Cultivating the Entrepreneurial Mindset through Design: Insights from Thematic Analysis of First-year Engineering Students' Reflections

Mr. Mark Vincent Huerta, Arizona State University

Mark Huerta is a PhD student in the Engineering Education Systems and Design program at Arizona State University. He earned a B.S. and M.S. in Biomedical Engineering at Arizona State University. Mark possesses a diverse background that includes experiences in engineering design, social entrepreneurship, consulting, and project management.

Dr. Jeremi S. London, Arizona State University

Dr. Jeremi London is an Assistant Professor of Engineering at Arizona State University. She holds B.S. and M.S. degrees in Industrial Engineering and a Ph.D. in Engineering Education, all from Purdue University. Prior to her PhD, she worked in quality assurance and logistics roles at Anheuser-Busch and GE Healthcare, where she was responsible for ensuring consistency across processes and compliance with federal regulations. For four consecutive summers (2011-2014), she worked in the National Science Foundation's Division of Undergraduate Education on research and evaluation projects related to the use of technology in STEM education. Dr. London masters mixed methods and computational tools to address complex problems, including: science policy issues surrounding STEM learning in cyberlearning environments; evaluation and impact analysis of federal investments in R&D; and applications of simulation & modeling tools to evaluate programs.

Amy Trowbridge, Arizona State University

Amy Trowbridge is a Lecturer and Director of the Grand Challenge Scholars Program in the Ira A. Fulton Schools of Engineering at Arizona State University. Her teaching focuses primarily on first year engineering students, and she is interested in curricular and co-curricular experiences that broaden students' perspectives and enhance student learning.

Mr. Marvyn Arévalo Avalos, Arizona State University

Marvyn R. Arévalo Avalos is a 2nd year Doctoral Student in Counseling Psychology, in the College of Integrative Sciences and Arts at Arizona State University. Marvyn's research interest include Latino/a Career Development and Multicultural Counseling Competencies. For instance, his research examines environmental and socio-cognitive variables associated with academic attainment among Latino/as in higher education.

Wen Huang, Arizona State University

PhD. student, Engineering Education Systems and Design (PhD) The Polytechnic School Ira A. Fulton Schools of Engineering Arizona State University

Dr. Ann F. McKenna, Arizona State University

Ann F. McKenna is a Professor in the Ira A. Fulton Schools of Engineering and Director of The Polytechnic School at Arizona State University. Prior to joining ASU she served as a program director at the National Science Foundation in the Division of Undergraduate Education, and was on the faculty in the Department of Mechanical Engineering and Segal Design Institute at Northwestern University. Dr. McKenna received her B.S. and M.S. degrees in Mechanical Engineering from Drexel University and Ph.D. from the University of California at Berkeley.

Cultivating the Entrepreneurial Mindset through Design: Insights from Thematic Analysis of First Year Engineering Students' Reflections

Abstract

Design is often specified as the characteristic that distinguishes engineers from professionals in other fields. This skill gives engineering graduates a competitive edge for pursuing diverse career paths and for responding to a range of social and technological needs throughout their careers. A component of this competitive edge includes affording students the opportunity to develop an entrepreneurial mindset (EM). According to the Kern Entrepreneurial Engineering Network (KEEN), the EM includes three dimensions: curiosity, creation of value, and connections. While entrepreneurship is frequently associated with commercialization and business, it is a critical but undervalued aspect of designing products and solutions in engineering. Over the past decade, various members of KEEN have embedded the EM in engineering curriculum offered by programs across the U.S. This is one of few studies that investigate the impact of doing so.

Given the inherent characteristics of an EM and the engineering design process, this paper starts by describing the overlap between the two and reveals how they complement one another; then goes into a thematic analysis of the mindsets of twenty-seven students who had just completed a design activity accompanied by EM interventions in a first-year engineering course. The purpose of the study is to explore how their mindsets were revealed in their written reflections on: the attitudes and behaviors they perceive were necessary for successfully completing the design activity; the specified attitudes and behaviors they feel they possess; and which attitudes and behaviors they perceive are necessary for success after graduation. The results of this study reveal that students seamlessly weave together thoughts on actions performed during the design process with facets of an EM throughout their reflections. It includes evidence of how engineering design and EM can inform and influence one another while engineers engage in their work. The findings of this study help make the case for the need to co-facilitate the development of an EM as part of teaching engineering design in undergraduate engineering education.

Motivation

It takes time for new norms to be established in the engineering education community, but given enough time and a little reflection, changes become more apparent. Froyd, Wankat, and Smith (2012) wrote an article that summarizes five major shifts that have happened in engineering education over the past century-- the third of which includes the "renewed emphasis on design" (p. 1346). Engaging in the engineering design project is one of the activities that unifies the work of all engineers, regardless of the specific discipline. Former National Academy of Engineering president, William Wulf, succinctly defined engineering as "design under

constraint" (NAE, 2002). In fact, some would argue that design is the characteristic that distinguishes engineers from professionals in other science, technology, engineering, and mathematics (STEM) fields (Draper, 2009). The role and importance of design in engineering cannot be overstated.

