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The Time for Design-Based Research is *Right* and *Right Now*

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The science-to-service problem continues to taunt the field of education (Fixsen, Blasé, Naoom, & Wallace, 2009). As an academic discipline, the field requires knowledge generation that adds to or deepens theoretical understandings. As a profession, knowledge generation that solves local problems and supports continuous improvement is necessary. Using design-based research (DBR) provides a means of serving theoretical and practical needs in education, addressing the complexity of education by informing immediate practice while simultaneously contributing to theoretical understandings in the field of education. Using Stokes' (1977) model of scientific research and knowledge generation, we situate DBR within Pasteur's quadrant, describe how to increase its use, and recommend a new means for dissemination.

The debate over the theory-to-practice divide continues in many fields, including education. Coburn and Stein (2010) suggested that the path from theoretical knowledge to classroom application is neither linear nor direct. Fixsen, Blasé, Naoom, and Wallace (2009) stated that research results are not utilized enough to impact communities. In essence, the current process of scholars disseminating information and practitioners applying information results in a perpetual science-to-service problem. Given the complexity that lies at the heart of teaching and learning (Cochran-Smith, 2003), it is no longer reasonable to rely on the passive dissemination of knowledge. Rather, researchers and practitioners must collaborate to create and disseminate knowledge that will address the issues facing education today. This will require not only generating knowledge to expand understandings of theoretical foundations that comprise the science of the field, but also generating knowledge from practice that elucidates the act of applying the science of education. The purpose of the this article is to discuss the role that design-based research (DBR) can play in addressing the complexity of education, by informing immediate practice while simultaneously continuing to develop theoretical understandings in the field of education. In this article the authors: 1) describe Stokes' (1977) quadrant model of scientific research and elaborate on DBR's placement in Pasteur's quadrant based on its dual purpose of theoretical knowledge generation and practical knowledge generation; 2) describe the foundational elements of DBR; 3) discuss ideas of how to increase DBR use in education research; and 4) suggest an approach to disseminating DBR research that more accurately represents the methodological practice of this type of research.

Overcoming the Theory to Practice Divide: Dwelling in Pasteur's Quadrant

The process of knowledge dissemination suggests that knowledge generated to broaden the theoretical understandings in a discipline will directly lead to the application of that knowledge by practitioners. Knowledge generated in pursuit of informing a discipline is disseminated through articles, books, and presentations with the expectation that practitioners will read these and readily adapt and use the knowledge to improve their practice. This process of knowledge dissemination assumes a direct and linear route from researcher to practitioner that by nature is passive, by assuming that the results and conclusions of research designed to deepen theoretical understanding will transfer easily to context and be used directly by practitioners in the field.

Stokes (1997) challenged this linear view and proposed that the purpose of knowledge generation exists on two separate axes. One axis emphasizes scientific knowledge generation for the purpose of deeper theoretical understanding of the particular phenomenon, with little concern for localized use; whereas the other axis emphasizes practical knowledge generation for immediate localized use, with little concern for deeper theoretical understanding. Instead of following a one-dimensional trajectory, Stokes suggested a dually dichotomous square called *the quadrant model of scientific research*. This model illustrates the belief that forms of research should match their knowledge generation purpose, and that specific actions taken by a researcher in the design and conduction of research should match this purpose as well. Stokes' model includes four quadrants (See Figure 1).

The upper left hand square is called *Bohr's quadrant* in honor of Niels Bohr, "whose quest of a model of atomic structure was a pure voyage of discovery" leading to deeper theoretical understanding of atomic structures (Stokes, 1997, p. 73). The lower left hand square, not formally named by Stokes, refers to inquiry-based learning that generates understanding and application of knowledge for personal purposes. The lower right hand square is labeled *Edison's quadrant* after Thomas Edison, who was driven by "applied goals [of knowledge generation] without seeking a more general understanding of the phenomena related to a scientific field" (Stokes, 1997, p. 74). The upper right hand quadrant is called *Pasteur's quadrant* because of Louis Pasteur's experimentation with dairy (Stokes, 1997). It represents knowledge generation that shares the purpose of theoretical understanding *and* practical application, and provides an example of the shared purpose of deepening understanding and applying knowledge (Stokes, 1997).

