Demystifying Theory-Based Research

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DEL Talk

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Topics

- Theory and how it is used
- Theory in engineering education
- Examples of career-related theories

Quantitative, Qualitative, and Mixed Research Methods in Engineering Education

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ABSTRACT

The purpose of this research review is to open dialog about quantitative, qualitative, and mixed research methods in engineering education research. Our position is that no particular method is privileged over any other. Rather, the choice must be driven by the research questions. For each approach we offer a definition, aims, appropriate research questions, evaluation criteria, and examples from the *Journal of Engineering Education*. Then, we present empirical results from a prestigious international conference on engineering education research. Participants expressed disappointment in the low representation of qualitative studies; nonetheless, there appeared to be a strong preference for quantitative methods, particularly classroom-based experiments. Given the wide variety of issues still to be explored within engineering education, we expect that quantitative, qualitative, and mixed approaches will be essential in the future. We encourage readers to further investigate alternate research methods by accessing some of our sources and collaborating across education/social science and engineering disciplinary boundaries.

Keywords: quantitative, qualitative, and mixed-methods research

I. INTRODUCTION

Engineering education[1] as a developing field shares many characteristics of a discipline undergoing a scientific revolution as described by Thomas Kuhn (1962, 1970). As Kuhn describes the transition associated with change, he asserts that negotiation over the path and endpoint are inevitable. While engineering education is not undergoing a purely scientific revolution in Kuhnian terms, which occurs when established disciplines experience a paradigm change, development of the field bears many similarities to his scientific revolution argument (Borrego, 2007b; Borrego et al., 2008). For example, Kuhn maintains that new paradigms require prior understandings to be reconstructed. He argues that this time of "tradition shattering" is difficult, time consuming, and met with much resistance. In this case, the established disciplines which must undergo tradition shattering are the constituent engineering, education, and other disciplines in which most engineering education researchers were traditionally trained. This may be particularly frustrating to engineers and others who are more accustomed to working within long-standing paradigms (Borrego, 2007a).

Kuhn argues that formation of a paradigm is necessary and assists researchers in building a discipline. In order to establish itself as a research field, engineering education is negotiating input from both qualitative and quantitative methods advocates, both with strong investment in the field. Though there have been efforts to identify important research areas (Steering Committee of the National Engineering Education Research Colloquies, 2006) and results (Heywood, 2005), appropriate methods, convincing evidence, and standards for evaluating the quality of research studies are just as important to scientific field development.

The purpose of this paper is to open a dialog of methods in engineering education research. Our position is that no particular method (quantitative, qualitative, or mixed) is privileged over any other. Rather, the choice of method must be driven by the research questions (Creswell, 2002). For quantitative, qualitative, and mixed methods, we offer a basic definition, aims, appropriate research questions, or hypotheses. A separate section compares and contrasts evaluation criteria for the three approaches. Our references are a combination of methods texts from social sciences and examples from the *Journal of Engineering Education* (JEE) since its repositioning as a scholarly journal in 1993 (Ernst, 1993) (The journal was also repositioned in 2003 to focus exclusively on research (*Journal of Engineering Education*, 2005).) In our JEE search, we emphasized articles framed as investigating research questions or testing hypotheses over descriptions of interventions or assessment methods. One notable exception is articles directly addressing methods, which, while directly relevant to research methods, were often framed as assessment topics. Our intention is not to provide a comprehensive review of studies, but rather to use selected examples to illustrate the ways in which educational research methods have been and could be used in engineering education.

Finally, we offer some empirical data to substantiate our claims that methods need to be more openly discussed in engineering education. Observations at an international engineering education research conference uncovered a strong preference for quantitative methods and their associated evaluation criteria, likely due to most participants' technical training. While participants lamented a lack of reviewers' acceptance or understanding of qualitative work, the same participants enacted a quantitative,

[1]By Engineering Education, we refer to the field of engineering education research, not the practice of educating engineers.

