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Using Simulation Experiences, Real Customers, and Outcome Driven Innovation to Foster Empathy and an Entrepreneurial Mindset in a Sophomore Engineering Design Studio

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Abstract

For many years, Lawrence Technological University has been engaged in a campus wide effort to instill an entrepreneurial mindset in our engineering undergraduates. As part of this effort, we have intentionally created opportunities at all levels of our curriculum for students to practice an enterprising attitude. At the sophomore level these opportunities take the form of a team based, multidisciplinary, engineering design experience in our EGE 2123: Entrepreneurial Engineering Design Studio course. In the design studio, students build on the foundation of entrepreneurial mindset development laid in our first-year introductory design course. As such, at the sophomore level, they spend a semester identifying opportunities for design within a theme, engaging real customers beyond the walls of the classroom, and creating a working prototype that creates value for these customers.

The purpose of this paper is to describe some of the pedagogy used to foster an entrepreneurial mindset in this sophomore design studio course. Specifically, we will focus on aspects of the course in which students are identifying opportunities for design, interacting with customers, and determining how to create the most value based on the jobs these customers are trying to perform. Building off of lessons learned from the initial offering of this course, we have created a program that allows students to interact with actual customers through a partnership with a non-profit organization that helps people with disabilities in the workplace. We also foster empathetic design by having students engage in an accessibility simulation we developed to help our students understand the everyday experiences of people with disabilities and placing those experiences in an historical context. We also use the principles of outcome driven innovation to help our students gather focused customer feedback and identify where they can create the most value for their customers in the workplace. Assessment of the impact of these studio course activities on empathy and the development of an entrepreneurial mindset will be discussed based on the experiences of multiple sections of course participants.

Introduction

Lawrence Tech is committed to its mission to be recognized for transformative STEM and Design education that develops leaders with an entrepreneurial mindset and global perspective[1]. The College of Engineering seeks to provide students with a strong foundation in the fundamentals of engineering in an environment infused with an entrepreneurial mindset. For many years, Lawrence Technological University has been a part of the Kern Entrepreneurial Engineering Network (KEEN). KEEN is a collaboration of universities across the United States dedicated to instilling an entrepreneurial mindset in their undergraduate engineering and technology students. KEEN, through the Kern Family Foundation, provides financial and developmental resources to participating institutions to enable the growth of curricular and

extra-curricular activities that enhance the entrepreneurial mindset in their students. Specifically, KEEN emphasizes the development of engineers that exhibit an "entrepreneurial mindset coupled with engineering thought and action expressed through collaboration and communication and founded on character." In support of this, KEEN has created a framework of student outcomes and example behaviors that may be used to inform the design of programs seeking to develop an entrepreneurial mindset. These outcomes and behaviors are centered around what KEEN calls "The 3 C's" - curiosity, connections, and creating value. Specific example behaviors of curiosity, connections, and creating value as described by KEEN may be seen in Figure 1[2].

The campus wide effort at LTU to foster an entrepreneurial mindset in our graduates is focused on three areas. These are faculty engagement, curriculum development, and student engagement. With regard to curriculum development, we intentionally weave a continuous thread of entrepreneurially minded learning through our core engineering curriculum. In the freshman year, we lay the foundation of entrepreneurial mindset development in our EGE 1001 Introduction to Engineering Design Projects. EGE 1001 is an active and engaging course that demonstrates the many aspects of engineering and the engineer's role in society. This course introduces the student to basic engineering concepts and the various engineering disciplines through design and project work. It also lays the groundwork for the professional skillset all engineers need to possess in order to effectively communicate technical concepts to others while working in a team setting.

In the sophomore year, engineering students take EGE 2123: Entrepreneurial Engineering Design Studio and build upon the foundation of entrepreneurial mindset development laid in the introductory design course. At the sophomore level, students spend a semester on a multi-disciplinary team that identifies opportunities for design within a theme, engages real customers beyond the walls of the classroom, and creates a working prototype that creates value for these customers. This real customer interaction fosters empathetic design while providing a more meaningful classroom experience as students are able to see directly the impact their designs have in creating real value – value as it is defined, not by the student or instructor, but by their customer.