Given the importance of design in the work of an engineer, it is not surprising that it is an activity that is emphasized in various parts of the engineering education ecosystem. The rise of makerspaces, TechShops, and design studios of all kinds give place for engineers and others alike to tinker and engage in the engineering design process in a variety of informal learning contexts. More formally, design is a critical part of all engineering students' last year of their undergraduate education (via capstone/senior design courses), and has increasingly becoming the norm in the first year engineering experience as well (Froyd et al., 2012; Lord & Chen, 2014). From a policy perspective, design is explicitly mentioned in two out of eleven of ABET's student outcomes (i.e., B and C) ("Criteria For Accrediting Engineering Programs," 2017). Thus, in informal, formal, and policy levels, there seems to be a shared understanding of the importance of engineering design.

While design is here to stay, emerging trends permeate the engineering education ecosystem. One of the trends that has gained a lot of traction over the years is the increased emphasis on entrepreneurship and the entrepreneurial mindset. There are many indicators of its increasing prominence. The opportunity for engineering students to obtain entrepreneurship-related credentials (via minors, certificate programs, etc.) through their engineering programs is a relatively new phenomenon (e.g., at University of Michigan) ("Michigan Engineering Interdisciplinary Minors & Programs," 2017). There has also been an increase in partnerships between engineering and business schools within a university (e.g., at Rensselaer Polytechnic Institute) ("Rensselaer Polytechnic Institute Entrepreneurship," 2010). Apart from these programmatic changes that reflect these trends, there is a growing body of scholarship within the engineering education literature that highlights the increase in the number of people working in the area and the expansions to the body of knowledge on this topic. For example, the development of publications venues like the Journal of Engineering Entrepreneurship (JEEN) and ASEE's Division of Entrepreneurship and Innovation speak to rise of scholars and scholarship in this area. Moreover, foundations like the KERN Family Foundation ("The Kern Family Foundation," 2016) is dedicated to supporting efforts that promote an entrepreneurial mindset among engineering students and faculty across the country as part of the Kern Entrepreneurship Engineering Network ("KEEN Engineering Unleashed," 2017). This set of activities speaks to the growing prominence of entrepreneurship in the engineering ecosystem.

Efforts to promote entrepreneurship in engineering education may come in a variety of forms. These activities can be conceptualized using a continuum with commercialization at one end and mindset at the other. The most common entrepreneurship-related activities that happen

in the engineering education ecosystem are experiential in nature involving steps toward commercialization or creating a startup (Duval-Couetil, Shartrand, & Reed, 2016). These activities include the development of a business plan, consulting with practicing entrepreneurs, interviewing potential customers, delivering pitches, applying to grants, and prototyping a physical product or application. What are not as common, however, are activities that focus on cultivating an entrepreneurial mindset (EM). A mindset can be defined as framework for making predications and judging the meanings of events in one's world (Yeager & Dweck, 2012). This trend is changing, however, due to the increasing set of EM focused activities sponsored by the KERN Family Foundation. While the activities at this end of the spectrum are increasing, the number of in-depth qualitative and/or quantitative analysis on the impact of cultivating an EM is lacking. This study helps address this need.

In short, this study describes the overlap between the EM and the engineering design process to reveal how they complement one another by analyzing the written reflections of engineering students who had just completed a design activity. The goal of the study is to explore how their mindsets were revealed in their written reflections on: the attitudes and behaviors they perceive were necessary for successfully completing the design activity; the specified attitudes and behaviors they feel they possess; and which attitudes and behaviors they perceive are necessary for success after graduation. The next sections provide a review of the interventions that have been used to cultivate an EM and ways in which it has been assessed, and a conceptual lens guiding this work. After discussing the methods of data collection and analysis, the themes that emerged will be discussed. Implications of this work and next steps will also be discussed.

Literature Review

In recent years, there have been several engineering faculty at KEEN partner institutions working on efforts to encourage students to develop an EM. Changes have been made to a variety of different aspects of courses to encourage the development of EM including the content, assessment methods, and pedagogical techniques. These efforts are typically focused on behavioral and mindset outcomes defined by KERN's '3Cs'. Specifically, most efforts are focused on helping students to develop *curiosity* to explore the world, and make *connections* between different sources and types of information in order to *create value* for others ("KEEN Engineering Unleashed," 2017). Pedagogical techniques developed and implemented in the classroom aimed at developing EM have sometimes been referred to as entrepreneurially-minded learning (EML) (A. Gerhart & Melton, 2016). This review provides an overview of the different approaches that have been used by faculty to encourage students' development of EM, and the attempts that have been made to assess the results of their efforts.

