Using Research to Explore and Define Successful Strategies for Educating Innovative Engineers

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Introduction

This poster uses three lenses to explore various approaches to educating innovative engineers:

1. A literature review of innovation as a concept and as a skill used by engineers
2. Interviews of faculty and TAs about their experiences with a Scenario-Based Learning (SBL) curriculum
3. The Engineering Majors Survey (EMS), a longitudinal study of engineering students' interests and career goals surrounding innovation and entrepreneurship

Methods

Literature Review: In order to learn more about innovation in the context of engineering education, I conducted a literature review of relevant work. This search focused on a few specific areas:
- Definitions of innovation
- Measurement of innovation
- Innovation and the engineering student experience
  - Research dealing with innovation and career intent
  - Research addressing the teaching and learning of innovation

This search focused on papers from 2005 or later, ranging from quantitative and qualitative studies of students to concept pieces presenting theories about innovation. About 20 papers satisfied the above criteria, 15 of which dealt specifically with engineering students, and including a few papers that focused particularly on “design thinking”.

SBL Interviews: I conducted 6 interviews of faculty and TAs from Stanford, UC Merced, and University of Wisconsin - Madison, regarding their experiences implementing a Scenario-Based Learning curriculum in introductory Statics courses. The data from these interviews provided a point of reference for investigating new approaches to educating innovative engineers.

EMS Analysis: The Engineering Majors Survey (EMS) was deployed in Winter 2015 to a nationally representative sample of 27 institutions, ultimately resulting in 7,197 usable responses. In my analysis I focused on two questions:
- Q11: “As part of your undergraduate coursework so far (including courses you are currently taking) have you taken courses that include any of the following topics or components?”
- Q12: “Below are various extra- and co-curricular activities you may have been involved in while an undergraduate. Many of these have to do with innovation and/or entrepreneurship; others are more general to the college experience. Please mark which of the following you have done during your undergraduate years so far (including activities you are currently doing).”

Figure 1. Concept map showing the various components of innovation, which emerged from the literature review

One model of innovation that emerged from the literature review suggests that innovativeness is composed of four different types of skills: design, entrepreneurial, problem-solving, and creativity (Ferguson & Ohland, 2012). I adapted this model in mapping the various components of innovation (see Figure 1). Based on this, as well as many other models, theories, and definitions of innovation, I formed my own definition:

Innovation is the process of applying four different types of skills (empathetic design, problem-solving, entrepreneurial, and creative skills) to create value by implementing a new or significantly improved product, method, or approach.

This body of research also yielded several common themes surrounding innovation teaching and learning. Several widely recognized best practices include:
- Interdisciplinary collaboration among students
- Hands-on learning
- Out-of-the-classroom experiences
- Emphasis on empathetic problem-solving
- Scaffolding to improve students' self-efficacy

On the other hand, the literature suggests that engineering education of innovative skills is lacking in the following areas:
- Anticipating unintended consequences
- Conducting experiments
- Information gathering/asking questions

Literature Review Findings

SBL Interview Findings

The SBL curriculum included several in-class labs with associated reading materials that introduced business and entrepreneurial topics through case studies. These interviews also yielded important data that corroborate the results of the literature review. Professors and TAs emphasized several key elements of the curriculum:
- Hands-on learning
- Context and relevance of material
- Collaboration among students

These crucial elements of the SBL curriculum also align with several best practices that emerged from the literature review. Below are several key quotes (paraphrased) from these interviews, illustrating the importance of implementing innovation and entrepreneurship curriculum in an engineering classroom.

“I really appreciated the hands-on learning – the ability to touch and play with stuff. I think that’s really important.”

“It’s more motivating to do the work when you know it’s for something tangible.”

“Most important was the group learning – students were learning together, discussing, arguing. They learned what it was like to be in a business and engineering environment – it’s a give and take.”

EMS Findings

A few take-away ideas from the above data:
- The majority of students took courses involving design and/or prototyping
- Fewer students participated in innovation-related activities outside the classroom (e.g., only 9% were members of a design club)
- All of these activities reflect hands-on learning and collaboration!
- Percentages reflect the number of participants who marked “yes” to a question/total 7,197 participants
- Next step: ASEE paper comparing EMS results by class standing and analyzing the relationship between innovation self-efficacy and participation in these “best practices” from the literature review and SBL interviews

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