In the junior year, engineering students are typically engaged in much of their discipline-specific engineering coursework. Thus, this thread of entrepreneurially minded learning is extended by means of discipline-specific applications through projects deployed in multiple junior-level courses. Finally, the senior capstone experience brings together students' engineering skillset and their entrepreneurial mindset in a year-long, real-world design project. Throughout the curriculum, professional skills such as oral and written communication, innovation, understanding constraints, sustainability, technical feasibility, customer value, societal benefits, economic analysis, and professional ethics are addressed with increasing depth as students develop their skillset.

Course Overview

The focus of this paper is the sophomore level EGE 2123: Entrepreneurial Engineering

Design Studio course mentioned above. Specifically, in this course, students identify opportunities for engineering design themselves within the context of the design theme "Accessibility in the Workplace". The focus of this theme is to design and build a working prototype that will assist real customers with disabilities in the workplace. Students engage real customers and identify solutions to these opportunities based on their customers' needs. Finally, students design, build, and test working prototypes that create value for these customers. Throughout the design process, students must work in a team setting, manage a long term project, account for cost and market implications, and communicate to all stakeholders in written, verbal, and public presentation formats. EGE 2123 meets twice a week for 2.5 hours each class period in a dedicated studio classroom that has been intentionally designed to be flexible and enhance collaboration and innovation. The specific learning objectives for this course are seen here.

By the end of the semester, students will be able to:

1. Generate, screen, and select promising design opportunities.
2. Organize, plan, and manage a long term engineering project within a team environment.
3. Identify and communicate the value of a design in terms of economic, professional, personal, and societal value.
4. Translate customer feedback into design specifications.
5. Utilize a systematic design process in order to bring a project to fruition.
6. Identify and utilize technical tools and skills needed to create a viable design solution.
7. Account for cost, value, and market implications at all stages of development.
8. Communicate design status and results to all stakeholders in verbal, written, and public presentation formats at appropriate points in the development timeline.

Since the students in this course are engaged in a systematic design process from opportunity identification and ideation through building and testing prototypes, the course is structured in stages that mirror the stages of the design process. The stages of the entrepreneurial engineering design process followed in this course are shown in Figure 2 and are based on those described by the creators of the Innovation Portal.[3] The content needed for each stage of the design process is spread progressively through the course and delivered at the appropriate points in the design process when students are ready to apply the concepts. This format fits well with the chosen studio-based pedagogy of the course and the need to scaffold student learning as they work through a semester long project. A weekly overview of the topics covered during the semester may be seen in Figure 3.

Figure 3 also shows the points in the semester at which student teams must prepare and present milestone reviews. These reviews are oral presentations of the team's progress at various points in the design process. The audience members for these reviews are not only the studio instructors and classmates but also additional faculty from a variety of disciplines, industrial advisors from companies in the local area, and stakeholders from our non-profit partner, Services to Enhance Potential (STEP). This type of audience provides the students an opportunity to communicate their work in a professional manner to multiple stakeholders having a broad range

of experiences and viewpoints. Indeed, these milestone review presentations have proven beneficial for the students by both enhancing their communication skills and providing them with valuable input on the technical aspects of their projects throughout the semester. As seen in Figure 3, these reviews occur four times during the semester at various stages of the design process.

Interacting with Real Customers

As customer engagement is vital to achieving the above course learning objectives, students interact with real customers through a partnership with a local non-profit organization, Services to Enhance Potential (STEP). STEP works with clients with a wide range of cognitive and physical disabilities as well as those with mental health needs to develop, train, and place them into meaningful employment. STEP's mission fits well with the design theme used in EGE 2123 - "Accessibility in the Workplace" since the focus within this theme is designing and building prototypes that will help people with disabilities in the workplace. STEP's operations include several regional resource centers where their clients are trained in a variety of hands-on experiences mainly focused on light manufacturing jobs. In addition, STEP provides internships where clients participate in on-site training in a variety of areas including janitorial, dietary, and clerical work at a community-based host site. STEP has helped to place hundreds of persons with disabilities into community jobs.[4]