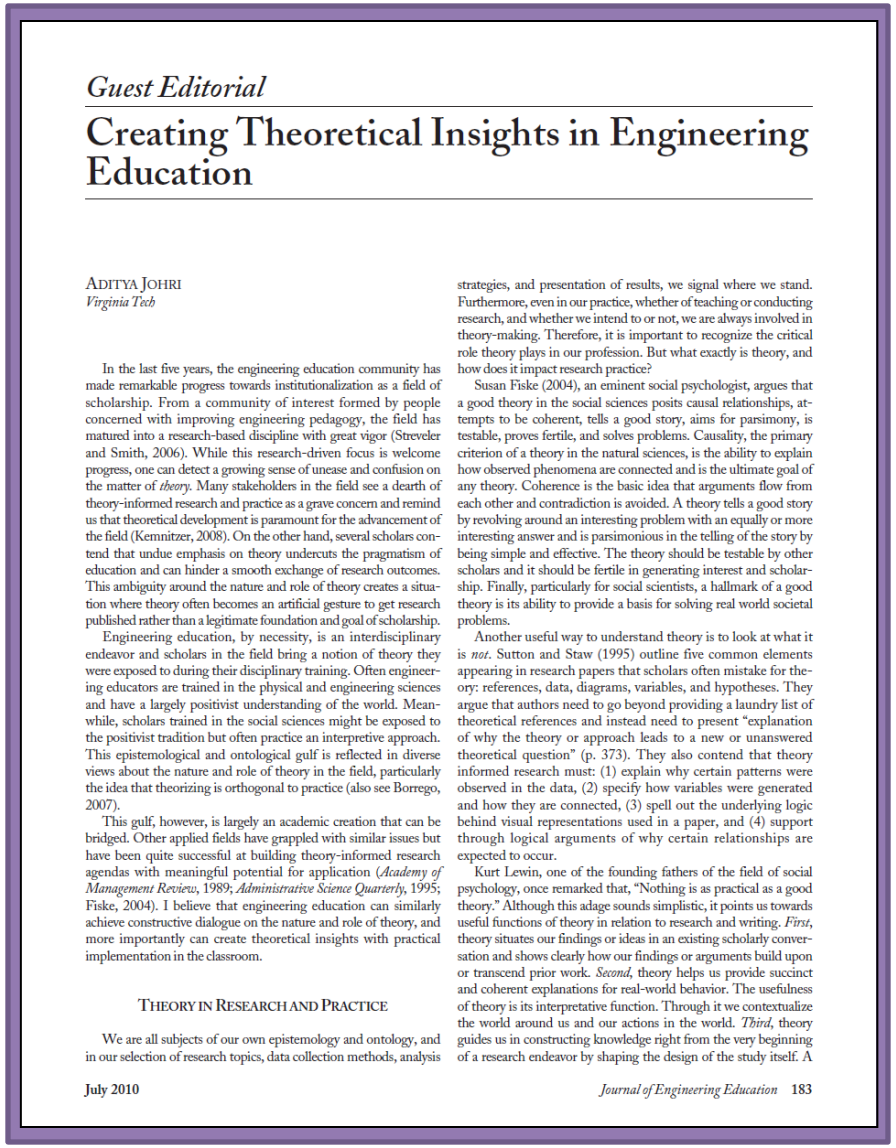
What is Theory?

A description or explanation
of a phenomenon
(*how* or *why* something happens)

What is it used for?

Quantitative research –
To identify hypotheses and select appropriate instruments

Qualitative research –
To provide a lens through which findings can be interpreted



Guest Editorial

Creating Theoretical Insights in Engineering Education

ADITYA JOHRI
Virginia Tech

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.

