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Introducing the Entrepreneurial Mindset to Freshman Engineering Students Through an Agriculture Sector Project

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This full paper addresses the topic of introducing the KEEN (Kern Entrepreneurial Engineering Network) entrepreneurial mindset to freshman engineering students. The KEEN entrepreneurial mindset encompasses three parts - curiosity, connections, and creating value. During a project course, freshman engineering students discover the entrepreneurial mindset through the process of completing a team project. The assignment consists of five real-life problems from the agriculture sector. These issues tackle the reduction of water usage for crops, increased efficiency on the farm, and a reduction of over planting and chemical use on crops. The students are exposed to equipment and topics most have never analyzed or contemplated in the agriculture sector. After announcing the five problems, the students are immediately curious about the issues and enthusiastic about how they are going to develop solutions. The student teams select the problem they want to solve for their project. The teams research the subject matter and make connections with a farmer to gain more insight about the problem. With this connection, the students determine the requirements for the project design and realistic constraints about the equipment. The students explore creating value to the prototype by having results that can be retro-fitted on an existing piece of equipment, improve existing technology, or develop something new within a reasonable budget. The student teams benchmark their prototypes to determine where their product would fit in the market. They create value by knowing how their final solution benefits the user. Finally, the students build mechatronic prototypes using an Arduino, and the user is able to view the final demonstration and the innovative solutions from the student teams. This project exposes students to the entrepreneurial mindset and the importance of being curious, connecting with their user, and creating value in a design. Since the inception of this project, it has become a fundamental assignment in the course and an integral part of the class.

Introduction

At Arizona State University, The Polytechnic School, project courses are a critical part of the engineering curriculum. Foundations of Engineering Design II is the second project course for freshman engineers and a core course for a general engineering degree. During the Foundations of Engineering Design II class, a team project introduces the students to the entrepreneurial mindset. Project-based learning can increase the motivations and interests for studying engineering [1]. The author received a KEEN Professorship Mini-Grant to develop a project with the entrepreneurial mindset. The KEEN entrepreneurial mindset consists of curiosity from the students about our changing world, connections from sources to gain insight and assess risk, and creating value in a prototype through unexpected opportunities [2].

The agriculture sector is a highly technical field that offers many open-ended problems for students to explore. The farming industry has gone away from manual labor and embraced technology, oftentimes being a leader [3]. John Deere was an early adopter of precision agriculture by implementing GPS on tractors in the mid-1990's [4]. Recently, John Deere announced a sprayer that acts as an inkjet printer for precision spraying of plants [5]. Automation can monitor water usage and ensure plants are receiving the correct amount of water [6]. Drones also have many uses in the agriculture sector from mechanical to environmental. Images from drones can help determine a flat tire or clogged sprinkler on a pivot irrigation system [7]. Drones can also collect data to monitor soil quality, planting, crop spraying, crop health assessment, pest infestation, wildfire detection, and observe water usage [8]. More commonly, drone technology helps monitor large fields with aerial views. Farmers and crop analysts have recently started using aerial images from drones to analyze various stresses and resulting crop health [7, 9].

After deciding to focus on a project in the agriculture sector, a connection was made with a farmer from Harrison Farm to help determine current issues in agriculture. The farmer identified topics that would help the overall productivity of the farm. Solutions to some of these problems do exist on newer models of equipment; however, irrigation systems and machinery may be utilized for decades on a farm. Therefore, being able to supplement older technology is also a consideration for project designs.

Foundations of Engineering Design II Class

The agriculture sector project was first introduced during the Fall 2017 semester and has been an important part of the Foundations of Engineering Design II class. The Foundations of Engineering Design II class is the second project course for students in the engineering degree path at Arizona State University. During the class, the students focus on the engineering design process, prototyping skills, basic circuits, introduction to coding, and teamwork skills. The curriculum consists of individual assignments to assess skills attained during the class, and team assignments to assess projects. The agriculture sector project is introduced during the second half of the semester after the students have gained experience with Arduinos and sensors. The students use a 5-step design process in the class with the following steps: empathize, define, ideate, prototype, and test. Individual assignments supplement the team project work as well. The first individual assignment tied to this project is Design Process: Empathize and Define. In this assignment, the students interview the user, develop a POV statement and requirements, and start benchmarking the team's ideas. The next assignment is SolidWorks Assembly. SolidWorks is a CAD program. Students use this program to develop an assembly (multiple parts assembled) to demonstrate their design idea. The next assignment is Technical Communication. In this assignment, the students must combine their POV statement, requirements, benchmarked devices, a discussion of how their design fits the current market, and a bill of materials all into one technical document with references. The last individual assignment is Testing. The students must demonstrate that they have tested their prototype before the final demonstration day. The Testing assignment emphasizes the importance of testing your design as you build the project. Since this project is mechatronic, it is important to test every step of the design with coding, wiring, and building. Lastly, there are team assignments that include developing a poster with benchmarked devices, requirements, and POV statement to assist the students during their final demonstration assessment. The teams also submit a final technical document regarding the user, project development, design, bill of materials, code, and lessons learned.