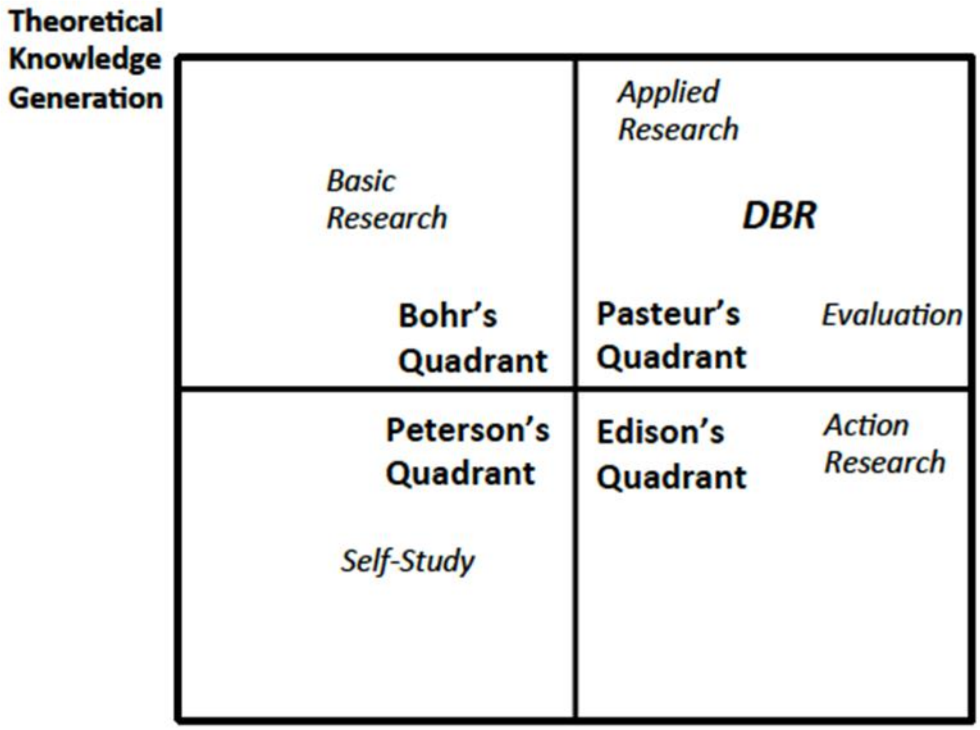

Figure 1. Adapted from Stokes (1997, p.73) Each research type is mapped onto the Quadrant Model based on its knowledge generation purpose. DBR falls into the center of Pasteur's Quadrant due to its focus on theoretical as well as practical knowledge generation.

Education is both an academic field and a profession; therefore education research must address both theory and practice. Education researchers must generate knowledge that expands the academic discipline and has practical applications to address societal needs. Similar to other disciplines, researchers in the field of education currently address knowledge demands utilizing various forms of inquiry, such as basic, applied, evaluation, and action research. Each of these accentuates a specific reason for generating knowledge (Hart, 1998; Johnson & Christensen, 2012) that can be aligned to Stokes' quadrants.

Education research is often discussed as being based upon epistemological and ontological foundations, and these discussions lend themselves to explaining the differences between the broad paradigms of quantitative, qualitative, and mixed methods (Creswell, 2009; Johnson & Christensen, 2012). For our discussion, we propose that when researchers conduct different types of research (i.e., basic, applied, action, and evaluation) they can and do draw from the broad paradigms. That is, researchers use qualitative, quantitative, and mixed methods to carry out various types of education research. However, regardless of the paradigm alignment, the knowledge generation purpose of each type of research remains the same. Thus, the type of knowledge generated stems more from the purpose of the research than the paradigm alignment.

Bohr's Quadrant

By focusing on the knowledge purpose of the research, we can describe how the various forms of education research map onto Stokes' quadrants. For example, research conducted in Bohr's quadrant has the sole purpose of heightening understanding of a phenomenon within a scientific field and focuses knowledge generation on the expansion of a discipline's theoretical understandings without concern for the practical use of that knowledge. Basic education research reflects Stokes' description of Bohr's quadrant, as it aims to extend existing interpretations and test hypotheses related to theories, and focuses on questions that produce knowledge to promote generalized or deeper understandings of phenomenon for other education researchers (Hart, 1998; Johnson & Christensen, 2012). Researchers narrow the objective of basic research by focusing on exploring, predicting, describing, and explaining specific phenomena within a theory (Creswell, 2009; Hart, 1998; Johnson & Christensen, 2012). Regardless of the research objective, basic education research seeks to produce knowledge by answering *why* questions that guide the field of education on a theoretical level, and aims to contribute to academic scholarship rather than professional practice.