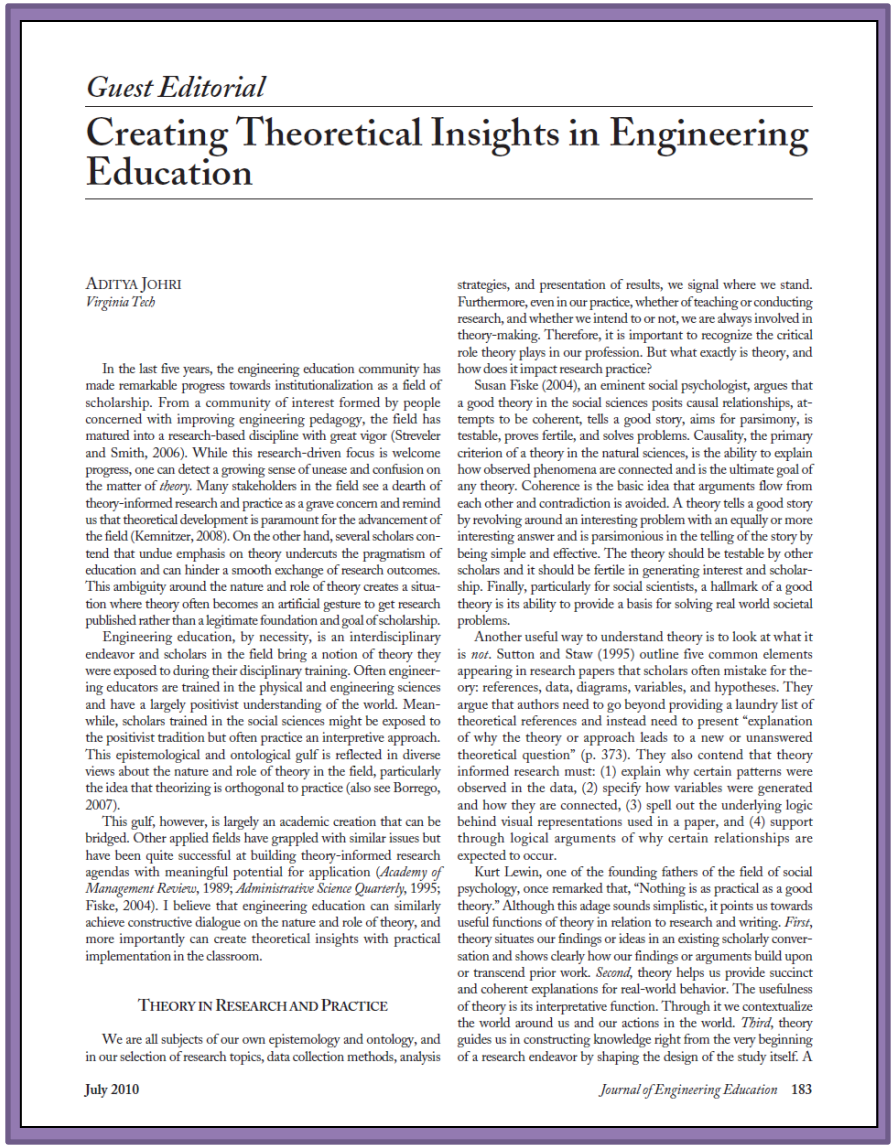
Kurt Lewin, one of the founding fathers of the field of social psychology, once remarked that, "Nothing is as practical as a good theory." Although this adage sounds simplistic, it points us towards useful functions of theory in relation to research and writing. *First*, theory situates our findings 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

Develop vs. Borrow

"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."

"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."



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Positivist vs. Interpretive

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"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."

At the end of the day, it's assumed you'll have a theory

Journal of Engineering Education Review Criteria

Literature: Does the article identify, synthesize and evaluate the relevant the literature that led the author to propose the research? Is there a specific and persuasive explanation of how the present study will contribute to the literature as well as to practice or policy? What conceptual or theoretical framework informs the study?