The learning outcomes from the individual and team assignments for the agriculture sector project are the following:

- Display curiosity and reframe problems as opportunities.
- Conduct an effective customer interview during which you gain new information/insights about the customer's needs and use that information to develop an appropriate Point of View statement (user + need + insight). Accurately translate design needs into metrics and specifications. Benchmark existing solutions that meet the customer's need. Be specific; e.g., give data, specifications, on what is already there.
- Research and brainstorm multiple design solutions.
- Accurately apply basic engineering concepts to a design problem.
- Fabricate a functional prototype as a SolidWorks assembly, in which at least one intended function of the final product is realized.
- Use evidence-based writing with equations, figures, and tables in the context of a technical document.
- Create prototypes rapidly, using engineering design principles without having all the necessary information.
- Assess the design concept based on experiment/testing.
- Communicate the value of a design from a market, economic, and social/environmental perspective.

The learning outcomes help to guide the students through the design process, while building curiosity, connections, and creating value in the prototype.

Curiosity

The introduction of the project gives the students the objective to improve the farm-to-fork supply chain by reducing chemical exposure, increasing efficiency of planting and harvesting, and conserving water. The students learn about common agriculture equipment such as planters, sprayers, combines, grain carts, and pivot irrigation systems.

Planter: A tractor pulls a planter. Oftentimes, a planter has anywhere from twelve to twenty-four boxes that deposits the seeds across the same corresponding number rows in a field as shown in Figure 1. All the boxes release the seeds at the same rate. Depending on the terrain, the farmer may want to apply more or less seed in certain areas. Also, due to the field layout some boxes may need to be shut off. <u>Project problem:</u> automatically adjust each box, or a set of boxes, rate of spread on a planter and field layout.

Sprayer: A sprayer applies chemicals to crops in a field with extended arms called booms as shown in Figure 2. Due to the terrain, the farmer does not want the booms to hit objects or the ground, while keeping the spray close to the plants for maximum coverage. <u>Project problem:</u> automatically adjust the height of the sprayer booms while driving through the field.

Figure 1. A planter attached to a tractor.

Figure 2. A sprayer with booms extended.

Combine/Grain Cart: A combine harvests crops in the field as shown in Figure 3. A tractor pulls a grain cart, shown in Figure 4, and receives grain from the combine as it is cutting crops. The grain cart increases efficiency during harvest, so the combine does not have to stop mid-field. The tractor and grain cart must stay close to the combine to receive the harvested crop without impeding the combine. Project problem: be able to set the combine as a primary with the tractor and grain cart as a secondary to adjust speed and distance through auto steering.

Figure 3. A stationary combine.

Figure 4. Top down view of a tractor and grain cart.

Pivot Irrigation System: A pivot irrigation system waters the crops while making a circular rotation in the field as shown in Figure 5. The water flow is constant from the valves, called drops, therefore the system rotation speed must change to increase or decrease the amount of water applied to a field. Based on the terrain, some areas may need more or less water. Project problem: adjust each irrigation drop, at a variable rate, the amount of water flow based on terrain.

Figure 5. Pivot irrigation system.

Rain Gauge: A rain gauge collects and measures the amount of precipitation received. The amount of precipitation affects the speed of the irrigation system. If a small amount of rain falls, the system may be kept at the same rate or increased. If a sizeable amount of rain falls, the system may be turned off. Project problem: a rain gauge with a daily flush that automatically controls the rate of rotation of the irrigation system.

The student teams discuss the problems and ask questions to the user regarding the equipment and desired outcomes. Based on user-centered questions and preliminary research the team picks the project that interests them the most. Letting the student teams pick the project problem heightens their interest in developing the prototypes [10]. Once the students learn about the technology related to the equipment, they are immediately intrigued and start conducting research on their own to learn more about the problem/equipment, and how they can generate possible solutions.

Connections

The student teams interview a farmer via email. Through the interview process, the students are able to empathize with the user group (farmers) and understand what they are concerned about with regards to the specific agriculture problem. The students then develop a point of view (POV) statement. The POV statement defines the user, the need, and the insight behind the problem in specific detail. An example of a POV statement for this project would be the following: *a corn farmer in the Midwest needs a way to variably adjust the amount of water applied to his field because the field is not perfectly level; and since corn requires a lot of water, he wants to conserve water and produce the most bountiful corn*. Then the students define in detail the specific problem that their team addresses to make a positive impact for the user group's experience. The student teams develop requirements for the project based on the interview, the constraints of the equipment, and the desired outcome of the project.

Creating Value

The project prototype must have some mechanical/moveable part that must be automated using an Arduino, actuator, and sensor. The student teams must brainstorm possible design ideas and benchmark their possible solution against other designs available in the market. Through benchmarking and user feedback the teams are able to determine appropriate design requirements. Through the benchmarking process the students must assess the value of their design, which can be in the form of a novel idea, an economical idea, or an idea to improve existing machinery. The teams must create a functional prototype of their most promising solution and present the final prototypes during the project demonstration day. The user can see the final prototypes remotely via electronic media. Figures 5-10 show student prototypes for a planter, sprayer, combine/grain cart, irrigation system, and rain gauge, respectively.