"Peterson's Quadrant"

Research conducted in the bottom left quadrant represents inquiry-based learning meant to promote personal use and understanding. Stokes (1997) informally referred to the bottom left hand quadrant as *Peterson's quadrant* in reference to the book "Peterson's Field Guide to Birds," but did not give the quadrant that formal title; nor did he provide any in-depth comparison to the other quadrants. The emphasis on acquiring knowledge for one's personal and professional development places self-study in this quadrant. Self-study involves the systematic examination of one's own practice for the purpose of gaining deeper understandings in order to acquire knowledge about oneself as a practitioner (Cochran-Smith & Lytle, 2009; Pine, 2009). When it comes to education research, self-study challenges one's own thinking by reflecting on beliefs and practices and questioning inconsistencies between the two when transforming one's practice to better serve students (LaBoskey, 2004). Given the heavy emphasis on personal development over the generation of theoretical or practical knowledge, we will not examine this quadrant's alignment to education research beyond this point.

Edison's Quadrant

Research conducted in Edison's quadrant is intended for practical use, by posing questions that generate knowledge that is applied immediately to solve a problem or make improvements on a product. The research objective in this quadrant emphasizes knowledge generation to understand *what* product or intervention works or *how to improve* the product or intervention. Explaining or understanding the *why* behind how a product or intervention works, or furthering theoretical understandings, is of little or no concern for scholars conducting research in this quadrant.

Action research maps to the top portion of Edison's quadrant as it emphasizes the immediate and practical use of the generated knowledge, with less concern for the advancement of theoretical understandings of the discipline. Action research, as the name states, emphasizes taking immediate action based on the knowledge generated from the research. Researchers pose questions to solve localized problems and develop the skills of practitioners as the main outcome generated through action research (McNiff & Whitehead, 2010). This contextually specific knowledge is used to understand problems, as well as to design and develop, implement, and evaluate the solutions to these problems (Johnson & Christensen, 2012; Stringer, 2007). Action researchers have limited interest in generalizing knowledge to the broader field of education. Whereas action researchers do use theoretical knowledge when developing or improving solutions to problems, the emphasis on generating knowledge is for the purpose of taking immediate action to address practice-based problems (Stringer, 2007). Action research emphasizes knowledge generation about *what* works or *how to improve* what is working with minimal or no concern for *why* it works.

Pasteur's Quadrant

Stokes (1997) coined the term "use-inspired basic research" to describe the research that fits Pasteur's quadrant. The aim of research in this quadrant is to expand both theoretical and practical knowledge (p. 73). Some evaluators utilize theory as a key component of evaluation education research (Chen, 1990); however, the main purpose of evaluation is to generate knowledge about a specific program in order to make value statements about program improvement (formative evaluation) and impact (summative evaluation) (Fitzpatrick, Sanders, & Worthen, 2011; Scriven, 2003). In evaluation research, knowledge generated from questions about a program is used to make value statements about the program, making its purpose different from the purpose of other types of research; as Fournier (2005) argued "It is the value feature that distinguishes evaluation from other types of inquiry, such as basic science research" (p. 140). Stakeholders use such statements of value when making decisions about a program. We map evaluation research to the bottom of Pasteur's quadrant, as its aims are less about generating knowledge to inform education theory than generating knowledge for these practical purposes.

Applied education research involves academic researchers testing theoretical understandings in natural settings or examining the application of theoretical understandings to address problems within education (Hart, 1998; Johnson & Christensen, 2012). Although applied education research has some focus on *how to use* theory, the main emphasis is on developing understanding of *why* theory works within the context of real world settings, with little concern for adjusting the theory in real time to meet practical problems. We map applied research to the top of Pasteur's quadrant, as research questions generate knowledge for the purpose of expanding theoretical interpretations based on the application of those theories in natural settings. The field of education serves both a scientific and a practical aim, therefore it is critical that education research represents Pasteur's quadrant to the fullest. Although applied research and evaluation research fall within Pasteur's quadrant, their overemphasis on either theoretical *or* practical knowledge generation creates a dichotomy.

