design endeavor. Teachers design activities for students, curriculum developers design materials for teachers and students, administrators and policymakers design systems for teaching and learning. If the ultimate goal of educational research is the improvement of the education system, then results that speak directly to the design of activities, materials, and systems will be the most useful result. In the past, practitioners have complained that they are unable to apply the results of educational research to the problems of design and implementation. The reason is that they were not generated to serve those purposes. The two forms of prescriptive theories that design research yields, design frameworks and design methodologies, both provide educators and designers with directly applicable research products. Even descriptive domain theories from design research are more useful to practitioners because they respond directly to design issues.

The third argument for engaging in design research is that design research directly involves researchers in the improvement of education. Educational researchers, by virtue of their training and experience, are in a unique position to construct solutions to meet needs of the educational system. Although I have focused in this article on the research results that can be gleaned from design, I do not mean to overlook the direct impact that the products of design research—the innovative designs themselves—can have. Because researchers have the freedom to explore innovative design free from the market considerations that drive traditional educational designers, they have the opportunity to create truly innovative designs. The large problems faced by our educational system call for true innovation. Design research provides an opportunity for educational researchers to draw on contemporary research on teaching and learning to create new designs that, if they are successful, could achieve broad, direct impact.

Taken together, these three arguments present a view of educational research as an applied science that differs from the view of research that is held by the broad community of educational researchers and has been taught in graduate schools of education in the past. Changing that view may be the key to enabling educational research to play a larger role in educational reform in the future.

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