121st ASEE Annual Conference & Exposition
Indianapolis, IN
June 15-18, 2014
Paper ID #9995

What's wrong with Evidence? Epistemological Roots and Pedagogical Implications of "Evidence-based Practice" in STEM education

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Abstract
Education's drive toward instrumentality is manifest in the no-child left behind regime of K-12 education in which "rigorous" curricula are measured by how efficiently and cost-effectively information is transferred. It is this context that informs the surge in popularity of "evidence based practice" across STEM education, with grave consequences for the field of engineering education research and for liberal education efforts in engineering.

This paper first examines the history and epistemological roots of evidence based practice, beginning with the field of medicine, where randomized controlled field trials are the *sine qua non* of validity and rigor. What ways of knowing are included and excluded in evidence based practice? What counts as evidence? What questions are worth asking, and what questions are out of bounds in this regime? How have federal government definitions that guide evidence based research reproduced certain values and assumptions in our community as we apply standards of rigor in engineering education research?

The paper then takes up the pedagogical implications of the evidence based model in which interventions are the sole purview of teachers, with presumed power to *cause* students to learn "better." The contradictions of using this approach despite "learner centered" rhetoric lead us to a closer examination of enacted and intended pedagogies in engineering education. A critical practice calls out the lack of reflexivity in evidence based practice; critical practice asks only what is effective in a classroom, not what is appropriate, or what should be learned.

Those of us concerned about liberal education in engineering ought to be especially wary of evidenced based practice because it stands to narrow our research epistemologies, limit our pedagogies, and inhibit our critical practice.

Roots and Contexts for emergence of evidence based practice

Engineering educators and engineering education researchers need to continually consider the larger education policy contexts of our work. The influence of policy initiatives and educational movements like "No Child Left Behind," "Outcomes Based Education," or "Race to the Top" are manifest in engineering education, and we need to increase our attention to and participation in public debate to fully understand their impacts on engineering education. In this section I seek to briefly trace the political antecedents of "evidence based practice" which currently guides federal funding for engineering education research.

Outcomes Based Education – Underlying the federal K-12 policy initiatives of the last decade is a movement for outcomes based education (OBE), largely formed out of the work of Bill Spady[11] dating back to the 1980s, and characterized by Towers[12] as having four elements: clearly defined outcomes; achievement based measures; multiple assessment strategies; and sufficient time and assistance supporting student achievement of outcomes. Engineering educators will recognize the influence of OBE on the 1990s reforms that resulted in ABET 2000. I have summarized the ideological roots of OBE in previous work[13] as a hybrid of educational literature

on mastery, positivist evidence-based epistemologies, early 20th century corporate models of Ford and Taylor, and present-day corporate jargon.[14-16]

No child left behind (NCLB) – the 2001 No Child Left Behind Act[1] brought about an era of yearly testing as part of a standards-based reform effort focused narrowly on performance outcomes in reading and math. Reform strategies were required to be grounded in "scientifically based research," which had a specific definition encoded in the law. Much has been written about the impact of this law on public education, with some critics noting a narrowing of education to focus on certain skill sets that improve test performance and certain subjects (reading and math) to the detriment of others (arts, physical education, social sciences, foreign language).[2] Objections to the centrality of standardized testing focus on the ways in which high-stakes testing disconnects students' lives from learning, and deskills teachers, reducing education to instrumental test preparation.[3] Even more damning critiques from critical pedagogy scholars Henry Giroux, Rodolfo Leyva, and Peter McClaren focus on how NCLB ultimately provides choice only to the most privileged students in the nation while limiting opportunities for the rest of the population, serving and reproducing the neoliberal economic status quo.[4-6]

Race to the Top (RTTT) – In 2009, the Department of Education launched a competitive multi-billion dollar grant process that rewarded states who could (inter alia) demonstrate improved scores on teachers' and principals' annual performance reviews, remove restrictions on charter schools, and adopt Common Core standards.[7] This reinforces the problematic standards-based reform approach of NCLB, as teachers' performance assessments have many of the same accuracy problems as standardized testing of students, and mandated "scientifically based" rubrics seem to some teachers to be incompatible with good teaching.[8] RTTT further reinforces social inequality in education by allocating funds to select states.[9] In particular the expansion of charter schools (along with the closing of low-performing schools under NCLB) restrict access for low-income and minority children, as public funding is drained away from public education toward privately run schools that do not necessarily have improved performance.[10]

