

*Design-Based Research: Old PER Wine in a New Bottle*¹

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Some prominent education researchers now work in Pasteur's interdisciplinary, use-inspired, basic-research quadrant doing what they call "Design-Based Research" (DBR). After quoting a description of educational DBR by one of its leading advocates, I attempt to make the case that: (a) some Physics Education Research (PER) is DBR, and has been DBR for several decades; (b) the DBR-like pre/post test movement could develop into a force sufficient to accelerate even the ponderous educational system; and (c) non-classical analyses of tests heretofore used primarily for pre/post testing might assist the understanding of "transfer."

WHAT IS DESIGN-BASED RESEARCH?

Anthony (Emmon) Kelly [1], guest editor of the *Educational Researcher* theme issue [2] on "The Role of Design in Educational Research" described educational "design-based research" as follows: "Inspired by the seminal work of Ann Brown [3,4] Allan Collins [5,7], Roy Pea [6], and Jan Hawkins [7], a growing number of researchers have begun to adopt the metaphors and methods of the design and engineering fields. . . . [The] emerging research dialect attempts to support arguments constructed around the results of active innovation and intervention in classrooms. The operative grammar, which draws upon models from design and engineering, is generative and transformative. It is directed primarily at understanding learning and teaching processes when the researcher is active as an educator Design research in education would fall under Stokes' [8] use-inspired basic research category. . . . [Pasteur's quadrant]. . . In Toulmin's [9] sense, this research is *clinical*. . . . [where the shared task of the experimenter, the designer, and the practitioner is to move the educational system from malfunction to function and not, primarily, the assured contribution to a body of basic knowledge propositions' [10]] Further, its proponents are willing to attempt to address, simultaneously and iteratively, the scientific processes of discovery, exploration, confirmation, and dissemination. In its goals and in its context of use, this emerging design research methodology attempts to be both scientific and educational."

SOME PER IS AND HAS BEEN DESIGN-BASED RESEARCH (DBR)

In their resource letter on physics education research (PER), McDermott & Redish [11] list about 160 empirical studies, extending over almost three decades, that (a) focus on the learning of physics by students, (b) represent systematic research, and (c) give procedures in sufficient detail that they can be reproduced. Of these studies, those reported by long-established PER groups [e.g.: Arizona State University, Berkeley (pre-1990), Carnegie Mellon (post-1990), Dickinson College, Kansas State University, North Carolina State University, Ohio State, and the Universities of: Maryland, Minnesota, and Washington] can be interpreted as examples of design-based research (DBR), even though none of those groups, as far as I know, ever characterized its own brand of PER as falling under the design-based research (DBR) banner held aloft by Kelly [1]. Nevertheless, I think it's fair to say (paraphrasing Kelly) that:

- (1) these researchers seem "willing to attempt to address, simultaneously and iteratively, the scientific processes of discovery, exploration, confirmation, and dissemination" with a research methodology that "attempts to be both scientific and educational"; and
- (2) their research: (a) involves active innovation and intervention in classrooms, (b) draws upon models from design and engineering, (c) is generative and transformative, (d) is directed primarily at understanding learning and teaching processes when the researcher is active as an educator, (e) could be placed in Stokes' use-inspired basic research category, and (f) attempts to move the educational system from malfunction to function. I submit, therefore, *that some PER qualifies as educational design-based research as characterized by Kelly.*

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Further support for this assertion is to be found in Lesson #5 of the physics education reform effort [12]: “*The development of effective educational methods within each discipline requires a redesign process of continuous long-term classroom use, feedback, assessment, research analysis, and revision.*” Wilson and Daviss [13] suggest that such a “redesign process,” used so successfully to advance technology in aviation, railroads, automobiles, and computers can be adapted to K-12 education reform through “System Redesign Schools.” Redesign processes in the reform of introductory undergraduate physics education have been undertaken and described by, among others, McDermott [14] and Hake [15].

Thus the role of design was recognized by Wilson and Daviss [13] in *Redesigning Education*, but their exemplary DBR-like program was apparently never implemented, presumably because of a lack of funding. Wilson & Barsky [16] later wrote (my *italics*): “We see the need for a launch of a research and development initiative in education, paralleling existing national research initiatives related to AIDS or global climate change . . . Today we have to think of education as demanding in multiple dimensions: as a science, *as a design challenge*, and as a performing art while still being an imperative for life in a democracy. Handed down traditions are no longer enough.”

The U.S. educational system’s monumental inertia - witness the stagnation of K-12 education and the inaction on the potentially fruitful Wilson/Daviss plan - was considered in a volume of *Daedalus* [17] that contains essays by researchers in education and by historians of more rapidly developing institutions - all with a DBR orientation - such as power systems, communications, health care, and agriculture; and that set out to answer a challenge posed by Wilson: “If other major American ‘systems’ have so effectively demonstrated the ability to change, why has the education ‘system’ been so singularly resistant to change? What might the lessons learned from other systems’ efforts to adapt and evolve have to teach us about bringing about change - successful change - in America’s schools?”

