NSF CAREER: Towards a framework for engineering student innovation

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Abstract

The ability to innovate is essential in the rapidly evolving technological landscape. Many efforts have been made in engineering education to support student innovation (e.g., innovation and entrepreneurship programs and targeted courses). Yet, research on how engineering students approach and experience innovation has been limited. In this CAREER project we conducted a series of empirical studies using interviews, think-aloud protocols, and surveys to examine engineering students' innovation skills, views of the innovation process, and experiences that supporedt their development of innovative competencies. Informed by these studies, as well as the broader body of literature, we developed a framework for engineering student innovation that can guide instructional practices to support student innovation. In this paper, we present this framework with supporting evidence from recent and ongoing studies.

Introduction

Despite the importance of innovativeness as an engineering competency, research on how engineering students approach and experience innovation has been limited. In this CAREER project, to better understand these approaches and experiences. A summary of three studies are provided below.

Thematic Analysis of How Engineering Students Characterize Innovation

Understanding how engineering students characterize innovation provides a pathway to developing more responsive and effective pedagogy. In this qualitative study, we explored the way engineering students described projects during which they experienced innovation. Our analysis revealed three overarching themes: creating value for oneself, one's stakeholders, and one's peers; a cycle of challenge and engagement; and meaningful components of project contexts that supported innovation. These results provide a robust baseline for interpreting how engineering students view innovation across a variety of project types. They also provide guidelines for the project and environment characteristics that support student innovation and awareness of how students perceived the activities and outcomes of these projects. Based on these findings we recommend that (a) instructors encourage/provide authenticity, autonomy, support, interest, and novelty (three sub-themes comprising the *meaningful components of project contexts* theme) in their innovation projects and (b) embrace the unique and unexpected student outcomes that innovation projects can provide.

Analyzing Engineering Students' Understanding of Innovation through Process Maps

In addition to interviews, we developed a process mapping activity to explore students' conceptions of innovation at a more abstract and procedural level. The process mapping task

provided an open-ended way for students to identify the components and processes they would employ when developing and implementing an innovative solution. We analyzed process maps using an a priori coding scheme which was modified from a coding scheme that was originally developed to analyze expert-created process maps[1]. The coding scheme focused on the content of the map along two categories: (1) stage of innovation and (2) focus area. Analysis revealed that students identified a majority of components at the *opportunity identification* (earliest) stage of innovation and included a decreasing number of components in each later stage of innovation. Students also emphasized the *technological* elements of the process, with lesser, but moderate, emphasis on *strategic* and *societal* elements.

Investigating the Variety of Ways Engineering Students Experience Innovation

Following from the thematic analysis, we utilized phenomenography to identify variation in ways engineering students experienced innovation. This allowed us to better understand student differences with respect to innovation, but also the unique personal and project characteristics that supported those differences. This ongoing project has tentatively identified eight unique ways of experiencing innovation that differ along two dimensions: *technology-stakeholder continuum* and *extent of process*. Differences seem to relate to specific aspects of the project (e.g., type of problem being solved) and individuals (e.g., motivation to pursue innovation), especially misalignment between the two.

In light of these three studies as well as others, we developed a framework for engineering student innovation. The purpose of this framework is to help guide assessment and instruction in innovation education, emphasize a comprehensive view of innovation, and account for the variety of student and environmental differences that can affect the ways students learn and experience innovation.

A Framework for Engineering Student Innovation

A framework for engineering student innovation is necessary to guide and evaluate future efforts to support the development of innovation competencies in engineering. The development of such a framework requires research, including an understanding of: a) student experiences with innovation projects; b) student understanding of innovation as a process; and c) engineering students' abilities to innovative. The last five years of studies, conducted on student innovation with support through an NSF CAREER award has informed the development of the engineering student innovation framework. The framework also builds on the broader literature on design and innovation.

Similar to creativity[2], innovation is influenced by many factors, including cognitive, psychological, and cultural aspects (See Figure 1). The *cognitive factors* include students' understanding of the innovation process and demonstrable competencies such as perspective-taking, questioning, and experimenting. The *psychological factors* make up aspects of student motivation to create, learn, self-direct, cope, and engage. The *cultural factors* are created by the contexts where students engage in projects, in or out of the classroom. Figure 2 provides a summary of publications that informed the development of the framework.

