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Instilling Entrepreneurial Mindset by Vertical Integration of Engineering Projects

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Work-in-Progress - Instilling Entrepreneurial Mindset by Vertical Integration of Engineering Projects

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***Abstract* - The goal of this research project is to instill an entrepreneurial mindset by vertically integrating a single design project among two consecutive freshmen engineering design classes. The paper describes the context and background of two vertically integrated classes. Example work from students show the interpretation of the entrepreneurial mindset. A survey measures the effectiveness of the entrepreneurial mindset among students that are taking part in the project. Next, there are recommendations based on the information gathered during the implementation, including specific recommendations about the types of projects, constraints and methodologies. Other vertically integrated classes and curricula can use this case-study as a starting point for introducing entrepreneurial mindset. Lastly, there is a current discussion of case studies of vertical integration among student groups in non-consecutive semesters of a program, and student groups from completely different programs.**

Index Terms – entrepreneurial mindset, vertical integration, engineering design, project

INTRODUCTION

The entrepreneurial mindset (EM) is a problem-solving approach defined by the three Cs: Curiosity, Connections and Creating Value, as defined by the three Cs outcomes framework at Arizona State University (ASU). The approach instills curiosity about the surroundings or the world to explore different perspectives, connects information from varied sources to obtain empathy and insight, and recognizes possibilities to create value. As a partner in the Kern Entrepreneurial Network, ASU is implementing EM content through their courses, programs and labs. Table I shows ASU's framework for documenting student and faculty outcomes related to the three Cs.

BACKGROUND

This work-in-progress vertically integrates engineering projects in consecutive courses during the freshman year. The project connects more than 375 engineering students with each other as well as approximately 35 high school students as customers to instill Curiosity, Connections and Creating Value across multiple levels of activity and engagement.

TABLE I
ASU'S FRAMEWORK FOR DOCUMENTING STUDENT AND FACULTY OUTCOMES RELATED TO THE THREE C'S [1]

THREE C'S	MINDSET OUTCOME (ATTITUDE)	BEHAVIORAL OUTCOME (ACTION)
CURIOSITY	1. Inherently interested in a wide variety of things 2. Thinking from both an epistemic and divergent perspective 3. Empathetic to perspectives and viewpoints of others 4. Comfortable with ambiguity 5. Willingness to challenge accepted solutions	a. Observes surroundings to recognize opportunity b. Explores multiple solution paths c. Gathers data to support and refute ideas d. Suspends initial judgement on new ideas e. Observes trends about the changing world with a future-focused orientation/perspective f. Collects feedback and data from many customers and customer segments
CREATION OF VALUE	6. Willingness to take risks 7. Persistence through setbacks and willingness to overcome failure 8. Willingness to change direction on an idea (pivot) 9. Motivated to make a positive contribution to society	g. Applies technical skills/knowledge to the development of a technology/product h. Modifies an idea/product based on feedback i. Focuses on understanding the value proposition of a discovery j. Describes how a discovery could be scaled and/or sustained, using elements such as revenue streams, key partners, costs, and key resources k. Defines a market and market opportunities l. Engages in actions with the understanding that they have the potential to lead to both gains or losses
CONNECTIONS	10. Appreciation for different disciplinary knowledge and skills 11. Aware of one's own limitations in knowledge and skills 12. Willingness to work with individuals with different skill sets, expertise, disciplines, etc.	m. Articulates the idea to diverse audiences n. Persuades why a discovery adds value from multiple perspectives (technological, societal, financial, environmental, etc.) o. Understands how elements of an ecosystem are connected p. Identifies and works with individuals with complementary skill sets, expertise, etc. q. Integrates/synthesizes different kinds of knowledge

The three stakeholder groups include high school students, freshmen enrolled in Foundations of Engineering Design Project I (EGR 101) and freshmen enrolled in Foundations of Engineering Design Project II (EGR 102) at ASU, the Polytechnic campus. EGR 101 is the introductory course to the project spine of the engineering degree. The skill sets introduced during this course are working with wood, using a band saw and a drill press, implementing the engineering design process, and productive teamwork. In EGR 102, the second course in the project spine, students are introduced to electrical circuits, soldering and programming using a microcontroller board. Both courses are offered in fall and spring semesters where students work in teams on hands-on projects. While EGR 101 produces prototypes, EGR 102 students produce functional prototypes that combine machining skills, electronics and programming. This work-in-progress seeks to vertically integrate a single project between these two classes.

The projects consist of two hands-on projects that are implemented in two halves of a semester: i) the hovercraft project and ii) the user-centered project. The stakeholders for the hovercraft project consist of high school students and freshmen enrolled in EGR 101. The stakeholders for the user-centered project consist of freshmen enrolled in the EGR 101 and EGR 102 sections. The authors are leading the project with the assistance of teaching assistants and other faculty teaching these courses. The following sections detail how each project implemented the 3Cs of the Entrepreneurial Mindset in the 2017 spring semester.

HOVERCRAFT PROJECT

Freshmen teams enrolled in EGR 101 designed a rideable hovercraft based on the needs of high school students who participated in the racing competition.

I. Curiosity

EGR 101 students were given a brief project statement that lacked specificity about the design. The freshmen students then researched DIY hovercraft models in existence, and developed a problem definition and identified important criteria in the designs. Students then listed the deficiencies (bugs) in existing designs and created bug lists. Next, they interviewed high school students to determine the user requirements of the hovercraft. The interview process enhanced the curiosity and creativity of possible solutions for both stakeholders.

II. Creation of Value

During the interview stage, high school students had the opportunity to think critically about the usability of the final hovercraft. The final product had a budget that limited the type of materials the teams used to design the final working hovercrafts.