Evidence-Based Practice in Medicine and Education

In medicine the phrase Evidence-based Medicine gained prominence through the 1990s as a new manifestation of a centuries-old argument about how research and clinical practice ought to relate to one another.[17-18] It seeks to base clinical decisions on high quality research, with Randomized Controlled Trials (RCTs) held up as the gold standard of good evidence. Even in medicine, this approach has its limitations. Some have pointed to the narrow definition of evidence focused on quantitative research, particularly RCTs, which are not relevant for all contexts or fields of medicine.[19] Taking a social justice approach, Wendy Rogers[20] has argued that evidence based medicine does not support decision making for groups that are under-researched and other vulnerable populations including low-income, minority, and mentally ill patients, compounding negative effects on these populations.

> EBM turns our attention away from social and cultural factors that influence health and focuses on a narrow biomedical and individualistic model of health. Those with the greatest burden of ill health are left disenfranchised, as there is little research that is relevant to them, there is poor access to treatments, and

> attention is diverted away from activities that might have a much greater impact on their health (141).

It did not take long for this framework to find its way into education, despite its known limitations, let alone the inappropriateness of transferring a patient model into educational settings. It caught hold of an older pragmatic desire for teachers to employ effective strategies, i.e. "what works"[21] – and what better way to determine what works than this evidence based approach borrowed from medicine? These ideas emerged in the mid and late 1990s and were codified into NCLB and other federal laws by the early 2000s as "scientifically based" practices.[22] A debate raged in the education community about this trend in the years leading up to and immediately after NCLB. Many in the education community raised concerns including the over-reliance on experimental design and positivist epistemologies, and the loss of other ways of knowing including in fields like history and philosophy as well affective, postmodern, and practical approaches.[22] While the federal definitions inched toward including a broader range of research designs based on public outcry in the education community, ultimately the changes were modest and many of the critiques continue to hold a decade later.[23]

One of the continuing critiques (in addition to epistemic critiques, which will be discussed at length below) regards the appropriateness of the medical analogy. David Olson[24] took evidence-based practice advocate Robert Slavin[25] to task over the issue that students simply aren't patients, and the "treatments" in educational settings are metaphorical at best. For example, in practical terms, one cannot avoid the Hawthorn effect – the changes that inevitably occur in behavior when individuals know they are being studied. Olson notes that it is not possible to enact double blind trials, assigning a placebo randomly to one group, and one cannot control the beliefs that students develop about the expected effectiveness of a "treatment" – nor should researchers try to control these beliefs, which are themselves an essential part of their learning process. "Treatments" in education are not uniform; doses cannot be controlled, and there are too many activities that make up a single treatment, and too many confounding variables, including differences among individual learners. To pretend one can control for all of these, or to ignore much of this context, is to be overly reductionist and produce meaningless results. Finally, Olson notes, based on results from prior large scale studies, "Treatments that on the surface may appear quite different turn out to be quite similar when they are implemented under constraints of a fixed set of goals and common criteria for achievement." The impact of the overall context may overwhelm the effects of particular treatments. Engineering education researchers would be wise to take heed of this phenomenon, especially given the constraints of the fixed set of goals and common criteria for achievement that constitute ABET accreditation.

Evidence based approaches resonate with a new emphasis on "rigorous" curricula in elementary and secondary education, which are measured by how efficiently and cost-effectively information is transferred.[3] In higher education, we see parallels to this emphasis on efficiency as Massive Open Online Courses (MOOCs) are hyped as the solution to budgetary crises, taken largely as reasonable facsimiles of what goes on in face to face classrooms. If information transfer is all that is required for education, MOOCs appear to be a great vehicle for doing just that, and their weaknesses in hands-on or face-to-face interactions are set aside in the name of efficiency

This new rigor should be of particular concern to liberal education advocates in engineering. The devaluing of knowledge from history, from culture, from philosophy, and other disciplines – and the devaluing of context in the name of abstraction -- explains how these trends have taken such strong hold in engineering education, since engineering has a long history of casting aside social and humanistic knowledge. Those of us who advocate that engineers ought to learn how to think from a broad set of disciplines must also advocate for multiple ways of knowing, multiple theories, and multiple valid research methods for determining how students best learn to think from these disciplines.