For many students, the sophomore studio course is their first opportunity to work with people with disabilities. In preparing students to interact with their customers, a foundation of general knowledge in disability awareness and some guidelines on effective, respectful communication using 'person-first' language are provided.[5] Also, students are shown excerpts from the documentary *Lives Worth Living* to set the historical context of the disabilities rights movement.[6] This general knowledge and awareness debunks some common myths about people with disabilities. Students are made aware that the disability community does not discriminate - people of every color, gender, religion, ethnicity or age are, or may become, a member of this community. However, the inclusivity of the community does not translate to inclusivity in the workforce. Nearly 80% of people with significant disabilities do not have jobs even though most people with disabilities want to work. In fact, two out of three people with disabilities who are unemployed said they would prefer to be working.[5] Some of the barriers that prevent individuals from participating fully and equally within society include prejudice, discrimination, inaccessible environments, inadequate support, and economic dependence.[7] Having this awareness and understanding of the disability community helps to put the impact of the students' "Accessibility in the Workplace" projects on their customer's lives in perspective.

The students engage with their customers at the STEP worksites five times over the course of the semester. These visits occur at specific points in the entrepreneurial engineering design process (Figure 2) that require customer feedback. Before each visit, students prepare for the customer interaction based on the information that they need to obtain. Getting the right customer input is essential to the creation of value for their customers and to the students' success in the course.

At their initial site visit to STEP, the students are focused on identifying potential opportunities for design. The topics of ethnography and painstorming are delivered to the

students before the visit to emphasize the need for a naïve state of mind when observing the customers in their workplace. With this focused observation, the pain points for the workers become more easily recognized as opportunities for innovation.

After the students have formed their teams around the opportunity that they are most passionate about pursuing and completed some preliminary research, the teams return to the STEP worksite to compile a list of design requirements based on their customers' needs. Before this second visit, the teams are introduced to outcome-driven innovation principles to focus their interactions with their customers.[8] The purpose of this second visit is to gain insight into the potential for innovation based on what their customer views as successful execution of each step of their job.

The teams do not return to the site for their third visit until they have selected a final concept for design. To prepare for the third site visit, teams build full-scale mock-up prototypes of their final design concept constructed of cardboard, tape, and repurposed materials. The purpose of this prototype is to communicate to their customer both the form and function of their design concept in a preliminary way. The focus of this customer interaction is to validate the viability of the design. Once the viability of their design is validated with the customer, teams finalize product architecture and component drawings. They then select and order materials to begin building their final working prototypes.

For the fourth site visit, teams bring their working prototypes to their customers to test these prototypes with respect to the target specifications they prescribed for their designs. In addition, teams consider robust design methodology principles to predict and test the capabilities of their designs under nonideal conditions. This fourth visit focuses on the value created for the customer, both quantitatively, in meeting the target specifications, and qualitatively, in the subjective evaluation of the prototype by the customer.

The final visit to the STEP worksite takes place at the end of the semester. The students deliver their final working prototypes to their customers. This final visit is often bittersweet. By the end of the semester, both the students and the STEP workers have developed a relationship and are truly invested in the success of their project. "The way the students were able to engage and analyze the needs of the people we serve has been truly inspiring. Many of the designs developed by the students will not only improve the efficiency of our clients' work but also eliminate barriers that will allow people to perform new types of work," expressed Steve Slayton, STEP Resource Center Director.

This interaction with real customers is a unique aspect of this course and has made a significant impact on the students' experience. The students' ability to use their developing engineering tools in this way provides for a more meaningful experience as they are able to see directly the impact their designs have in creating real value as defined by their customer. The ultimate course outcome is that this awareness and understanding of the perspectives and motivations of others will propagate into their professional lives as practicing engineers.

Fostering Empathy for Real Customers

Design empathy is an approach that draws upon people's real-world experiences to address modern challenges.[9] The ability to see the world from the perspectives of others is a

critical component to success in the sophomore studio course. By infusing empathy for others into the students' experiential learning in the early stages of the course, all phases of the design process, from opportunity identification to ideation to prototype testing, will reflect insights that are both innovative and responsive to actual user needs and desires.[9]

To initiate this user-centered, empathetic design approach, students engage in an accessibility simulation exercise on the first day of class designed to foster greater understanding of the everyday experiences of people with disabilities. In this exercise, students break into groups and engage in multiple simulation activities including:

1. Mobility impairment in which students ambulate using either a wheelchair or a walker,
2. Dexterity impairment in which students place braces on both hands that limit range of motion,
3. Vision impairment in which students wear specially-designed goggles with lenses designed to simulate a variety of conditions,[10]
4. Hearing impairment in which students participate in lip reading activities,[11]
5. Activities that demonstrate acute sensitivity to noises, movement, and excessive stimulation experienced by individuals with autism.[11]

Before beginning each simulation activity, the students must predict what they anticipate as the most difficult aspect of dealing with that particular disability. The students then perform a prescribed list of common, everyday tasks and conclude the activity by reflecting on the difficulties they experienced, both predicted and unanticipated. As engaged participants, the students experience some of the realities that their customers experience both in their workplace and in their everyday lives.