In order to dwell fully in Pasteur's quadrant, education research must rely on a different type of research than is typically practiced. Pragmatic in nature, design-based research (DBR) draws from many types of research; however, there are several aspects that make it uniquely different from basic, action, evaluation, and applied research, and place it directly at the center of Pasteur's quadrant (Bannan-Ritland, 2003; Roschelle, Bakia, Toyama, & Patton, 2011). Design-based research's synergistic nature of theoretical and practical knowledge generation allows each to develop the other (diSessa & Cobb, 2004; Reeves, Herrington, & Oliver, 2005). Wang and Hannafin (2005) define DBR as,

> a systematic but flexible methodology aiming to improve educational practices through iterative analysis, design, development and implementation, based on collaboration among researchers and practitioners in real-world settings, and leading to contextually sensitive design principles and theories. (p. 6)

Similar to basic research, DBR studies seek to expand and refine the knowledge of theory. When using DBR, contextual variables are part of the study and are viewed as important elements in understanding the connection between theory and practice, and are not considered extraneous variables in need of control (O'Donnell, 2004). Similar to action research, which employs iterative cycles related to problem identification, solution generation, and solution evaluation for the purpose of understanding and solving local problems, DBR studies employ an ongoing approach to research that utilizes multiple phases and macro-, meso-, and micro-cycles (McKenney & Reeves, 2012) within one study. Even though DBR and action research may share epistemological and ontological foundations (Anderson & Shattuck, 2012), and employ similar cyclic processes within their methodology, the de-emphasizing of theoretical knowledge generation in action research differentiates the two forms (Morgan, 2013). Akin to evaluation research, DBR studies generates knowledge to inform stakeholders about the value of an innovation and produces knowledge about what stakeholders can do to improve the innovation within their contexts. Design-based research's additional purpose of generating knowledge about theory differentiates it from evaluation research. Similar to applied research, which aims to test the theoretical ideas and understanding within a natural setting, DBR studies go beyond the testing of theories by engaging in ongoing cycles of study that involve a systematic process of designing, developing, and implementing innovations to directly address education problems in real time. Design-based research aims to answer questions that generate knowledge of *what* worked, *how* it worked, and *why* it worked while understanding the contextual factors influencing the environment. Ultimately DBR studies aim to connect theory, innovation, and practice (Design Based Research Collective, 2003), thereby bridging the two purposes of scientific knowledge generation defined by Stokes.

Design-Based Research

Two decades ago, Brown (1992) and Collins (1992) separately concluded that experimental education research in laboratory settings did not always apply or transfer to the real-world classroom context. These two authors published landmark papers that launched DBR as a new genre within education research. Design-based research provides an approach to research that exemplifies Pasteur's quadrant by generating practical knowledge with an immediate use to address local problems and broadening theoretical knowledge through the implementation of research-based innovations (Bannan-Ritland, 2003; McKenney & Reeves, 2012; Roschelle et al., 2011).

Proponents of design-based research seek to address overarching questions such as "How do we design, develop, and implement an innovation to address a known education problem within a specific context?" or "How do we implement an existing educational innovation to make it work successfully in a novel education context?" Design-based research teams address these overarching questions by carrying out micro-, meso- and macro-cycles to answer specific questions about what works, how it works, how to improve what works, and why it works, utilizing a continuous improvement framework.

Three key features embody DBR: 1) collaboration with practitioners around local problems, 2) a pragmatic approach to addressing complexity, and 3) theoretical and practical cycles of inquiry (Dede, 2004; Tabak, 2004). Researchers using DBR work in teams utilizing theoretical and practical knowledge to design solutions within local contexts and then use multiple iterations of tweaking the innovation and studying it. McKenney and Reeves (2013) suggested that DBR utilizes a pragmatic approach that does not limit itself to a particular research design and concluded that the goals of DBR, not the methods, set it apart from other research types. Design-based research teams are encouraged to use what fits when needed, including pulling from qualitative and quantitative research methods, often resulting in mixed-methods studies. This encourages DBR scholars to keep updated on the most current developments in various types of research methods and designs.

Collaboration

The intermingling of university researchers and local practitioners results in the co-construction of knowledge and provides multiple benefits for both practitioners and scholars. Knowledge is generated and shared as interventions and innovations are designed and implemented, requiring local practitioners on DBR teams to assume the mantle of researcher and the university researcher to assume the mantle of practitioner.

University researchers begin to understand local constraints from an emic perspective (Cowie et al., 2010), questioning the design of studies that contribute solely to theory and encouraging alternative designs that increase usability, scalability, and sustainability (Dede, 2004). Being involved in the local setting exposes scholars to the disconnect between theory and practice; the collaborative relationship allows for engagement in the study of problems that have value to local stakeholders (Tabak, 2004). Further, Dede (2004) makes the argument that working with practitioners might prevent scholars from pinning any flaws in design on inadequate implementation.