Theories for Examining Major and Career Choice

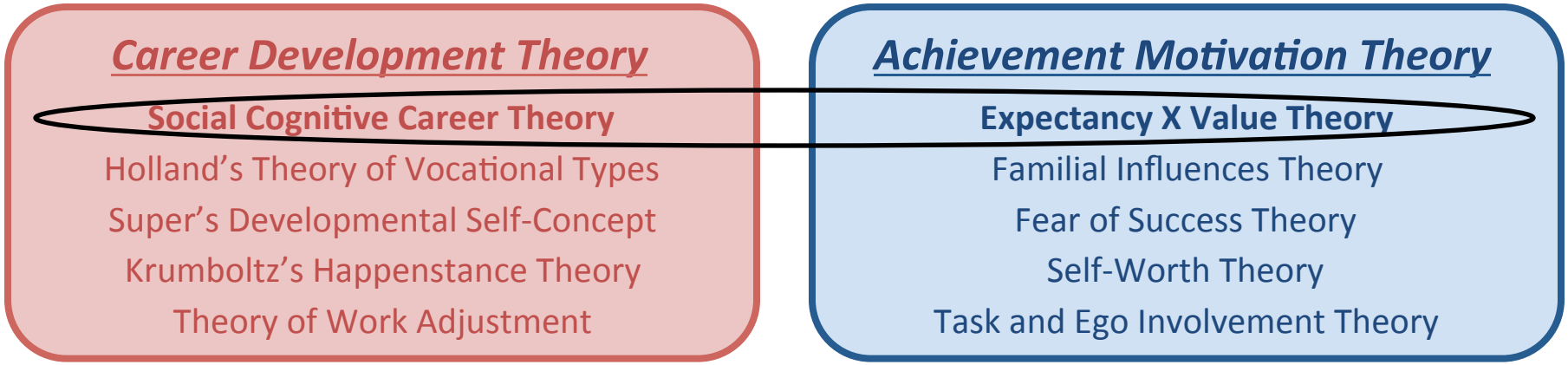
Career Development Theory

Social Cognitive Career Theory
Holland's Theory of Vocational Types
Super's Developmental Self-Concept
Krumboltz's Happenstance Theory
Theory of Work Adjustment

Achievement Motivation Theory

Expectancy X Value Theory
Familial Influences Theory
Fear of Success Theory
Self-Worth Theory
Task and Ego Involvement Theory

Theories for Examining Major and Career Choice



What Theory for Major Or Career Choice??