Interventions to Promote the Development of EM

Efforts to encourage students' development of EM have been implemented in a variety of different courses and extracurricular events at universities across the United States. The most common courses in which EM has been integrated are those which focus on engineering design, or project-based courses at all levels (freshman through senior) (Bell-Huff, Carpenter, & Gerhart, 2016; Cook & Cuper, 2010; Fry, Jordan, Leman, Garner, & Thomas, 2010; A L Gerhart & Carpenter, 2013; Andrew L. Gerhart, Carpenter, Fletcher, & Meyer, 2014; Kim et al., 2016; Rayess, 2016; Riofrio et al., 2015; Singh, Klingler, Dougherty, & Moncada, 2015). At several institutions, EM has been integrated into first year engineering courses through hands-on projects and activities (Condoor & Mcquilling, 2009; Fry & Van Treuren, 2016; Andrew L. Gerhart et al., 2014; Rayess, 2016; Reid & Ferguson, 2011; Riofrio et al., 2015; Thoroughman, Hruschka, & Widder, 2014). EML has also been integrated into fundamental engineering courses including statics (Mallory, Romoser, & Keyser, 2016), probability and statistics (Mallory et al., 2016), thermodynamics (Mallory, 2015), fluid dynamics (A. Gerhart & Melton, 2016), programming (Estell, Reeping, & Sapp, 2016), and other discipline specific courses (Davis, Hoff, & Riffe, 2011; A L Gerhart & Carpenter, 2013; Nezami, Tavakoli, & Torfeh, 2016). Elective courses and extracurricular activities focused on entrepreneurship are another location in which efforts have been made to help students develop EM (Ferguson, Cawthorne, & Streveler, 2013; Gettens et al., 2016; Kirkpatrick, Watt, & Bernal, 2016).

The method in which EML has been integrated into courses varies and often depends on the type of course in which it is implemented. However, there are some common trends. Across all types of courses, regardless of whether the focus is on design or technical content, a common strategy for incorporating EML is presenting students with a problem to solve which includes a fictional customer and a real world context (Bell-Huff et al., 2016; Cook & Cuper, 2010; Davis et al., 2011; Erdil, Harichandran, Nocito-Gobel, Carnasciali, & Li, 2016; A. Gerhart & Melton, 2016; Andrew L. Gerhart et al., 2014; Kim et al., 2016; Mallory, 2015; Nezami et al., 2016). In core engineering courses such as fluid dynamics, statics, or thermodynamics, problem based learning is combined with a customer focus to encourage students to find and pursue opportunities to create value while learning technical concepts (Mallory, 2015; Mallory et al., 2016). In these and other courses, students are also asked to consider economic viability as well as technical feasibility when choosing a solution for their often fictional clients. Another strategy that has been used to introduce EM related concepts to students is by showing the role that business plays in engineering, specifically by asking students to evaluate the market, develop business plans, and/or describe their solutions in economic terms (Cook & Cuper, 2010; Ferguson et al., 2013; Fry et al., 2010; Gettens, Robert, Riofrio, Jose, Spotts Jr., 2015; Mallory et al., 2016; Meyer & Nasir, 2015; Nezami et al., 2016; Rayess, 2016; Thoroughman et al., 2014). In design courses, common features of EML include asking students to identify customer needs, engaging the customer (real or fictional customer present through role play) for feedback, considering economic constraints, and a focus on creating value for customers through their design solutions (Cook & Cuper, 2010; Andrew L. Gerhart et al., 2014; Kim et al., 2016; Rayess,

2016; Riofrio et al., 2015; Singh et al., 2015). In some courses, students use various techniques to identify their own opportunities or problems to focus on, and/or interact with real customers as they work through the design process (Bell-Huff et al., 2016; Estell et al., 2016; Gettens, Robert, Riofrio, Jose, Spotts Jr., 2015; Rayess, 2016; Singh et al., 2015).

Assessment of EM

Despite the growing number of faculty implementing EML, the assessment of the success of those interventions has been more limited in scope and type. The majority of assessments that have been done are quantitative surveys focused on student self-assessment or perceptions about their abilities and skills related to the EM, as defined by KEEN. The most common approach to assessment is a pre-/post- assessment using a Likert-scale survey made up of several statements which exemplify the '3Cs' (curiosity, connections, creating value) and/or complementary skills or mindset related behaviors (Erdil et al., 2016; Fry & Van Treuren, 2016; A. Gerhart & Melton, 2016; Gettens, Robert, Riofrio, Jose, Spotts Jr., 2015; Mallory et al., 2016; Riofrio et al., 2015). Other studies have utilized validated quantitative assessment tools from related areas to assess the outcome of their interventions including the community service attitudes scale (for service learning related projects) (Estell et al., 2016), situational interest and motivation scales (Kim et al., 2016), and the Dweck mindset assessment (Reid & Ferguson, 2011).

Although quantitative surveys have been used quite often to assess EM related interventions, very limited qualitative data has been collected. In most of the studies, the only qualitative data that was collected was open ended feedback from the students related to their experience with the intervention (Estell et al., 2016; Andrew L. Gerhart et al., 2014). None of the studies performed any analysis on the qualitative data in order to form conclusions. In a few studies, the results of the intervention were presented by providing qualitative descriptions of examples of students' work or behaviors as evidence for the presence of each of the 3Cs (Kirkpatrick et al., 2016; Singh et al., 2015). However, in this case, the qualitative descriptions were provided by the author, not from the students. The qualitative study described in this paper will help to fill this gap in the literature, and will provide insights into the EM-related attitudes and behaviors students develop as a result of EML.

Research Question:

How does the integration of EML into a freshman engineering design course impact which behaviors and attitudes engineering students' perceive as valuable?