Local practitioners collaborate with university researchers at every step of the research process, beginning with candid discussions of practical issues (Dede, 2004). By being involved in every aspect of the research, practitioners become aware of theoretical frameworks and understand ethical and methodological research practices (Dede, 2004). The role of practitioners as co-developers of innovations may lead to the development of tools educators are willing to adopt (Penuel, Fishman, Cheng, & Sabelli, 2011) and empower capacity building in change processes occurring within their institutions (Cowie et al., 2010).

By working together scholars and practitioners examine data through different viewpoints, leading to insights neither could achieve separately. Publishing findings allows for both voices to be present in the literature. In addition to generating useful products and principles, DBR also results in the professional development of all participants (McKenney, Nieveen, & van den

Akker, 2006), and helps bridge the theory-practice divide by contributing to practical and theoretical knowledge generation (Herrenkohl, Kawasaki, & Dewater, 2010; Nutley, 2003).

Pragmatic Approach

The pragmatic approach allows design-based researchers to be methodologically creative (McKenney & Reeves, 2012); however, a pragmatic outlook is not to be confused with an "anything goes" philosophy (Design-Based Research Collective, 2003, p. 6). Design-based research employs an eclectic approach in the design and implementation of research methods by drawing on all research designs (e.g., case study and quasi-experimental design) depending on the immediate need within the DBR study. Anderson and Shattuck (2012) referenced the ideas of John Dewey and American pragmatism in support of using methods that fit the context or "messiness" of the work occurring in naturalistic settings. In order to understand and implement evidence-based practices, we must study the contextual variables that influence fidelity of implementation. As Lamott (1994) stated, "reality is unforgivingly complex" (p.104). Design-based research acknowledges the complexity inherent in schools and in the process of learning. Through empirical practices, researchers employing DBR engage in designing and re-designing innovations to fit contextual variables, recognizing that the ability to transfer programs or innovations across contexts is difficult.

Theoretical and Practical Cycles

Design-based research studies are considered long-term rather than longitudinal in that practical knowledge and theoretical understanding develop over time. The emphasis is not only on the movement or change in variables over time, but also on gaining insight into *how*, *why*, and *what* works by conducting multiple iterative cycles within a single larger DBR study (McKenney & Reeves, 2012). Examining the connections between cycles connects theory to practice through continuous improvement of innovations and interventions during a DBR study.

The macro-cycle is focused on theoretical knowledge generation or fundamental understanding while the micro- and meso- cycles are more concerned with generating local, practical knowledge regarding use and implementation of the innovation. Through the totality of the cycles, the entire DBR process reveals the complexity of the innovation, implementation, and theoretical foundations. Each DBR macro-cycle is made up of meso-cycles. A meso-cycle is formed when an iteration of micro-cycles is complete and researchers can make decisions or report findings. A meso-cycle can tell the story of an iteration that takes place as the DBR team analyzes data regarding how the product was modified based upon contextual variables and how well it is working.

Each micro-cycle focuses on the development of the innovation itself, thereby giving a more intimate look into the decision making around a particular problem. A micro-cycle is one step in the empirical inquiry process and aims to describe in-depth steps taken by the research team while analyzing the problem, designing a solution, and evaluating the results. Micro-cycles generate localized knowledge and note variations and changes regarding an innovation or product.

The GenScope project. The findings and processes of the GenScope project (Horwitz & Christie, 1999; Horwitz, Neuman, & Schwartz, 1996), developed and implemented over the course of a decade through multiple iterations, map well onto these cycles. While researchers attempted to learn more about inquiry and exploration using computer-based manipulatives, practical and theoretical understanding developed and was refined during every cycle and phase. During the first iteration of micro-cycles researchers developed and implemented GenScope computer software, which was designed to teach middle and high school students about genetics. Analyzing their results during the first meso-cycle, researchers discovered that students did not have enough direction, that learning did not transfer into formal content knowledge, and that the program missed out on "teachable moments" (Horwitz & Christie, 1999). At this point the researchers only addressed necessary links to real-world applications and more open-ended investigations, leading to the development of Dragon Investigation worksheets. Unfortunately, this addition did not result in significant changes to their dependent variable.