Epistemology of Evidence Based Practice

The most damaging aspects of evidence based practice lie in its constraint of epistemologies for engineering education research; it limits the diversity of ways of knowing, and limits the types of new knowledge that can be considered valid. If randomized controlled trials are the *sine qua non* of validity and rigor, what ways of knowing are excluded? The implication of calling one thing evidence-based, of course, is to suggest that something else is based without any evidence. What does and does not count as evidence? What questions are worth asking, and what questions are out of bounds in this regime? What happens to non-experimental knowledge, to history, to theory, to philosophy? And what, in turn, happens to the liberal education of engineers once these ways of knowing are invalidated (or simply not supported) in engineering education research?

Olson's critique of evidence-based practice[24] included several epistemological points. First, there are problematic assumptions about causality along the lines of a medical model in which a treatment is expected to induce a measurable causal effect. This denies the role of the student in their own education, as the model only makes sense if students are assumed to be passive receptacles of different treatments. Gert Biesta[26] argues rather that

> If teaching is to have any effect on learning, it is because of the fact that students interpret and try to make sense of what they are being taught. It is only through processes of (mutual) interpretation that education is possible. (8)

Biesta envisions a conceptualization of education research in which noncausal interactions in education are taken into account, one in which education is seen as a moral rather than merely a technical practice, resurrecting Aristotle's distinction between *phronesis* (practical wisdom) and *techne* (instrumental knowledge). He argues that the importance of effectiveness of interventions pales in comparison to the importance of the educational value or desirability of learning opportunities.

Ian Sanderson[27] identifies the underlying epistemology of evidence based practice as instrumental rationality, in which decision makers are presumed to produce objective, rational choices by extracting empirical questions from their political, normative, and organizational contexts. The evidence-based process is instrumental in that it is a means to a given end, and the ethics or morality of those ends is not considered. This critique applies to engineering epistemologies as well, as engineering problem solving similarly suffers from omissions of ethical/moral dimensions.[28] Biesta, citing Sanderson, notes that the focus on "effective interventions" – essentially on "what works" – completely ignores the role of judgment, critical

for professions like engineering that have a moral dimension – what *should* be learned? Not just what is effective, but also what is appropriate?

This is not to say it doesn't matter whether a technique is effective or not. Rather it is to refocus our priorities first on what *ought* to be learned, and how. If we do this, then the very meaning of effectiveness will change fundamentally, away from an efficiency framework focused on outcomes, reoriented to the moral purposes of education.

Another unacknowledged assumption of evidence-based practice in educational research is that empirical knowledge will somehow amount to or result in theoretical breakthroughs.[24] In fact, evidence based practice is theoretically impoverished, precisely because it fails to value ways of knowing outside positivist empiricism.

Biesta[26] further argues that Dewey's theory of knowing can provide an alternative epistemology for education research, because it is not based on a dualism between mind and materiality. Instead of separating the self from the knowable world, Dewey conceived an action-theoretical framework in which ways of knowing are active – they are ways of *doing*. Biesta notes that for Dewey, knowledge is not prescriptive, and research would not dictate practice: "no conclusion of scientific research can be converted into an immediate rule of educational art" (19).[29] Reflexivity (a practice of reflection that is critical of its own power relations) requires integrating knowledge with reflection and acting informed by knowledge, but not constrained by it. This is akin to Freire's notion of praxis, in which theory and action reciprocate.[30]

It was a deliberate strategy our community set a decade or more ago – to enact change in engineering education -- to generate "hard data" that would convince engineering deans and high level university administrators -- even our peers who teach engineering -- that we need to change engineering education. Some thought they would listen to the data. But we are finding, with Dewey, that it is not that simple; research has not dictated practice. The causal theory that rigorous data causes change was wrong; the theory that changing to an outcomes-based ABET model would induce liberal education of engineers was wrong[13]; can we draw on social movements that have succeeded in creating widespread cultural change to devise new strategies (based on experience rather than evidence) for change in engineering education? Cesar Chavez famously said:

> The name of the game is to talk to people. If you don't talk to people, you can't get started...You knock on twenty doors or so, and twenty guys tell you to go to hell, or that they haven't got time. But maybe at the fortieth or sixtieth house you find the one guy who is all you need. You're not going to organize everything; you're just going to get it started.[31]

Both the spirit and the tactics of organizing are not something endemic to engineering communities, but if we were to study and learn, perhaps in the tradition of Myles Horton and the Highlander Center, we might develop more effective strategies for cultural and institutional change.