Theoretical Lens

Engineering Design

In history, the development of design process research is divided into three stages based on the different focuses of attention: Prescription, Description, and Observation (Atman, Eris, McDonnell, Carbella, & Borgford-Parnell, 2014). In the era of Prescription, researchers

considered design from a systematic angle, and tried to fix the design process into a prescribed work-flow model. This movement ultimately failed because people started to recognize the uncertainty in design and iterative nature of the process. This led to a shift in the design movement towards the second era called Description. In this era, research focused on problems in design. A designer was the one who both set the problem and solved it; the design work involved a continuous improvement process. With the further development of design work, designers gradually formed their own solutions to different design tasks. Under this idea, the research of the design process led to the third era. Since the focus of finding out about design expertise was based on observational and psychological studies, this era is called Observation.

Engineering design process research is a branch of the design process. It aims to "advance our understanding of engineering practice, increase product development performance, and inform engineering education" (Atman et al., 2014). There are mainly three types of viewpoints on engineering design: work process, cognitive process, and social process (Atman et al., 2014).

Social Process: Researchers consider engineering design from the situative perspective of learning. Situative learning is developed from Vygotsky's Social Constructivism in which an individual's development and learning depends on the interpersonal interaction and activities under a social environment (Woolfolk, 2016). The situative perspective views knowledge "as distributed among people and their environments, including objects, artifacts, tools, books, and the communities of which they are a part" (Greeno, Collins, & Resnick, 1996); knowledge is socially reproduced and learning occurs through participation in meaningful activities that are part of a community of practice (Lave, 1991). From this angle, knowledge of engineering design is constructed under specific social context, and teamwork is essential for designers to complete design task.

Cognitive Process: The information-processing approach is one of the main approaches in contemporary cognitive research field. This approach attempts to explain the process of people's thoughts and reasoning processes by comparing them to the operating principle of computer system. Both of which have a process including acquire, process, store, and use information to different programs (Woolfolk, 2016). While referencing the theory of information-processing approach, this viewpoint on the engineering design process depicts the whole design process as one that includes information acquisition, processing creation, and sharing. There is a special focus on creativity, decision-making, expertise, and other cognitive constructs (Atman et al., 2014).

Work Process: The work process considers the design from a traditional engineering project perspective. Researchers decompose the whole design project into a series of subtasks. They emphasize the type of a task and the relationship between tasks. Workflow, resource

management, and planning are frequently used words when explaining design from the perspective of it as a work process (Atman et al., 2014). For example, the engineering design process used by National Center for Engineering and Technology Education (NCETE) includes (1) Identification of a need (consumer, and company); (2) Definition of the problem / specifications (design problem); (3) Search (for existing design); (4) Develop designs; (5) Analysis (of alternative designs; may include simulations…); (6) Decision (decision matrix); (7) Test the prototype and verify the solution (provide iteration as needed); (8) Communication (summarization report)..