After a second set of micro-cycles, researchers learned that context, such as the logistical placement of the computer lab outside of the classroom, was also affecting results by leading students to equate the computer program with play instead of learning (Horwitz & Christie, 1999). Taking everything that was learned through the meso-cycles, researchers developed a second model of the GenScope software called BioLogica, which built in computer-based feedback and included a pop-up prompting the students to turn to the teacher for help when needed. The next iteration also took contextual variables into consideration and moved laptops into the classrooms. All of these changes morphed a computer-based manipulative into a web-lab, leading to significant gains in classrooms that utilized BioLogica over those that did not (Horwitz & Christie, 1999). At the macro-level, researchers gained insights regarding student learning with regard to the transfer of knowledge using technologically-based formats. In addition, researchers were able to discuss new approaches to theory development that take practicality and applicability into consideration. Each cycle led researchers to develop a successful innovation for a certain educational environment (Hickey, Kindfield, Horwitz, & Christie, 1999).

Much like a motion picture, a DBR study seeks to tell the whole story to the observer rather than providing a photograph that requires the observer to create assumptions about what happened before or after the photo was taken. Continuous improvement is represented with the micro-cycles as the frames, the meso-cycles depicting each scene, and the assembled scenes comprising the macro-cycle which tells the full story about the design, innovation, and implementation process.

Examples of DBR in Education Research

Although the roots of design-based research were established in the fields of engineering and design, DBR has shown promise for education researchers in the last ten years. In the Biology Guided Inquiry Learning Environment project, Tabak (2004) described the intervention software and instructional activities used to enhance inquiry skills for middle and high school students working on a five-week evolutionary unit. Although the original design involved structured discussions with whole groups, the researchers and practitioners jointly realized that it was the impromptu discussions and teaching opportunities that happened organically that better solidified concepts around inquiry. After analyzing transcripts, the design team recognized patterns and built the premise for these types of discussions into the next iteration. Taking the local context into consideration and working with the practitioner allowed for insights that resulted in students getting one step closer to gaining a deeper understanding of inquiry. Tabak (2004) noted that a switch "from the notion of intervention as a 'prepackaged' artifact that is imposed on the local participants toward a notion of intervention as a process of iterative co-construction between 'outsiders' and 'insiders'" (p. 231) promoted both a deeper understanding of the context and support of novel forms of learning. On a theoretical level, insights were gleaned around inquiry-based learning, particularly relating to teacher-student group discussions. Characteristics that made this DBR study successful included collaboration between researchers and practitioners, iterative cycles of design over a period of years, and a pragmatic outlook towards naturally occurring phenomena.

Utilizing DBR also allowed Hoadley (2004) to follow revelations as they unfolded in the local context. In trying to promote productive participation and collaborative learning between people who were not in the same place, the Multimedia Forum Kiosk (later called *SpeakEasy* after multiple iterations) is a perfect example of how following a pragmatic approach leads to more practical, in-depth insights. Utilizing the innovation first in collegiate classrooms and then in a middle school science class allowed for the analysis of unanticipated consequences, including the use of anonymous responses. Hoadley (2004) probed and refuted theories related to anonymity and attribution in a way that would not have worked without iterative design, which allowed the "cultural practice" to develop the "nature of the tool" over time (p. 208). Overall, theoretical knowledge was developed regarding online collaborative learning through iterative cycles that were pragmatic in nature, allowing the research to take place at multiple educational levels.

Lai, Calandra, and Ma (2009) used a mixed methods approach to study pre-service teachers' difficulties with online journal writing. Based on the theoretical understanding of scaffolding, question prompts and a writing display were added to the original innovation. Conceptualizing a solution within a theoretical framework and checking on its application in a real-world context through six iterations led to results that significantly improved pre-service teacher reflection and contributed to theoretical knowledge on reflective practice and scaffolding in online environments.

Studies that deviated from the key features of DBR faced greater challenges with achieving successful outcomes. In the "Thrill Walabi" project, progress was jeopardized when an egalitarian partnership between researchers and practitioners did not exist and iterative cycles occurred without reflection (Leeman & Wardekker, 2011). Researchers, teachers, and amusement park staff who engaged in a study to improve pedagogy for a vocational course in the Netherlands failed to work collaboratively and share the decision making processes. Instead of joint reflection and design as is characteristic of DBR, problems between stakeholders and a lack of teacher voice resulted in unfulfilled aims. A lack of true collaboration led to power struggles and miscommunication. Although iterative cycles did occur, often no time was given in between for reflection, resulting in low utilization of acquired knowledge. Overall, very little theoretical or practical knowledge was gained from this study, which did not appropriately adhere to DBR's key features.