Social Cognitive Career Theory or Expectancy X Value Theory

1. Both are based on young adult populations
2. Both focus on “factors” versus “stages” or “types”

but

They answer the question in different ways

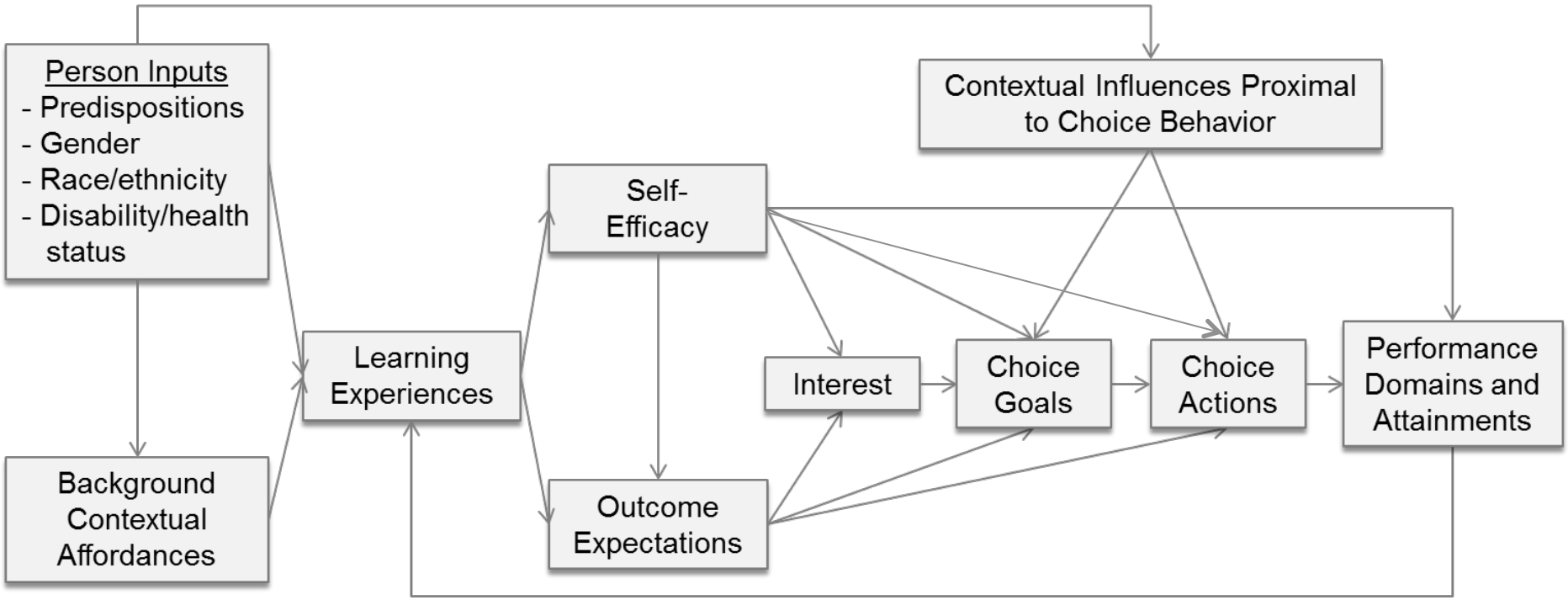
Social Cognitive Career Theory

Robert W. Lent
Professor, Education
University of Maryland

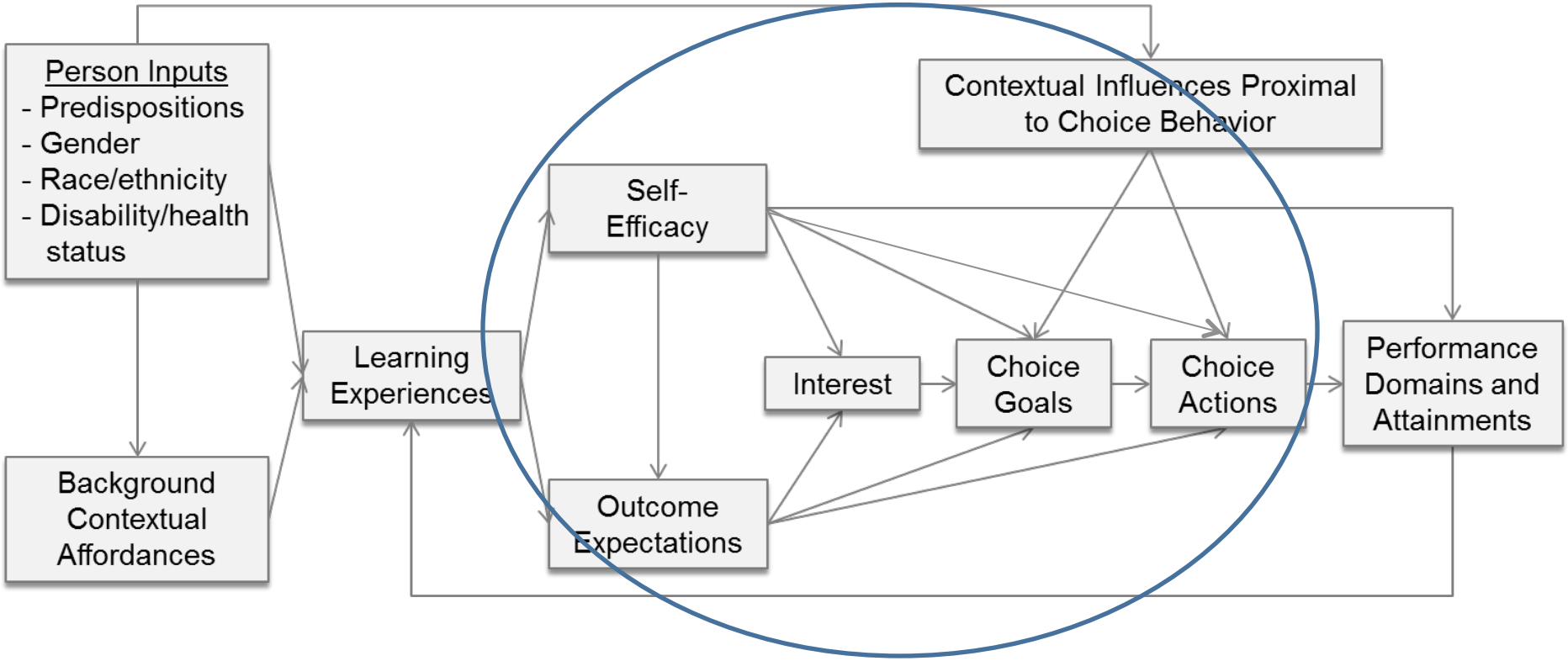
Influenced by Bandura; many studies of engineering students

Lent et al. (1994). Toward a unifying social cognitive theory of career and academic interest, choice, and performance. *Journal of Vocational Behavior, 45*(1), 79-122.