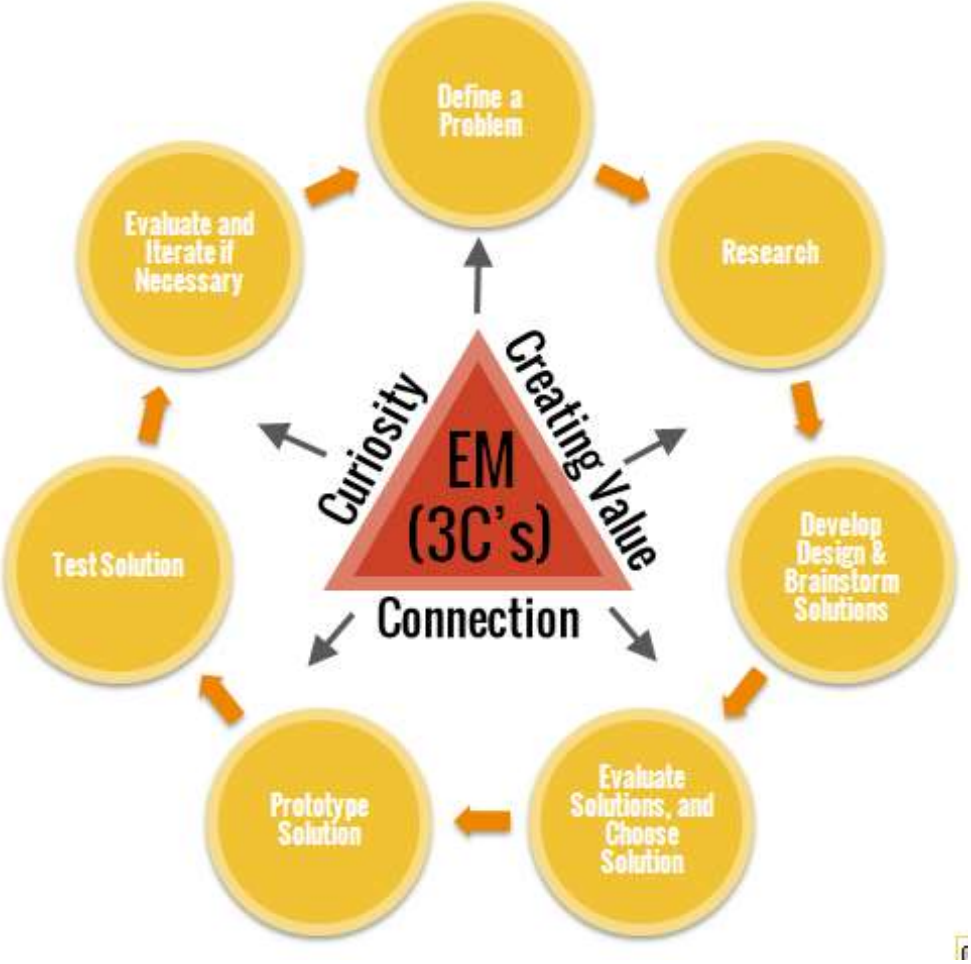
Entrepreneurial Mindset - 3 Cs

The term entrepreneurship is often referred to as the commercialization or business. Although that is certainly an important aspect, it is not the complete picture. Entrepreneurship is generally considered a process from the creation of new ideas to the implementation of creative solutions to running a new business (Kuratko, 2007; Lazear, 2005). KERN focuses on the initial phase of this process: how to contribute to the society with innovation.

Curiosity, connections, and creating value are the three key components in the EM framework published by KERN, commonly referred to as the '3C's'. In KERN's view, curiosity is to empower students to develop an insatiable curiously to investigate the rapidly changing world to avoid the obsolescence of existing solutions ("The Kern Family Foundation," 2016). Connection is to teach students "to habitually pursue knowledge and integrate it with their own discoveries to reveal innovative solutions" ("The Kern Family Foundation," 2016). Creating value is to train students "to persistently anticipate and meet the needs of a changing world" in order to make their solution meaningful ("The Kern Family Foundation," 2016).

There are connections that can be found between the design process and EM. "Curiosity" helps students to keep learning and investigating the world. This spirit is especially important for students to find problems and understand customers' needs in the initial phase of an engineering design process. "Connection" is closely connected to the steps related to the design development activities in a design process, as it means students have to develop solutions based on their learning and investigate. In steps of the design process, like evaluation, brainstorm, prototype, and so on, students have to evaluate the value of their solutions, and test them under specific environments. The best criterion for a solution is whether it can satisfy the needs of customers and add value to our society. Those steps are aligned with "Creating value". The congruent relationship between the engineering design process and EM is shown in Figure 1.

Figure 1: The connection between the design process and EM



Context

This paper discusses the impact of a pilot effort focused on integrating entrepreneurially minded learning (EML) into one section of the Introduction to Engineering course at a large southwestern institution. The Introduction to Engineering course is a 2 credit course taught to first year engineering students through a weekly 1-hour lecture and 3-hour lab in class sizes of approximately 40 students. The students in this course are primarily first year students in mechanical, aerospace, chemical, and electrical engineering. In this introductory course, students learn and apply various design concepts, modeling tools, teamwork, and technical communication skills in the context of the engineering design process. The course is focused primarily on engineering design, and a significant portion of the course consists of students working through the engineering design process in a team design project. In the specific course section described in this paper, students first completed a 3 week structured mini-project in which they learned basic concepts related to engineering design process steps, technical drawing, mathematical modeling, and testing. After that introduction to important concepts, students spent eleven weeks of the semester working through all stages of the design process from problem

definition through building and testing a prototype in a team design project. The efforts made to integrate EML into this course were all done in the context of the team design project which focused around the National Academy of Engineering (NAE) Grand Challenges for Engineering ("NAE Grand Challenges for Engineering," 2017).

Grand Challenges Design Project

The team design project that students completed in this course was focused on solving problems related to the NAE Grand Challenges (Zhu & Trowbridge, 2016). Multidisciplinary teams of three to four students were provided with three real world project options to choose from which related to making solar energy economical, providing access to clean water, and advancing personalized learning. The details of the original version of this project were previously described in Zhu and Trowbridge (2016). In this design project students are asked to go through all stages of the design process culminating with the creation and testing of a functional prototype that solves a real-world problem. The original version of this design project already contained a few aspects which may encourage students to develop an entrepreneurial mindset including a (fictional) customer, a real world scenario, and opportunities to collect, analyze, and make connections between multiple pieces of information. Additional changes were made to the project during the semester course offering described in this paper as part of a more focused effort to encourage students to develop an entrepreneurial mindset as defined by KERN and the 3Cs (Curiosity, Connections, and Creating Value) [cite].

Changes Implemented in Project to Encourage EM

The changes made to the project to encourage the development of an EM were focused on providing opportunities for students to explore project-related topics with curiosity and make connections between multiple types of information they gathered in order to develop a solution that creates value for customer(s) and society. Throughout the project, student-driven learning and exploration was encouraged, and a strong emphasis was placed on creating value for the customer(s). The problem statements provided to students when starting the project was altered to make the scenario more ambiguous and open-ended. For example, for the project focused on providing access to clean water, all specific requirements and criteria such as portable, lightweight, easy to setup, and requires minimal maintenance were removed from the problem scenario. The students were then asked to define the problem(s), identify the customer(s), and define the specific customer needs and wants based on the problem statement and additional research. Students were not told what specific information they needed to gather or what technologies they would need in order to develop a solution; student teams identified what information they needed to obtain through research, the customer, or experimentation. To obtain the data needed to make their design decisions in order to choose a successful solution and build a successful prototype, students designed and conducted their own experiments to explore relevant scientific principles. Additions were also made to the written project deliverables and presentations to encourage students to place more emphasis on customer awareness and value

creation. For example, students were asked to identify and describe the target customer and discuss the value that their solution adds for the customer and the market from multiple perspectives including societal, financial, and environmental.