Expanding the Use of DBR

To meet this new call for DBR, we must begin to support its legitimacy as a research type, advocate for its inclusion in training of future researchers, and foster its representation in published literature.

Legitimacy of DBR

Randomized control trials (RCT) have often been held up as the benchmark design for rigorous education research (Department of Education, 2003) and may contribute to the underutilization of DBR. Randomized control trials seek to establish cause-and-effect relationships by controlling extraneous variables in order to perform "laboratory type" research in the field. The emphasis on establishing these cause-and-effect relationships has led some to refer to RCTs as the "gold standard" of scientific research (Department of Education, 2003; Shadish, Cook, & Campbell, 2001).

In reality, education research occurs in natural settings among complex and interrelated contextual variables, but the desire to tweak and change innovations violates the laboratory research practices that underscore RCT and may cause some scholars to raise questions regarding the legitimacy of DBR studies (Design Based Research Collective, 2003). An overreliance on randomized control trials to generate knowledge for education solutions, however, may only serve to sterilize the value of contextual variables and fail to provide a deeper understanding of the way practice and theory interact with one another in a natural setting.

The tweaking of innovations that occurs in DBR can raise questions of concern about the validity of DBR findings. The interventionist nature of DBR studies requires researchers to be more alert to issues surrounding validity and objectivity. Design-based research scholars suggest that objectivity and validity are addressed when researchers focus on being transparent, reflexive, and critical of their DBR study (Collins, Joseph, & Bielaczyc, 2004; Shavelson, Phillips, Towne, & Feuer, 2003). Additionally, promoting consensus on conclusions among stakeholders serves as a defense of validity of DBR results (O'Donnell, 2004).

Furthermore, DBR scholars legitimize their studies by employing established qualitative and quantitative validity practices based on the design of a study at each cycle level. These validity practices can include such actions as using narratives to document the understandings of participants involved in the study (Shavelson et al., 2003), collecting data using standardized tools from multiple sources, being present over a long period of time, and repeatedly measuring multiple dependent variables (Design Based Research Collective, 2003; Hoadley, 2004). Finally, Gutiérrez and Penuel (2014) advocate for "relevance to practice" as a criterion of rigor; this includes the perception of the problem as important by multiple stakeholders, the involvement of stakeholders in the research, and the recognition that accurate documentation of the research processes are as important as establishing standards of cause and effect (p. 20). By presenting these practices in their publications, DBR scholars allow readers to understand how conclusions are reached.

Design-based research seeks a balance between establishing cause-and-effect relationships while acknowledging the important role contextual variables play in the success of innovations. Design-based research allows for the use of randomized control trials in micro-cycles while valuing the contextual variables through meso-cycles, thereby promoting rigor within reality. The balance that is achieved between establishing cause-effect relationships and valuing contextual variables situates DBR as a type of research well suited to examine the complexity inherent in the practice of education

Training Future Researchers

As with all forms of education research, the credibility of the findings are tied to the actual implementation of the study by the researchers, and therefore DBR is subject to the same concerns about improper implementation as other types of education research. Thus, the importance of training future researchers and providing them the opportunity to engage in DBR as part of their education is critical for DBR to gain legitimacy.

Though on the rise, the use of DBR in education is still limited. Why are education researchers not using DBR more frequently? A potential reason is that DBR as a type of education research has had limited visibility, particularly in the training of new education researchers. Using the terms *design-based research, design experiments,* and *educational design research*, we examined the index of introductory research methodology textbooks (see Appendix) published by Pearson and Sage between 2004 and 2012 to determine to what extent DBR is present in the resources used for initial training of education researchers.

No reference to DBR was found in the reviewed textbooks, suggesting that exposure to DBR is limited if potentially nonexistent in the early training of future researchers in comparison to other types of research (e.g., basic, action, evaluation). Although textbooks dedicated to DBR as well as DBR chapters within advanced research methodology textbooks do exist (e.g., D'Amico, 2005; Kelly, Lesh, & Baek, 2008; McKenney & Reeves, 2012), the failure to include DBR in introductory texts promotes a false perception that it is reserved for scholars seeking alternative or more advanced forms of research designs. Authors of introductory research methods textbooks ought to consider adding descriptions and discussions of DBR as this would expose students to DBR earlier in their research training.