DBR-LIKE PRE/POST TESTING MIGHT BRING ABOUT SUCCESSFUL CHANGE IN AMERICA’S SCHOOLS

Aside from Wilson & Barsky’s [16] vision of a new applied research discipline called “change science,” the potentially seminal issue of *Daedalus* [17] did not, as far as I know, provoke any ideas that were actively pursued to overcome the inertia of the educational system. But more recently Slavin [18] has argued that

randomized control trials (RCT’s), now hailed as the gold standard for measuring an intervention’s true effect by the U.S. Dept. of Education’s Institute for Educational Sciences [19], will lead to successful change in the education system - never mind the problem of inadequately prepared teachers and the rudimentary state of exploratory research. Although RCT’s will *not*, in my judgment, be the gold bullet that will transform K-12 education as maintained by Slavin, the *Daedalus* [17] discussions of the relatively rapid development of non-educational DBR-driven systems and the educational DBR literature [e.g., the articles in ref. 2 and references therein], suggest that *educational DBR might develop into a force sufficient to accelerate the ponderous educational system.*

As an example, I think that the DBR-like multi-disciplinary pre/post testing movement [for a discussion see Hake [20]], initiated in large part by the landmark physics-education research of Ibrahim Halloun and David Hestenes [21], has the potential to drastically improve undergraduate science/math education (SME) instruction and thereby substantially upgrade K-12 SME. In my opinion, vigorous reform of K-12 SME is required to raise the appallingly low level of SM literacy among the general population [22,23], and thus increase our chances of solving the monumental SM intensive problems (economic, social, political, and environmental) that beset us.

What is the (generally unrecognized) connection of undergraduate and K-12 SME? Just this: currently, many prospective K-12 teachers derive little conceptual understanding from traditional undergraduate introductory SM courses and then either tend to teach as they were taught (with similar negative results), or else attempt reform curricula without the conceptual understanding and pedagogical content knowledge [24] required for their successful implementation. As emphasized by Goodlad [25] to deaf ears: “Few matters are more important than the quality of the teachers in our nation’s schools. Few matters are as neglected A central thesis of this book is that there is a natural connection between good teachers and good schools and that this connection has been largely ignored. . . . *It is folly to assume that schools can be exemplary when their stewards are ill-prepared.*” (My *italics*.)

FROM PRE/POST TESTING TO INVESTIGATION OF TRANSFER

Most of the analysis of the *Mechanics Diagnostic* (MD) [21] test, *Force Concept Inventory* (FCI) [26], *Force Motion Concept Evaluation* (FMCE) [27], and other physics diagnostic tests (for listings see [28]) have been done within the framework of “Classical Test

Theory” in which only the number of correct answers is considered in the scoring. However more sophisticated analyses are being developed [e.g., by Bao & Redish [29] for the FCI, and by Thornton [30] for the FMCE. These analyses can indicate incorrect student models that students form during instruction in a single course or in a series of courses successively redesigned in attempts to improve their effectiveness; suggest possible pedagogical improvements; and provide data for the investigation of “transfer,” i.e., the transfer of learning or capability from one area to another [Bransford et al. [31, Chap, 3 “Learning and Transfer”], Barnett & Ceci [32], Lobato [33], Hammer [34], Rebello et al. [35].

Research on “transfer” is not easy. Barnett & Ceci’s [32] abstract reads, in part: “Despite a century’s worth of research, spanning over 5,000 articles, chapters, and books, the claims and counterclaims surrounding the question of whether far transfer occurs are no nearer resolution today than at the turn of the previous century. We argue the reason for this confusion is a failure to specify various dimensions along which transfer can occur, resulting in comparisons of ‘apples and oranges’. . . the past 100 years of research shows that evidence for transfer under some conditions is substantial but critical conditions for many key questions are as yet untested.”

Could sophisticated analyses of conceptual tests such as the FCI and FMCE offer a productive path to the understanding of transfer? Design-based researcher Joanne Lobato [33] (2003) writes (my *italics*): “*Reflecting upon several cycles of design led to a more nuanced and differentiated view of levels of transfer.* Lobato et al. [36] discussed how a further revision of their design approach to slope . . . (evidently in the mathematical sense). . . resulted in evidence of even more sophisticated levels of transfer. Identifying levels of increasing sophistication in non-normative or incorrect displays of transfer is related to Minstrell’s [37] articulation of facets of students’ understanding of physics. In Minstrell’s approach one can identify a particular facet as indicative of more complex and sophisticated understanding than another facet, even when both facets represent incorrect or non-normative reasoning. One can similarly identify levels of actor-oriented transfer, which is powerful for design studies because moving up levels of sophistication may be linked with successive iterations in the design cycle.”

It would seem that “reflecting upon several cycles of design” might be augmented by non-classical analyses of tests heretofore used primarily for pre/post testing. In fact, Rebello et al. [34] have already analyzed student

responses to interview questions on FCI problems in an attempt to gain insight on transfer.

CONCLUSIONS

Design-based research has been pursued in physics education research for almost three decades, evidently unbeknownst to psychologists, cognitive scientists, mathematicians, and education specialists. The deplorable insularity of educational research that has shielded PER’s for DBR’s and vice versa has been discussed in ref. 20. In my opinion, the DBR-like pre/post test movement has the potential to drastically improve first undergraduate and then, through better prepared teachers, K-12 education. Diagnostic tests of the salient concepts of core sciences and mathematics, developed by disciplinary experts engaged in rigorous qualitative and quantitative research, can promote the pre/post testing movement and thereby student learning. Moreover, if such diagnostic test results are scored so as to indicate the succession of incorrect models that students form during instruction, then our understanding of “transfer” may be enhanced, leading to further improvement in the effectiveness of education.

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² More extensive references along with hot-linked URL’s (generally omitted here because of space limitations) are given in ref. 20.

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