Creating Value for Real Customers

As discussed above, interaction with real customers is an important part of this design studio course but is also one aspect of the course that students are often least prepared to do effectively. Getting the right customer input is essential to the creation of value for each team's STEP customers and to the overall success of the team's design. In order to gain the most benefit from their customer interactions particularly with regard to using customer feedback to create their design requirements, students are introduced to the principles of outcome-driven innovation[8] prior to the second site visit.

Quite often student teams and even practicing engineers find it difficult to adequately determine customer needs in a way that can be used to create comprehensive design requirements. Examples of common misconceptions related to determining customer needs include the idea that customers' needs change quickly over time, or it is impossible to determine all of the customers' needs, or even that customers don't really know what they need. Outcome-driven innovation methods help focus the students' interactions with their customers and address these common misconceptions.

The basis for outcome-driven innovation can be summed up in the well-known Theodore Levitt quote, "People don't want quarter-inch drills, they want quarter-inch holes." [8,12] In other words, from the student teams' perspective within the design theme of "Accessibility in the Workplace" and within the context of their particular project, a design will create the most value

for their customers if it enables the customer to get a desired job or activity done well. Indeed, outcome-driven innovation methods focus on the customers' job or activity as the unit of analysis to determine opportunities for innovation rather than attributes of a specific product. The idea is that if designers and engineers can address those points along the job process that the customer sees as slow, unpredictable, or costly they will be able to meet their customers' needs in the most effective way.[8]

When gathering customer feedback, students are instructed to focus on the job or activity the customer needs to perform, deconstruct that job into process steps, and critically analyze those steps based on direct customer input. Ultimately, the goal is to determine where in the process innovation could most impact successful job execution and create the most value for the customer. This type of structured interaction with customers also helps the student teams gather feedback that can be used to focus the scope of their design and be translated directly into quantifiable design requirements. In addition, this hands on experience with outcome-driven innovation provides a valuable tool for students to take with them into the professional world and will help them as practicing engineers to identify opportunities to create extraordinary value for their future customers.

Assessing Course Impact on Entrepreneurial Mindset Development

Across four sections of EGE 2123 with 51 students during the fall of 2016, the impact of the Entrepreneurial Engineering Design Studio course on the developing skillset and mindset of engineering students was assessed using survey and course evaluation data. By the end of the semester, 90% of the students reported feeling "capable" or "very capable" with regard to all of the stated learning objectives for this course. In addition, using a survey developed and used internally at Lawrence Tech for assessing entrepreneurial mindset development, students performed a self assessment in the areas of problem solving and critical thinking, teamwork, business acumen, and societal issues both at the beginning and the end of the semester.

The results of these self assessments are shown in Table 1. As seen in the table, a majority of the students felt they had experienced growth in all of the given areas to some degree. Also shown in the table is the specific survey item that was most commonly listed as improved within a given category. In particular, the fact that many students reported growth in understanding and identifying with the feelings, experiences, and motives of others demonstrates the impact this course is having not only on students' entrepreneurial mindset but also on their understanding of the importance of empathy in design.

In addition to the self assessment surveys of entrepreneurial mindset development, we also administered a more extensive course evaluation survey at the end of the semester that involved several writing prompts. Based on the results of these assessments, 57% of the students called out the accessibility simulation activity described in this paper as their favorite in-class activity and commented on the positive impact this exercise had on their view of the importance of empathy in engineering and design. With regard to customer interaction as described in this paper, 67% of the students stated that the opportunities to interact with and create value for real customers in this course was a meaningful part of their development as engineers.

Table 1: Results from Fall 2016 Entrepreneurial Mindset Self Assessment Surveys

Category	% of students reporting improvement	Item most commonly reported as improved within a given category
Problem solving and critical thinking	84	I am good at devising multiple solutions when solving problems.
Teamwork	92	I understand and identify with the feelings, experiences, and motives of others.
Business acumen	80	I assess and undertake reasonable risks.
Societal issues	67	I am aware of how global issues influence society.