Simply providing an orientation to DBR in research methods courses may not be enough. Universities can create opportunities for beginning researchers to engage in DBR studies under the supervision of more experienced researchers. Anderson and Shattuck (2012) urged DBR scholars to create "legitimate space and roles for graduate students to undertake and 'own' significant pieces of this larger agenda" (p. 18). The characteristics of DBR allow for mentorship throughout a project (Bradley, 2004; Raval, 2010). McKenney & Reeves (2012) suggested incorporating graduate students into DBR studies and provided a model for DBR dissertations.

Dissemination of DBR

As the use of DBR expands, dissemination practices in education research need to be revisited. Currently, studies are published at the end of the entire DBR study, reflecting mostly the macro-cycle. Design-based research incorporates multiple studies employing micro- and meso- cycles within one macro-cycle, making one single article insufficient to cover the complexity of a DBR study. Space limitations in single articles prevent the sharing of key information from micro- and meso- cycles, resulting in an emphasis on reporting theoretical knowledge over practical knowledge. A better approach would be for researchers and practitioners of DBR studies to generate multiple articles on a single DBR study. These installments would highlight the DBR journey of design teams sharing their decision making, data collection, and analysis throughout the DBR study, and promote a dissemination of knowledge on continuous improvement during development.

The multi-article format encourages journals to re-conceptualize submission requirements to allow a series of publications from one DBR study. We suggest the following format to achieve this aim. The first article would set the stage by analyzing and exploring the naturally occurring problem, as well as providing a literature review synthesizing prior knowledge on the topic and describing the purpose of using DBR to address the problem. In subsequent articles authors would describe each meso-cycle/iteration in detail, including what was learned about the design, implementation, and evaluation during the micro-cycles within that meso-cycle. Practical knowledge generation would give other scholars, practitioners, and developers an in-depth view regarding how the design of the innovation evolved, how it was implemented, what steps were taken to make it work, and the decision making process along the way. These articles may have a greater practitioner draw, due to a heavy emphasis on contextual variables and how decisions were made. Reflecting on the macro-cycle in the last article, the DBR research team would synthesize what was learned by the project and elaborate on theoretical knowledge gained. Contributions to theoretical knowledge would detail how the fundamental principles of the innovation informed theory.

A DBR series of articles would promote theoretical as well as practical understanding, and thus bridge the science-to-service divide by allowing the voices of scholars and practitioners to be heard in unison. It should be noted that we caution against the arbitrary “cheap” publication of cycles, rather suggesting that researchers publish only substantial knowledge generation resulting from any cycle. Conference presentations provide opportunities for researchers to present DBR findings from cycles that may not have the substantial knowledge generation to meet the requirement for journal publication.

A continued and permanent presence of published DBR articles could lead to an expansion of professional educational organizations promoting DBR as a focus of conversation at conferences and seminars, allowing DBR scholars and practitioners to build a larger DBR community. Design-based research discussions in academic circles could lead to further use in research studies designed for school environments.

Conclusion

In order to improve teaching and learning, researchers and practitioners in the field of education need to know *what* works, *how* it works, *why* it works, and *how* to make it work in certain contexts. Knowledge generation for theoretical understanding and practical use leads to better innovations in schools. Moving forward, education researchers should evaluate the purpose of their work and consider research that fully represents Pasteur's quadrant. The qualities of DBR place it centrally in Pasteur's quadrant and make it a worthwhile approach to conducting research in educational settings. Taking a pragmatic approach that considers contextual variables as well as collecting, analyzing, and using real-time data through multiple cycles may lead to more long-term sustainability of innovations and interventions in schools, making the investment of time and money meaningful. Collaborative in nature, DBR studies bring together university researchers with local practitioners in order to fashion tools that truly work in our schools. In order to prepare for this future, novice researchers need to be exposed to this genre of research, along with traditional forms such as basic, applied, evaluation, and action research, early on in their methodology courses. All scholars and practitioners involved in the development and implementation of innovations at their schools can benefit if DBR should become better known through prominent educational journals and at annual conferences. Hoadley (2004) argued that "the promise of having better alignment in research—certain and sure links from theories to hypothesis to interventions to data gathering activities to interpretation and application—should be a strong incentive to continue to pursue the design based research approach" (p. 211). Given the complexity that underscores the issues present in the field of education, researchers should become more responsive to both the expansion of theoretical knowledge and the development of innovations to solve current issues. The time to advance DBR in education research is *right* as well as *right now*.

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Appendix: Introductory Textbooks

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