Work-in-Progress – Entrepreneurial Mindset in First-Year Engineering Courses

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Abstract - **One challenge faculty face when working with first-year engineering students is how to "hook" them into being interested and motivated in introductory courses. Many universities are experimenting with programs in innovation and entrepreneurship that focus on upper division students, but there are fewer examples of this in first-year programs. In the fall of 2017, first-year engineering students at our university completed a design project to help them begin developing an entrepreneurial mindset. Students were given the freedom to develop a product that would improve upon an existing design in an innovative way or to develop a new product with a designated purpose. Student teams self-selected their project and the projects developed encompassed seven classifications (Student Life, Assistive Technologies, Outdoor Activities, Appliances, Personal Use Conveniences, Environmental/Road Management/Office Arrangement, and Phone/Portable Technologies). Over the course of the semester student teams completed project deliverables. This paper not only describes what was observed and analyzed for this introductory engineering course, but it also outlines key lessons learned during this semester and next steps to improve the course which may be helpful to others who are working to implement innovation and entrepreneurial mindset into their first-year engineering courses.**

Index Terms – Innovation, Entrepreneurial mindset, First-year engineering, Design thinking.

BACKGROUND

The topics of innovation and entrepreneurial mindset in undergraduate engineering education are gaining momentum. Many universities have courses and opportunities for students to explore their interest in advancing their own innovations whether through an independent endeavor or within an existing organization. In 2011, a study found that over 100 entrepreneurship programs were available to undergraduate students. Of these, 40 were "administered solely or jointly by schools and colleges of engineering". [1] The University of Ottawa has been offering an entrepreneurship course for several years. The class is open to any undergraduate or graduate engineering student, but most students take it in their final year. The students' reason for waiting until their last year, is that that they can better apply the methods learned to their career. As part of the course, students complete an elevator pitch on an idea/concept they have developed, complete design thinking exercises, meet with potential customers and evaluate how to launch their idea. [2] At the City University of New York (CUNY), high school through college students interested in entrepreneurship can be exposed to it through the Virtual Enterprise (VE). It is not a stand-alone program but must be incorporated into an existing course. This is one of the few programs that incorporates younger students. The VE allows students within a course to develop and launch a business in the virtual environment. [3]

The programs described above are primarily for upper division university students. While the programs do enhance engineering education and help engineering students develop critical skills, they do not "hook" students early in their college career. Courses that engage students in hands-on innovation and entrepreneurial activities are one way to create that hook. At Michigan Technological University, we piloted modifications in a first-year engineering course that allow students the opportunity to learn about innovation and design thinking through the completion of an open-ended design project.

One of the challenges we discovered through this pilot study was that students struggled with the self-selection of project opportunities when they were completely open-ended. When researching other institutions with entrepreneurial design projects, we found little information on what or how students or teams self-select a problem or opportunity to address. Through this, and subsequent pilot efforts, we hope to identify an optimal approach to helping students identify and select a project topic.

ENG1102 DESIGN PROJECT OVERVIEW

Michigan Technological University has a common first-year engineering program with two tracks based on math readiness. Students who are calculus-ready are enrolled in ENG1101, Engineering Analysis and Problem Solving, in the fall and ENG1102, Engineering Modeling and Design, in the spring of their first year. Students who are in pre-calculus or college algebra take ENG1001, Engineering Analysis, followed by ENG1100, Engineering Problem Solving, in the first year instead of ENG1101. These students complete ENG1102 in the fall semester of their second year. This paper focuses on a pilot study completed in ENG1102 during the Fall 2017 semester.

During the Fall 2017 semester, students in two sections of ENG1102 were introduced to the design thinking process through a series of interactive workshops and then were

encouraged through assignments to apply these concepts to their own projects. The design thinking methodology was selected for this pilot study as a way to build students' creative confidence and allow them to explore the human centered design process by applying it in the development of an innovative solution to a problem or opportunity they identified. Through learning and applying design thinking, students accomplish new mindshifts such as the development of a human-centered mindset where students move beyond an egocentric view of the world and focus on meeting the needs of others through their innovations and designs. An experimental mindshift is achieved when students realize that anything can be considered a prototype as long as they can learn from it and iterate on it. [4] Twenty-first century skills include creativity and innovation [5], and the design thinking methodology provides students with a powerful toolset and mindset to apply in the development of these skills.

In our pilot, there were a total of 111 students on 28 engineering teams that ideated, designed, built and tested an iterative series of prototypes as they worked toward a final solution due at the end of the semester. Due to the course structure in this 3-credit class, only five sessions were modified to include the design thinking material through a series of one-hour modules, each of which introduced a phase of the design thinking process – empathy, define, ideate, prototype and test. Utilizing a variety of sources for design-thinking curricula, including the Stanford d.school's Teaching and Learning Studio and Ideo.org's Design Kit, these modules were designed to facilitate a brief introduction to the concept followed by practical application. [6, 7]

A variety of stoke (or ice-breaker) activities were included at the beginning of each of the five class sessions followed by hands-on mini-projects and activities such as the Stanford d.school's backpack challenge, which allowed students the opportunity to experiment with the process prior to applying it to their projects. [8] A series of assignments were developed that required students to demonstrate how each of the design-thinking components were integrated into their semester design project. Students were encouraged to think past their preconceived ideas to create impactful solutions.