Methods

A reflection assignment given to students as part of the course was used to assess the impact of the design project and EM-specific interventions on students' mindsets. The students in this introductory engineering course were primarily first year students from four different engineering disciplines (chemical, mechanical, electrical, aerospace) and the 'engineering exploration' program. Students at a large southwestern institution who are enrolled in this introductory course come from a variety of backgrounds and may include first time freshman, transfer students, military veterans, and other non-traditional students. A total of twenty-seven students (81.8% consent rate) from this section of the course consented to participate in this study.

Upon completion of the team design project, students in the course were asked to complete a final one to two page written reflection on the engineering design process that their team went through in completing the project. Students were asked to think about the work they did related to collecting customer feedback, developing a well-researched and well-tested design solution, and justifying the value of their solution from multiple perspectives (e.g. technological, economic, societal, environmental, etc.). The reflection prompts then asked students to describe the behaviors and attitudes that are important in completing those work tasks, discuss which behaviors and attitudes they feel they have, and explain how those behaviors and attitudes might be helpful to them in the future. The assignment can be found in the appendix. Students submitted their written reflection assignments to their instructor electronically through the learning management system.

All the student reflections were uploaded to Dedoose, an online application for analyzing qualitative data. Thematic analysis was chosen as the method of analysis primarily because this is an exploratory study that sought to identify and report patterns within the reflections. The thematic analysis involved six phases, as recommended by Braun and Clarke (2006), which included (a) familiarizing/reading all data, (b) generating initial codes, (c) identifying initial themes, (d) reviewing themes for accurate representation of the data, (e) defining and naming the themes, and (f) reviewing the final findings for content and clarity. In addition, Creswell's (2016) recommendations on coding qualitative data were used as a reference during the thematic analysis process.

To start the thematic analysis, one researcher read all the student reflections so that he could familiarize himself with the data and took brief notes on the content of the reflections. The next step involved developing initial codes until theoretical saturation occurred on the twelfth

reflection. This initial set of codes was then consolidated into a codebook composed of forty-three codes broken into three major themes: Action/Behaviors, Attitudes/Mindset and Other. At this point in time, the responsibility of completing the analysis was transferred to another researcher. The researcher who had been working on the analysis met with the new researcher to thoroughly explain his process and the codebook. An inter-rater reliability test was completed by the new student to test the reliability of the codebook. The inter-rater reliability score was 0.48, a poor agreement (Huberman & Miles, 1994).

The new researcher consulted with another researcher on the team every two weeks while completing the data analysis. It was decided between the two researchers to continue iterating the codebook considering the poor agreement from the first inter-rater reliability test. The researcher, or coder, thus read through all of the reflections and then began making modifications to the codebook. The codes in the codebook were further consolidated to 35. Five reflections were then coded with the second draft of the codebook. An inter-rater reliability test was completed on Dedoose using these newly coded reflections with a third graduate student who had not been exposed to the coding process prior. The inter-rater reliability kappa score was 0.60, which is a fair agreement (Huberman & Miles, 1994). The codebook was revisited for a third time. After extensive mind mapping, the codes were collapsed into five major themes with twenty-seven codes. The inter-rater reliability test was completed once again, outputting a kappa score of 0.84, an excellent agreement (Huberman & Miles, 1994). The codebook was therefore confirmed to be reliable after multiple iterations and completing a thematic analysis in alignment with literature guidelines. All of the reflections were re-coded with the final version of the codebook.

Results

The five major themes that emerged from the reflections were problem solving using the design process, considering multiple perspectives, working effectively as a team, communicating effectively, and valuing attitudes and behaviors. The subsequent sections describe each theme in detail by highlighting the underlying codes and providing examples from the reflections.

1. Problem Solving using the Design Process

The engineering design process can be viewed as a series of steps that engineers follow to develop a solution to a problem. A number of design process steps were identified in the student reflections including identifying the problem, understanding customer needs, research, developing design specifications, brainstorming, evaluating potential ideas, prototyping, testing and evaluating the design, iterating and refining the design, and pitching your design. One student reflection concisely summarizes the design process as an important framework for problem solving. This student wrote:

> *An important behavior in the design process is to know how to tackle a problem that arises. What I mean by this, is knowing how to break down the problem into steps that include – recognize the need, define the problem, plan the project, gather information,*

generate alternative concepts, evaluate the alternatives, select the most promising concept, build the prototype, test, and evaluate the results.