Conclusion

To provide students with a strong foundation in the fundamentals of engineering in an environment infused with an entrepreneurial mindset, the College of Engineering at Lawrence Technological University intentionally weaves a continuous thread of entrepreneurially minded learning through the core engineering curriculum. The course described here, EGE 2123: Entrepreneurial Engineering Design Studio, is an integral part of this thread at the sophomore level. This course has been systematically designed in such a way as to allow students to practice their developing technical skillset within the context of a semester long design project in which they identify opportunities for design on their own, engage in empathetic design, and create value based on interaction with real customers. The ultimate goal is for students to combine their expanding engineering skillset with their developing entrepreneurial mindset through unique experiences in this engineering design studio course. Based on assessment of the implementation of this course, the pedagogy and activities chosen have been effective in accomplishing this goal.

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Figure 1: KEEN Example Behaviors of Curiosity, Connections, and Creating Value[2]

Figure 2: Stages of the Entrepreneurial Engineering Design Process Used in EGE 2123: Entrepreneurial Engineering Design Studio[3]

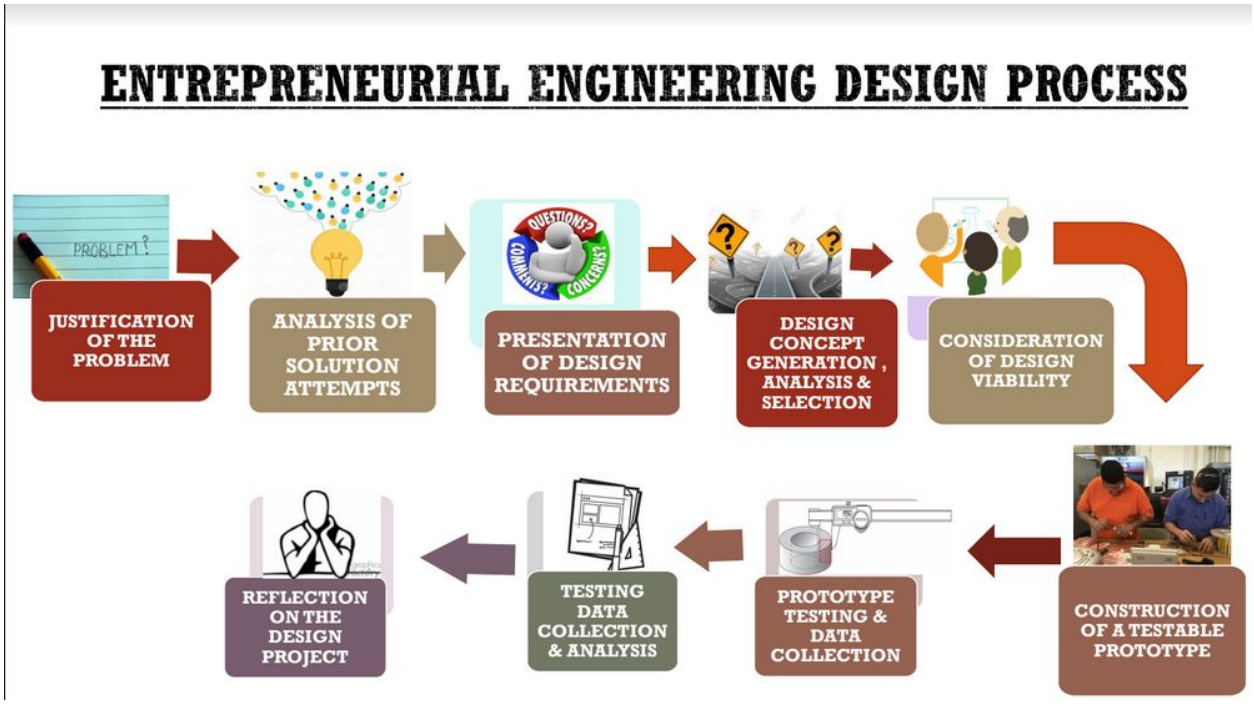

Figure 3: EGE 2123: Entrepreneurial Engineering Design Studio Course Content Overview and Milestone Review Schedule