Social Cognitive Career Theory



Social Cognitive Career Theory



NOTE THAT:

1. Interests are based on "can I do this?" and "will this be worth it?"
2. Goals are based on all of these things, plus supports and barriers

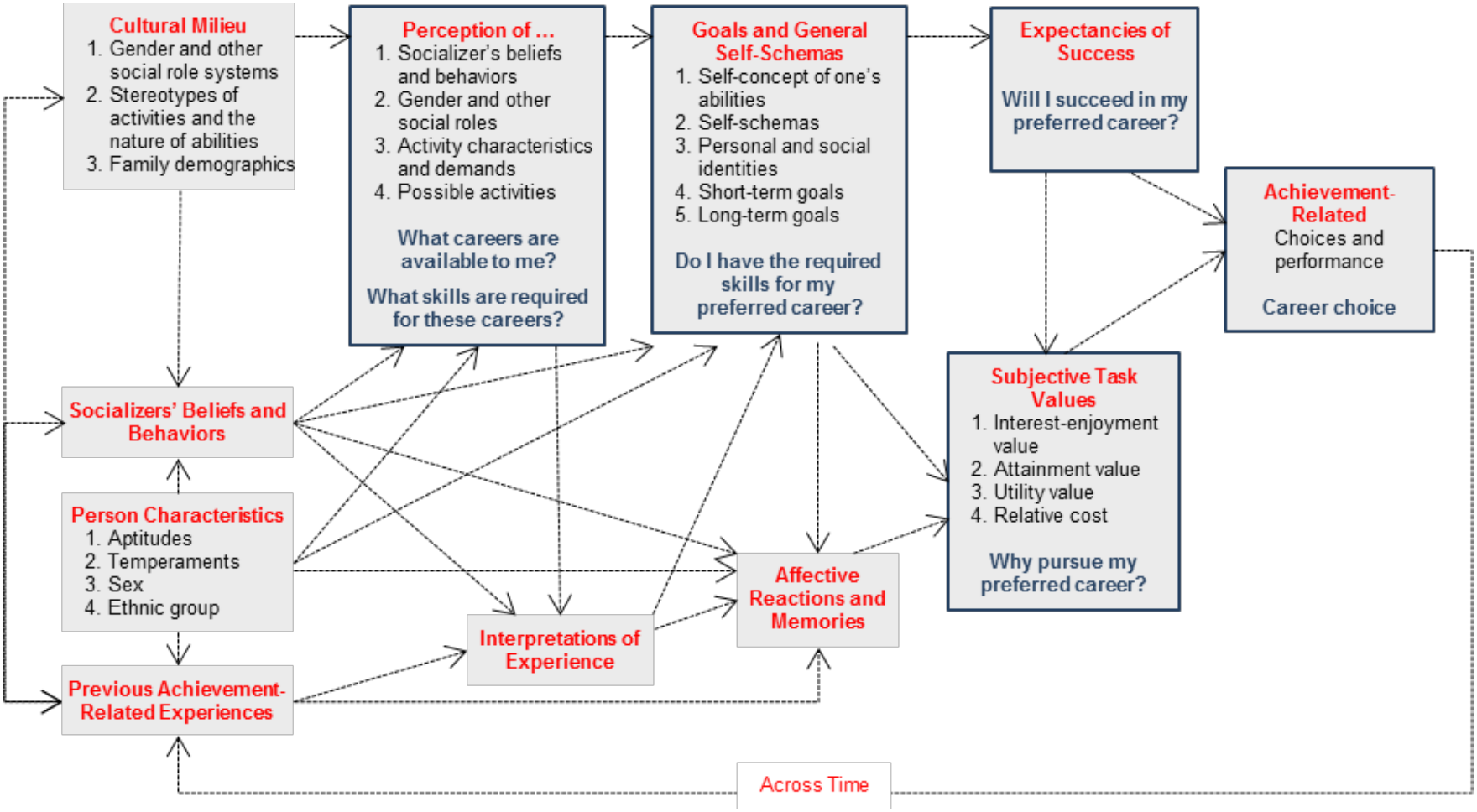
Expectancy X Value Theory

Jacquelynne Eccles
Professor, Education
University of Michigan

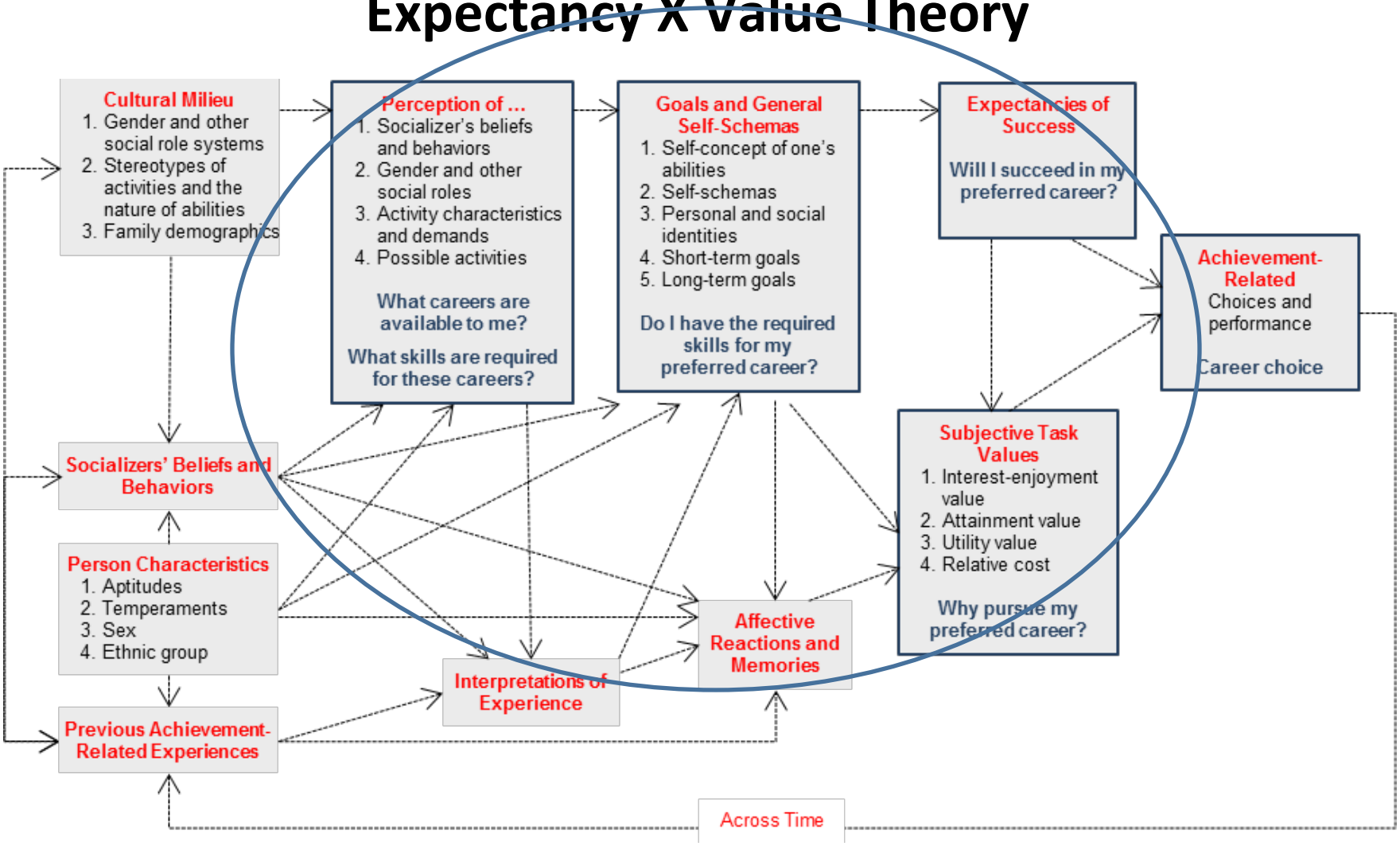
Originally developed to study mathematics achievement

Eccles et al. (1983). Expectancies, values, and academic behaviors. In J. T. Spence (Ed.), *Achievement and achievement motivation* (pp. 75–146). San Francisco, CA: W. H. Freeman.

Expectancy X Value Theory



Expectancy X Value Theory



NOTE THAT:

1. "Can I do this?" and "Will this be worth it?" are just two facets of interest
2. Goals inform efficacy and outcome beliefs, not vice versa
3. Instead, goals based on what you know, not how you feel