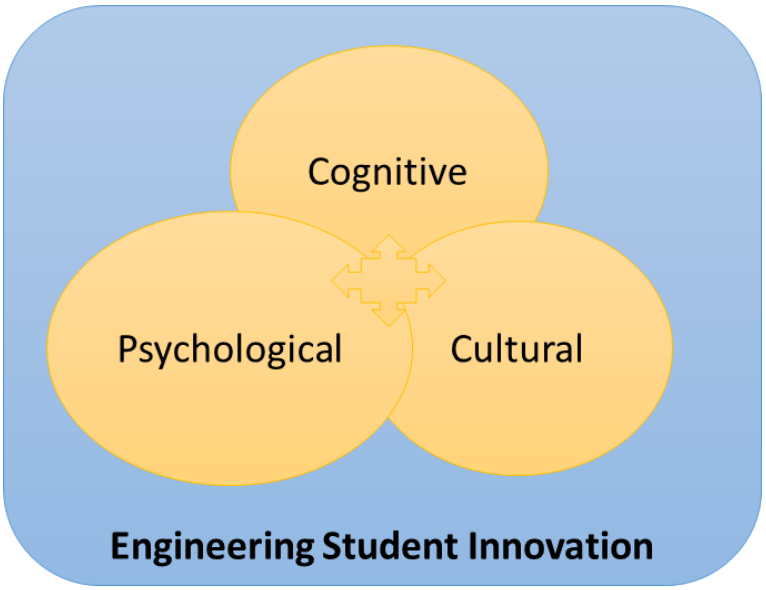

Figure 1. Three components of the engineering student innovation framework

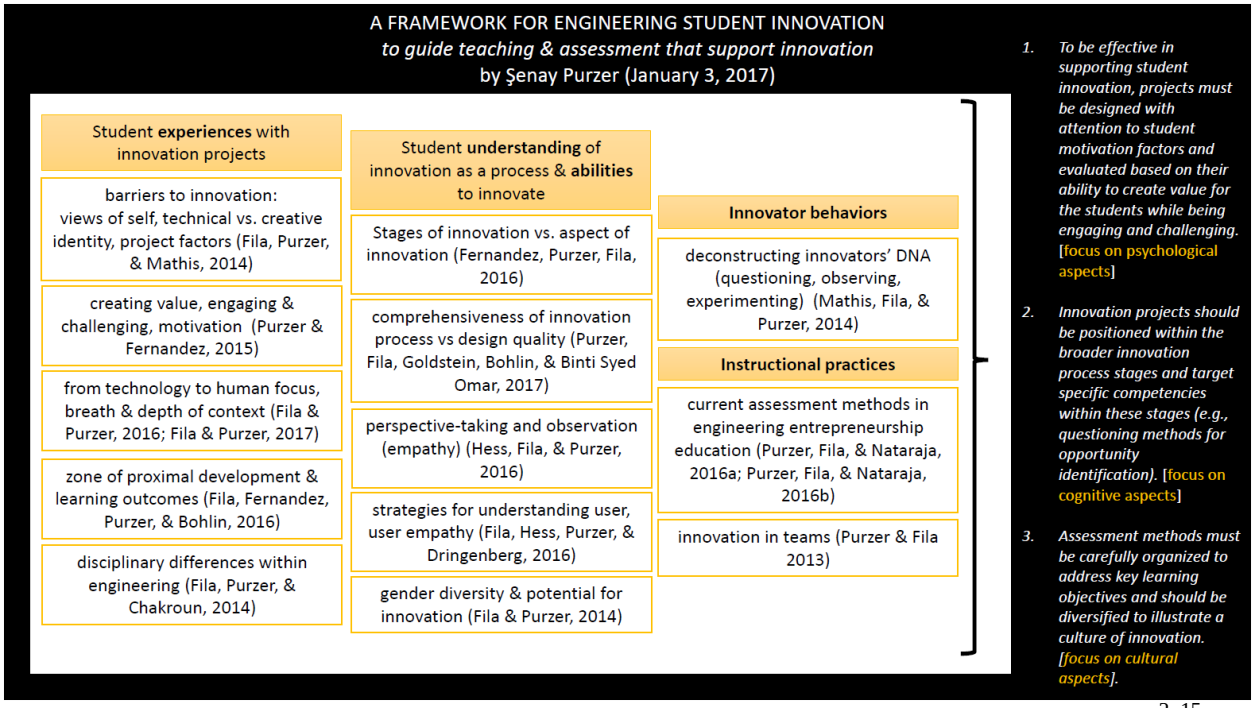

Figure 2. *Publications that informed the framework for engineering student innovation*[2–15]

The framework includes three propositions. To be effective in supporting student innovation:

1. design projects should be positioned within the broader innovation process stages and target specific competencies within these stages (e.g., questioning methods for opportunity identification). [*focus on cognitive aspects*]

2. design projects must be designed with attention to student motivation factors and evaluated based on their ability to support self-directed learning as students create value for themselves and others. [*focus on psychological aspects*]
3. teaching and assessment methods must be carefully organized to address key learning objectives and should be diversified to illustrate a culture of innovation. [*focus on cultural aspects*]

Understanding how engineering students characterize innovation provides a gateway into developing more responsive and effective design project and approaches to teaching and assessment that support innovative competencies.

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