Creating Theoretical Insights in Engineering Education

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In the last five years, the engineering education community has made remarkable progress towards institutionalization as a field of scholarship. From a community of interest formed by people concerned with improving engineering pedagogy, the field has matured into a research-based discipline with great vigor (Streveler and Smith, 2006). While this research-driven focus is welcome progress, one can detect a growing sense of unease and confusion on the matter of *theory*. Many stakeholders in the field see a dearth of theory-informed research and practice as a grave concern and remind us that theoretical development is paramount for the advancement of the field (Kemnitzer, 2008). On the other hand, several scholars contend that undue emphasis on theory undercuts the pragmatism of education and can hinder a smooth exchange of research outcomes. This ambiguity around the nature and role of theory creates a situation where theory often becomes an artificial gesture to get research published rather than a legitimate foundation and goal of scholarship.

Engineering education, by necessity, is an interdisciplinary endeavor and scholars in the field bring a notion of theory they were exposed to during their disciplinary training. Often engineering educators are trained in the physical and engineering sciences and have a largely positivist understanding of the world. Meanwhile, scholars trained in the social sciences might be exposed to the positivist tradition but often practice an interpretive approach. This epistemological and ontological gulf is reflected in diverse views about the nature and role of theory in the field, particularly the idea that theorizing is orthogonal to practice (also see Borrego, 2007).

This gulf, however, is largely an academic creation that can be bridged. Other applied fields have grappled with similar issues but have been quite successful at building theory-informed research agendas with meaningful potential for application (*Academy of Management Review*, 1989; *Administrative Science Quarterly*, 1995; Fiske, 2004). I believe that engineering education can similarly achieve constructive dialogue on the nature and role of theory, and more importantly can create theoretical insights with practical implementation in the classroom.

THEORY IN RESEARCH AND PRACTICE

We are all subjects of our own epistemology and ontology, and in our selection of research topics, data collection methods, analysis strategies, and presentation of results, we signal where we stand. Furthermore, even in our practice, whether of teaching or conducting research, and whether we intend to or not, we are always involved in theory-making. Therefore, it is important to recognize the critical role theory plays in our profession. But what exactly is theory, and how does it impact research practice?

Susan Fiske (2004), an eminent social psychologist, argues that a good theory in the social sciences posits causal relationships, attempts to be coherent, tells a good story, aims for parsimony, is testable, proves fertile, and solves problems. Causality, the primary criterion of a theory in the natural sciences, is the ability to explain how observed phenomena are connected and is the ultimate goal of any theory. Coherence is the basic idea that arguments flow from each other and contradiction is avoided. A theory tells a good story by revolving around an interesting problem with an equally or more interesting answer and is parsimonious in the telling of the story by being simple and effective. The theory should be testable by other scholars and it should be fertile in generating interest and scholarship. Finally, particularly for social scientists, a hallmark of a good theory is its ability to provide a basis for solving real world societal problems.

Another useful way to understand theory is to look at what it is *not*. Sutton and Staw (1995) outline five common elements appearing in research papers that scholars often mistake for theory: references, data, diagrams, variables, and hypotheses. They argue that authors need to go beyond providing a laundry list of theoretical references and instead need to present "explanation of why the theory or approach leads to a new or unanswered theoretical question" (p. 373). They also contend that theory informed research must: (1) explain why certain patterns were observed in the data, (2) specify how variables were generated and how they are connected, (3) spell out the underlying logic behind visual representations used in a paper, and (4) support through logical arguments of why certain relationships are expected to occur.

Kurt Lewin, one of the founding fathers of the field of social psychology, once remarked that, "Nothing is as practical as a good theory." Although this adage sounds simplistic, it points us towards useful functions of theory in relation to research and writing. *First*, theory situates our findings or ideas in an existing scholarly conversation and shows clearly how our findings or arguments build upon or transcend prior work. *Second*, theory helps us provide succinct and coherent explanations for real-world behavior. The usefulness of theory is its interpretative function. Through it we contextualize the world around us and our actions in the world. *Third*, theory guides us in constructing knowledge right from the very beginning of a research endeavor by shaping the design of the study itself. A

theoretical foundation for data collection and analysis helps avoid regurgitation and results in creative outcomes to help build and grow a body of knowledge. *Fourth*, theory assists us in the diffusion of research results by providing a guiding framework, a narrative structure, a discourse, or a schema, to assist us in talking about our work and its usefulness (Jamieson and Lohmann, 2009; Watson, 2009).

MAKING THEORY SERVE ENGINEERING EDUCATION RESEARCH

As engineering education scholars, our mission and goals are different than those of practicing engineers. Our scholarly and service objective is to go beyond prescribing solutions to specific problems by developing broader frameworks that can help solve classes of problems and can shed light on global themes of problem solving. The explanations we provide have to be applicable to more than a single case even if we draw on data that comes from local sample sets. It is this synthesis of data and translation into theory that constitutes critical scholarly activity. In the end, theory-making is the design of tools for improving understanding—it is how we contribute to knowledge. Broadly, in the social sciences the primary purpose of a theory is to help explain our observations in a coherent fashion and provide models for meaning-making that are applicable across a range of observations. Although prediction is something engineering education researchers are interested in, our core contribution is to provide succinct and reasoned explanations of the world around us so that we understand the underlying mechanisms and can design and construct better learning environments.

We can and must take concrete steps to improve the theoretical nature of our research as a path toward enhancing the learning skills of future engineers. I would like to make four practical suggestions toward that end. *First*, the field needs more synthetic review articles that provide a critical and comprehensive overview of theoretical paradigms with emphasis on its applicability to engineering education. Examples of this form can be found in series such as the *Annual Review of Psychology/Sociology/Anthropology* or journals such as the *Academy of Management Review*. In a similar vein, journals in engineering education can also publish special issues of research produced within particular theoretical paradigms or those that compare and contrast different theories to tackle a common problem. *Second*, workshops and conference sessions around theoretical themes can aid engineering education researchers in defining the boundaries of a theoretical paradigm prior to its formal use in one's research methods. *Third*, the review process for journals can be shaped towards feedback and revision to bring out theory rather than showcasing data without theoretical development or providing feedback based on a strict set of guidelines that prevents novel and risky ideas from making it to print. *Fourth*, data are critical for generating theory and therefore researchers should be encouraged to combine smaller studies they have undertaken into larger articles that are more theoretically grounded. It is hard in educational research to show the effects of interventions in short term beyond whether students liked an intervention or not. Therefore, systematic integration of research and data in conjunction with theoretical development is needed.

MOVING FORWARD

Five years ago, Lee Shulman (2005, p. 12) urged us to reach beyond our field and imagine our work as contributing to the sciences of learning and teaching in addition to our specific domain; it is time we take this challenge seriously (also see Streveler and Smith, 2006). I argue that theoretical development through introspective examination of the role and nature of theory in engineering education can help us achieve this goal by building a stronger foundation for both disciplinary and interdisciplinary scholarship. One possible way to advance disciplinary theorizing is by identifying and developing specific research areas within the broad field of engineering education, such as *engineering learning*. There is a huge array of options to advance interdisciplinary work. We can begin by collaborating and contributing to disciplines such as educational psychology, learning sciences, social psychology, organization science, science and technology studies, human-computer interaction, and information sciences. Finally, given the applied nature of engineering education research, it is imperative that theoretical developments are followed by synthesis work and implementation (Watson, 2009). But first, we ought to be fully cognizant of our current intentions and efforts; we can advance only through a reflective understanding of where we stand.

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