Examples of the design-thinking related assignments included:

- A problem statement assignment where teams had to "define" the problem they were designing for, with a summary of the observation and interviewing used to gain empathy for the user
- A list of ideas for solutions to the problem statement generated through brainstorming, and the methods the team used to evaluate their ideas such as dot voting or decision matrix
- A description of at least two prototypes the team developed with a summary of testing conducted on each prototype and how the results of that testing informed the subsequent prototype. Teams were encouraged to start with very simple low-resolution prototypes and then move toward increasingly sophisticated prototypes as the design was refined through user feedback.

By applying design thinking through in-class activities and project assignments, students were able to understand the importance of focusing on the needs of the user at a deeper level than experienced in a more traditional course.

The ENG1102 design project incorporated, along with design thinking methodologies, core engineering skills such as MATLAB simulations, and NX solid modeling. Students were given the freedom to identify a problem they wanted to solve by developing either a new product or an improvement to an existing product. As student teams developed their design, they completed deliverables that included:

1. Team Contract: a working document, signed and agreed to by all team members that contained norms for team behavior and team member expectations
2. Empathy Map (Design Thinking): a synthesis of key user information obtained through observation and interviews
3. Problem Statement and Ideation (Design Thinking): design ideas were developed and evaluated
4. Project Proposal: a description of proposed final product, background research, product selection methodology, target market research, a project management plan, and a concept sketch
5. Physical Concept Model (NX 3D Model): a 3D model including working drawings for all components and an assembly
6. Prototype/Test I (Design Thinking-Based): design teams interviewed potential users regarding their NX model
7. Hazard Analysis: a FMEA on their proposed design with mitigation of their top hazards
8. Resource Budget: a process flow diagram for manufacturing the product as well as a cost analysis of materials, energy, and labor required for production
9. Prototype/Test II (Design Thinking-Based): design teams created a physical model, often utilizing the university's Makerspace, followed by user feedback
10. MATLAB Product Marketability Analysis: a computer program analyzing the return on investment and calculated the revenue, expense, and profit for the first ten years of production
11. Design Project Poster: a team defense of their work to evaluators from the university community at a poster Expo
12. Final Project Book: compilation of deliverables

OVERALL OBSERVATIONS

For their entrepreneurial design project, students were given the freedom to identify and solve any design challenge they desired. The design projects the students self-selected were grouped into the categories shown in Table I. The most popular design project category, which a third of the teams selected, was Student Living. Projects included improvements to dorm furniture modularity, custom shower head designs, and enhancements to lecture hall chairs. Fourteen percent of the student teams chose designs related

to the Environment/Road Management/Office Arrangement. Another 14% had improvements to Outdoor Activities including kayaking and biking. The remaining categories included Assistive Technologies, Appliances and Personal Use Conveniences.

TABLE I
DESIGN PROJECT CATEGORIES THAT STUDENT TEAMS SELF-SELECTED

Description	Number of Teams (n = 28)	% of Teams
Student Living	9	32
Environment/Road Management/Office Arrangement	4	14
Outdoor Activities	4	14
Assistive Technologies	3	11
Appliances	3	11
Personal Use Conveniences	3	11
Phone/Portable Technologies	2	7

The most innovative design projects were those in the Outdoor Activities category. Design concepts in this category included an interior ski rack for transporting skis inside of a vehicle, a backpack with a built-in rain shield, and a kayak with additional features including a rudder and stabilization for beginner kayakers. These concepts were innovative in that they were new designs, not an iteration of an existing design. Design projects in other categories tended to be either variations on existing designs or were underdeveloped.

Students completed an on-line survey at the end of the course regarding the entrepreneurial design project and the design thinking methodology. They appreciated the opportunity to be creative and enjoyed the project. One student commented that "These classes gave us time to think outside the box and more time to work with our teams." Another student stated that "They helped … come up with new innovative ideas that just one person may not be able to come up with on his/her own." These comments show that students learned the value of working in a team and the power of a group to develop a variety of synergistic and innovative design ideas. Through the use of the design thinking methodology, many student teams refined their concepts through user feedback gained throughout the term. The creative confidence activities were uncomfortable for some students. Others were challenged by the completely open-ended opportunity to identify and solve a design problem. They suggested that it would have been helpful if the topic/category or user population were constrained in some way, thereby limiting the vast range of opportunities to select from.

CONCLUSIONS AND FUTURE WORK

Through our initial attempt to incorporate innovation and entrepreneurial mindset pedagogy into a first-year engineering course, students learned and applied design thinking methodology into the development and prototyping of innovative solution. Student teams self-selected a problem of interest to them and a third of the teams chose to focus on issues effecting student life. The most innovative designs developed were in the outdoor activities category. Students learned the value of incorporating the user perspective when developing a solution, and through the creation of low resolution prototypes followed by user feedback, students were able to iteratively improve their designs. This was validated through end of the term course feedback where students appreciated the innovative nature of the design project which gave them the opportunity to be creative.

While most of the teams developed viable solutions to their identified problem, some of their design ideas already existed or were poorly implemented. About a third of the student ideas were innovative in nature and had the potential to be further developed for commercialization. Although students appreciated how open-ended the project was, they felt they would have benefited by the addition of some constraints regarding the problem definition. This suggests that in future courses, the design project would be improved if constraints were incorporated. Possible constraints could include targeting:

- A specific population (i.e.: children, adults, physically/mentally challenged)
- A geographical region
- A global/regional issue (i.e.: grand challenges)

A second pilot is planned for Fall 2018 in which lessons learned from this project will be incorporated.

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