III. Connections

The EGR 101 students worked in groups with varying skillsets and backgrounds. By visiting the Freshman Engineering Studio at the Polytechnic campus, the high school students gained insight about the engineering program, as well as advanced their interest in engineering. Freshmen students completed a survey about the project regarding the EM outcomes.

USER-CENTERED PROJECT

EGR 101 and 102 students designed a futuristic solution for a real user from one topic out of the following three areas: transportation, amusement park rides and robots. The initial project brief given to the students outlined the deliverable constraints owing to schedule and materials available. EGR 101 students designed prototypes using wood, acrylic, vinyl or ABS plastic. After EGR 101 students completed their prototype design, EGR 102 students interviewed a student group from EGR 101 to discover the needs, and insights they considered to create their prototype.

I. Curiosity

The EGR 102 student teams created a point of view statement based on user interviews. Then, they benchmarked devices available in the market to identify opportunities to bolster their design solution. Based on market research of existing solutions, they presented a design proposal.

II. Creation of value

In the process of creating a functional prototype, EGR 102 teams made changes to their design based on feedback from EGR 101 students. The teams then prepared a Solidworks model of their design along with a bill of materials that fit the user's budget.

III. Connections

The EGR 102 students worked in teams of varying skillsets and backgrounds. The teams from both classes consulted through multiple meetings to ensure that they were meeting the design document requirements. After repeated meetings and referring to fabricated prototypes made by EGR 101 students, EGR 102 students made the prototypes functional using electrical connections and microcontroller programming. Both EGR 101 and 102 students presented their solutions describing how their product adds value from multiple perspectives.

PRELIMINARY RESULTS

Both EGR 101 and EGR 102 classes participated in a survey at the end of the spring semester based on the behavioral outcomes (a – q) listed in Table I. The results of the survey are shown in Figure 1. Students rated their behavioral outcomes between 1 and 5, where 1 corresponds to "Did not acquire" and 5 corresponds to "Excellent". Figure 2 shows the project directive provided to the students by the instructors. Students in both classes were able to demonstrate curiosity through the process of brainstorming, creating bug lists, and benchmarking market products. Based on these steps, student teams created a design directive statement. Through teamwork and communicating with students with different skill sets the students demonstrated behavioral outcomes 'creation of value' and 'connections' from Table I. An example functional prototype created by an EGR 102 student team along with their poster showing the design directive, benchmarked market products and user insight is shown in Figure 3.

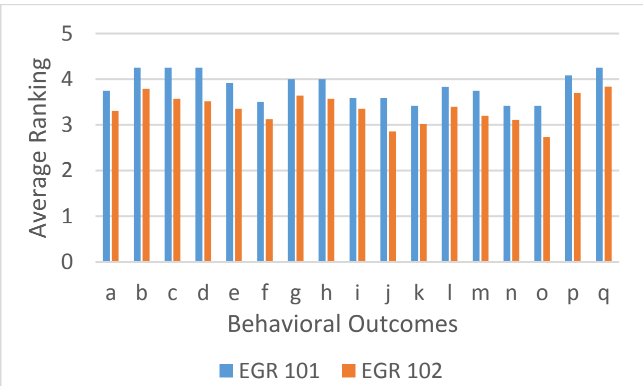

FIGURE 1
SURVEY RESULTS: BEHAVIORAL OUTCOMES

- Choose a user group from EGR 101 and empathize and understand what they are concerned about
- Define the specific problem that you will address to make a positive impact on the user experience
- Must have some mechanical part/moveable part that must be automated
- Brainstorm possible design solutions and functions for your idea to perform
- Create a conceptual mock-up and a 3D model of some of your team's promising solution(s)
- Communicate your idea(s) to users (using conceptual mock-up or CAD models) and get feedback
- Make improvements to your team's solution based on user feedback
- Create a **functional prototype** of your team's most promising solution
- Present your final prototypes to the class

FIGURE 2
PROJECT DESCRIPTION

FIGURE 3
STUDENT ARTIFACT: POSTER AND FUNCTIONAL PROTOTYPE

REFLECTION AND RECOMMENDATION

The survey results indicate higher ratings by EGR 101 students in all behavioral outcomes. Informal student feedback received by faculty indicated that EGR 102 students did not like that the user group and the problem addressed in the user-centered project were preselected. On the other hand, EGR 101 students responded positively to interview sessions and were eager to implement the high-school users' needs as indicated through high ratings (>4) in outcomes b, c, d and q. Based on these results, the faculty concluded that vertically integrating a project does not necessarily mean the loss of open-endedness of a project. The freshmen enjoyed the challenge of an open-ended project rather than having a preselected user and problem. Ratings from EGR 102 students indicated that designating a specific user and a problem might be better suited for a sophomore or junior level class. A project under implementation in EGR 102 and a sophomore year class of the engineering program will investigate this conclusion. Additionally, instead of assigning the same project to both classes, different aspects of the same project could be assigned to the two classes. This could result in recognizing the importance of working with people with complementary skillsets, specifically, outcomes m – q from Table I.

In general, the survey results indicate the need to include elements in the project that encourage students to reflect on scalability of their discoveries as well as to gain a bigger picture in terms of the ecosystem where their prototype is located. In EGR 102, benchmarking is a tool used before and after student prototyping to evaluate its position in the market. While it is not necessary that a single project demonstrate all the entrepreneurial mindset outcomes, the vertical integration paradigm allows instructors to seamlessly add more outcomes as students progress in their degree program. Specifically, EGR 101 students indicated lower ratings (< 3.5) towards outcomes k, n and o. It is difficult to implement the mindset outcomes related to these characteristics in the hovercraft project. However, the next class that the EGR 101 students are expected to enroll into, EGR 102, implements these outcomes. In that case, students can reflect on their prior experience connecting with other students and bring those interactions to develop these mindset outcomes.

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