Implications for Pedagogy

What are the pedagogical implications of the evidence based model in which interventions are the sole purview of teachers, in turn causing students to learn "better"? Clearly this hearkens to the "banking system" of education Paulo Freire[30] critiqued more than 40 years ago. It points to what Elliot Eisner[32] terms Curriculum as Technology:

> …knowledge is viewed as structured disciplines that are complete and coherent; have been validated through verifiable, value-neutral means; and are passively described as factual and explanatory, not evaluative. These neatly ordered boxes of verified structures of knowledge can be broken into component parts for easy acquisition by learners new to the discipline. These knowledge components can be easily measured in efficient, reliable, controllable ways (224).[3]

This sounds a lot like the 1930 Wickenden report on engineering education:

> Engineering education reflects our national genius for quantity production. Pressed to get a maximum result in a minimum of time, engineering educators have borrowed, half unconsciously, from the management methods of industry. The essence of the scheme consists in first visualizing the process as a whole. Then dividing it into major steps in a logical progression and finally breaking the work down into small units to be done in a definite sequence, under prearranged conditions and with the materials supplied precisely when needed and in the most convenient form, the task sequence to be carried out under close supervision, with continuous inspection and grading of piece parts, and the rewards to be paid in terms of a standard task with quality bonus. (109) [33]

This Fordist factory conceptualization of learning follows from these epistemic assumptions and precludes liberal education in any but the most perfunctory modular fashion. Capper and Jamison[16] would likely add that the structural-functionalist nature of this learning model facilitates the goal of educational institutions to train students to perform in an existing social order. "Success means mastering what people other than the student deem important and performing the mastered material in schools and society as they are currently structured" (439). Deep relational encounters that permanently alter one's world view happen in spite of rather than because of this pedagogical design.

The fact that "evidence-based" thinking has been coupled with "learner-centered" or "active learning" initiatives -- even used to assess their effectiveness -- is anathema to the goals of learner-centered education. This contradiction suggests the engineering education community might attend more closely to intended vs. enacted pedagogies in our classrooms. The ease with which this slippage has occurred points to the importance of our own epistemic awareness. Because our own educations in most cases relied on a narrow range of epistemic frames, and because our own educations occurred within certain power structures which likely continue to this day, eternal vigilance and reflexive practice is required to recognize and resist these constrictions. Communities of practice focused on identifying and dismantling these barriers of thought and action would be particularly beneficial.

I have noted elsewhere, but it bears repeating here, that ABET, like other forms of outcomes based education, is outcome centered rather than learner centered.[13] While externally imposed outcomes that go unquestioned present their own set of problems, the outcome centered approach is itself change limiting; in this sense it does not matter who sets the outcomes, or on what scale they are implemented. Enacting pedagogies that are learner centered but ultimately subject to an outcome-centered regime severely limits their impact. Process matters, but outcomes-based thinking presumes that the ends justify the means. We have been too focused on the destination and need to consider the experience of the journey for students.

We also need to remember that we do not and cannot operate outside of this group of assumptions that has brought us outcome-based learning, evidence-based practice, and no child left behind. What we can do is engage in a critical practice of reflexivity that continues to ask not what is effective in a classroom, but what is appropriate, what should be learned.

Conclusion

Those of us concerned about liberal education in engineering ought to be especially wary of evidence based practice because it stands to affect our research epistemologies, our pedagogies, and our critical practice. While many who are critical of these practices in either medicine or education have argued for making evidence based practice more inclusive, or for softening language to "evidence informed," "evidence influenced," or "evidence-aware" rather than "evidence based", these reformist strategies do not resolve the underlying problem of narrow epistemological assumptions about what constitutes valid knowledge. If we limit how knowledge can be produced in our field, we suffer in both intellectual and practical terms, because how we know and how we act are indeed interconnected.

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