Understanding the design process itself is and the behaviors involved is perhaps first and foremost to being able to execute it. Many of the student reflections discussed the general attitudes and behaviors that are important to have while navigating through the design process phases. These include not being afraid to make mistakes, having attention to the details, making deliberate decisions, and being patient and determined. The design process is not linear. Making mistakes and having to iterate and refine the design is an important component of the design process. One student chose to emphasize a part of their reflection on not being afraid to make mistakes. This is seen in the following excerpt:

> *The vital attitude when developing a well-researched and well-tested design solution is not being afraid of mistakes. The reason why this attitude is important is that the problems designers are solving haven't been solved before. So there is nobody who can lead designers on how to solve the problem. The only one who designers can count on is themselves. There may be so many mistakes are made during the design process. If designers are afraid of making mistakes, there will be no improvements on the project they are working on.*

This student reflection excerpt seems to indirectly address the ambiguity involved with the design process since it is a unique process each time. A designer must therefore be conscious of this and not let a fear of making mistakes hold them back from progressing since they are inevitable and necessary to make improvements. The quality of being determined was also an important attitude to maintain for some students while they iterated and refined their idea. This is supported by a reflection that says:

> *Determination is always useful in staying motivated and helping exceed expectations. For example, I might be faced with a problem where the final design in not functional similar to the problem that I faced in this project. I have to be determined enough to keep trying different things until the design is functional.*

Attention to detail was mentioned in a number of reflections as important throughout the design process including collecting data and feedback from customers, researching, and testing. This is exemplified in the following student reflection excerpt:

> *A behavior that is important in developing a well-researched and well-tested design is paying attention to detail. Being able to understand all of the criteria and information about the design is important in ensuring that the design is well-researched and well-tested. This is because you need to understand how to test the design and what research needs to be done in order to determine if the design meets all of the criteria and works as expected. By paying attention to detail, you can easily determine what kind of acceptance tests need to be done and what aspects of the design need to be researched in order to improve the design.*

Attention to detail can also mean making thoughtful, deliberative decisions as discussed by another student in the following reflection:

> *Being thoughtful in the work that we're doing lets the team thinks over each decision in a careful way. When our team were justifying the value of our design solution, we had to consider what was the most optimal and practical solution.*

Patience and staying determined were also key attitudes to have while in order to successfully navigate through the design process according to multiple student reflections. One reflection states, "Patience is a must during these steps of the design process. Rushing through these processes can lead to a design that is not effective because these steps were not taken care of in a thorough way." It therefore appears patience can help support the qualities of being thoughtful and deliberative.

2. Considering Multiple Perspectives

The ability to consider multiple perspectives is a theme that emerged as very important during the design process according to the freshmen engineering students. One such example is considering the societal, economic, and environmental impacts of an engineering design, which is discussed in ten student reflections. An exemplary example can be seen in the following except from a student reflection:

> *By considering how your design solution could possibly impact technology, society, the economy, and the environment is important in justifying the value of your design solution. By knowing how your design could impact society and the economy, you can justify the value of your design by mentioning how the lives and economic conditions of the target customers will be improved through the use of your design solution. By considering the effects of your design solution on the environment, you can argue that your design has value because it will protect the environment and will be a sustainable solution to the problem you are trying to solve.*

According to this student, considering the societal, economic, and environmental impacts during the design process can assist in developing a well-justified design that improves lives and is sustainable. A different student elaborated in their reflection the importance of specifically considering the environmental impacts of the design:

> *One important thing is considering the environmental effects when designers making decisions. For example, the water solution for Mawanga should be environmental friendly. That is one reason why the final design isn't drilling wells or using giant machines to transport water. Drilling wells may damage the soil and underground water supply. Using giant machines will cost so much gasoline. These two solutions will affect the local environment sooner or later. So the best solution for the final design is rain*

trap. Using rain source and activated carbon to filter rain is much less harmful to the environment.

In this reflection, the student describes specific examples of solutions they considered to potentially not be environmentally-friendly and therefore could inevitably negatively affect the community in the long-term. By considering the environmental impacts during the design process, the student describes how the design they ultimately chose is an environmentally-friendly solution that will prevent future problems from occurring.

Additionally, the importance of understanding customers' needs was a major code as evidenced by it being discussed in fifteen of the student reflections. The following student reflection excerpt discusses the importance of being able to see a design from multiple perspectives including a customer while also remaining objective:

In the last stated task, as stated before you should separate yourself from the designs and be prepared to critique and attack the design and solution from the many different angles so that you can be prepared to justify your solution from those angles. In the third task, I think that it is also important to have the attitude of being able to take on multiple personalities figuratively and see through the perspectives of what the customer might see and what a professional in this concept might see in the solution. These personalities would help you be able to readily defend the design solution in your presentation.

Empathy and open-mindedness emerged as important attitudes to maintain while considering multiple perspectives. One student specifically describes how empathy is important in understanding customer needs in the following passage:

In addition, being empathetic is an important way of thinking when collecting feedback from the target customer. This is because understanding how the customer will use your design and how the customer benefits from your design is important in deciding which criteria should be used in choosing the design solution.

Being open-minded was the second most frequent code applied to the student reflections as it was discussed in eighteen reflections. The quality of open-mindedness was often associated with the brainstorming ideas stage of the design process. Several reflections noted how being open-minded to different ideas often lead to creative breakthroughs that improved the team's design. This is exemplified in the following excerpt of one student's reflection:

An attitude that I think I have is being open-minded. I have considered different ideas from my team members and these ideas were very important features of the final design solution. If I had not been open-minded, these ideas probably would not have been used.