During the demonstration day, awards are presented in the following areas:

- Most Innovative/Creative (a unique design that has an eye towards the future)
- Best Craftsmanship (a well-built prototype)
- Most Technical Concept (a design that went above and beyond with coding, sensors, motors, etc.)
- The One the User Would Want (the most practical solution, the user would realistically buy this one)

Figure 6. Variable rate planter.

Figure 7. Adjustable sprayer booms.

Figure 8. Auto-steering grain cart.

Figure 9. Adjustable drops on an irrigation system.

Figure 10. Rain gauge to control irrigation system rate.

Learning Assessment

The goal of the KEEN Professorship Mini-Grant was to develop a user-centered project in the agriculture sector that introduced the 3C's of the KEEN entrepreneurial mindset to the students. No assessments were made on the entrepreneurial mindset growth, however several aspects of the agriculture sector project has brought about learning improvements in the Foundations in Engineering Design II class. Overall, the project-based grades have improved from previous user-centered projects. The first semester the agriculture sector project was implemented was with a small class of 42 students, as compared to the previous semester with 116 students. The project-based grades improved 1.5% from the previous semester. The second semester the agriculture sector project was implemented was with a more comparable-sized class of 107 students. The project-based grades improved 3.1%. The students relate to the user and technology better than previous projects. In previous projects, the students usually did not have a user to conduct interviews. Also, in previous projects the technology was somewhat limited. The agriculture sector is a leader in innovative technology. The students also enjoy picking their project and this is a large motivator in their willingness to complete the project and complete extra research [10]. Since Foundations of Engineering Design II class is a freshman-level class, several modifications were made to the delivery of the project assignment to assist with executive functioning skills in college. The students completed a survey regarding these modifications, shown in Figure 11. The survey results also indicate the delivery of the project assignment was conducive to a successful project. The questions followed a Likert scale with Strongly Agree, Agree, Neural, Disagree, and Strongly Disagree options. The second semester class to complete the agriculture sector project with 107 students answered the following questions:

- Question 1: Is the project brief (the document describing the project and associated assignments and due dates) too long?
- Question 2: Is the project broken up into a sufficient number of tasks/assignments/milestones?
- Question 3: Would you like more direction during teamwork time?

For question 1, 7% of the students thought the project briefs were too long (Strongly Agree and Agree results). 87% of the students thought the project was broken up into sufficient tasks (Strongly Agree and Agree results) and 38% of the students wanted more direction during the teamwork time (Strongly Agree and Agree results). A modification in future classes is to provide more specific instructions when students have project work time.

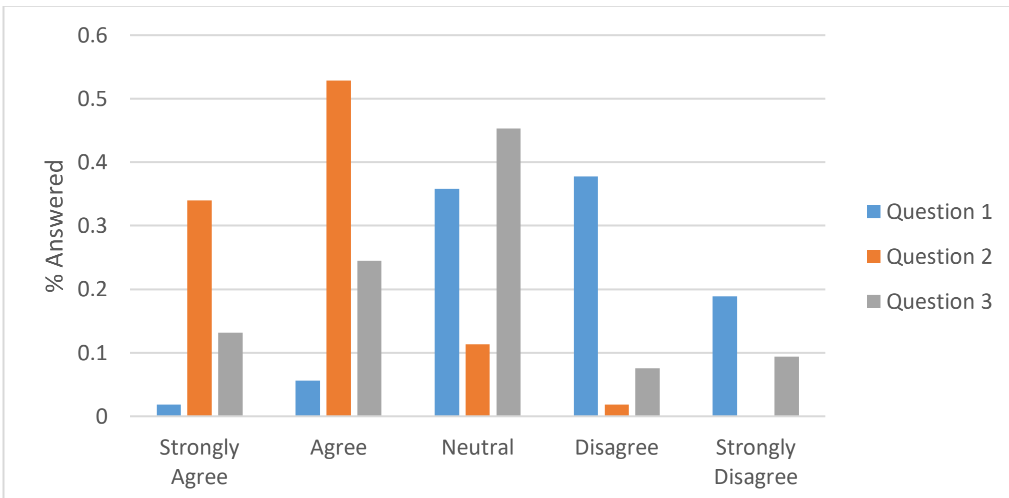

Figure 11. Class Modification Survey Results

Through the agriculture sector project the students are encouraged to develop their research further through various programs at Arizona State University that promote undergraduate research and entrepreneurial start-ups. Several students have completed additional research in the agriculture sector field, one student is currently researching start-up ideas, and several students are continuing the research into graduate school.

Conclusion

Freshman engineering students learn about the KEEN entrepreneurial mindset through project-based curriculum. Using a connection to a customer and information about issues in the agriculture sector, the student teams incorporated the entrepreneurial mindset into the engineering design process for creating a prototype.

An important aspect of the entrepreneurial mindset is to prototype and fail early to redesign from mistakes. This is also implemented in the design process with an iterative loop on the latter steps from ideate, prototype, and test. Future work will consider adding this iterative loop to the project. The students already intuitively go through this process as a part of developing their initial prototype. After the prototype demonstration, the author would like to add user feedback and have the students prototype a second iteration based on design improvements and user needs.

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