> *An example of my open-mindedness is in the addition of the heat turbine to the final design. This was not originally my idea for the final design, but it ended up being included in the final design. By being open to this new idea, my team was able to determine how to use the excess heat from the solar panels to provide additional electricity in the final design.*

According to one reflection, the inability for a group to be open-minded can lead to an environment that "hinders the ability for team members to freely voice their ideas." Another student remarked that, "it is helpful to be open-minded of different ideas, even if they are abstract and seem unlikely to work." Reflections supported these statements by commenting, "sometimes the craziest ideas are the best ones" or "sometimes inspiration for solutions comes from unrelated fields or topics." Another student reflection stated, "Any random idea could give someone a spark of inspiration that could be a breakthrough that your team might need." These student reflection excerpts demonstrate the freshmen students recognized open-mindedness as essential to the generation of creative ideas that can improve a team's design.

The quality of being open-minded was also closely associated with accepting feedback and listening intently. For example, one student reflection said, "Being on the receiving end of lots of constructive criticism throughout the design process meant that I needed to let my guard down and try and keep an open mind." This example illustrates that attempting to be open-minded may be important and enhance how feedback is accepted and applied to the design. Being open to other ideas also requires the ability to listen intently to truly understand what others are saying. The following passage illustrates this:

> *Another attitude that is very important is to listen. Everyone has their own ideas and sometimes people like to jump to the conclusion that their ideas are the best since they made them and already understand them. However, this is not the mindset that we should have. We must keep in mind that everyone has their ideas and we must listen to other suggestions and understand them. Only then can we ultimately choose which the best idea is.*

Being open-minded was therefore a very important attitude to have during the design process for many of the students and was closely associated with generating creative ideas, accepting feedback, and listening intently.

3. Working Effectively as a Team

The ability to work effectively as a team was another core theme that emerged from the freshmen engineering students' reflections. Many reflections described the importance of actively participating, being a team player, cooperating, distributing work, managing time appropriately, supporting group members, and trusting group members. In a typical group

project, roles must be assigned and work distributed accordingly. One student reflection elaborated on how they were able to distribute roles based on the strengths and weaknesses of team members. The student reflection states, “We, however, were able to overcome all the issues that came to fruition, as we as a team were able to work together, and even assign each other roles based on our strengths and weaknesses.” This is described more extensively in another student reflection which states:

> *Hence nothing can be accomplished without cooperation. Everyone has different education background and everyone has different characteristic. So if we are developing a design solution and we want the best yield, we better let everyone in the team perform their forte. We should never ask some to do something that he or she not good at.*

Certain tasks were even assigned based on technical experience as well as evidenced by a different reflection excerpt:

> *One behavior that we as a group adopted specifically during the building process was being able to assign each other roles, while the person who had the most technical experience was leading the whole operation of building it, making sure that everyone has a job, and that everyone had an important part in building.*

The ability to manage time appropriately was discussed in a few reflections as well. Being efficient, punctual, and completing deadlines on time were all mentioned as important in teamwork. For example one student reflection states, “It was important that all the team members were conscious of deadlines and punctual as data collecting, testing, and justifying our designs take time and effort on everyone’s part and there is a time constraint to finish all of the tasks.”

A key attitude in being able to effectively distribute work and appropriately manage time was trust. Distributing work requires trusting other teammates to complete their tasks in a timely manner. One student describes the importance of trust in the following excerpt:

> *One of the behaviors that I believe important is to have faith on your team members. Accomplishing tasks can be difficult or time consuming if you do not know how to complete certain tasks. It can be frustrating if one member is responsible for all the tasks, but that is where other team members come in. Assigning tasks to other members of the group is more efficient than one person doing all the work. Even though they are assigned a task, I have realized that I need to be faithful that they will complete their tasks just as they are expecting me to also complete my tasks as well.*

Another student describes their experience of not trusting their teammate in another excerpt:

> *Although this seems a bit pessimistic, I did not have faith in some of my teammates. There were times when I wondered if they were able to complete the tasks in a timely matter. Eventually, they were able to finish their tasks, but it seemed very last minute, according to my standards. For example, I was limited on the amount of time I had on taking care of the tracking system of the solar panels. Although I had most of the work taken care of on my end, I was being not being faithful that my teammates were able to complete their tasks in a timely matter. I realized that once they have completed their tasks, they were the ones who needed to be faithful on me to make sure that my tasks were able to meet their expectations.*

This student did not feel confident that their teammates would finish their deliverables on-time. Ultimately, the team members did finish their tasks, and the student came to a realization that trust goes both ways.

Supporting teammates by showing appreciation is mentioned in several reflections. For example one reflection states, "Showing genuine appreciation when someone offers to take on a task that some might be dreading, or when someone goes above and beyond is important because it fosters an environment where you want to give it your everything since everyone else is." Supporting teammates through encouragement was also important in managing the heavy workload at times as seen in this student reflection:

> *During many times throughout this project, such as towards the end of the project when we had to complete another presentation and document, the team would become discouraged with the work load and I would do my best to encourage them to persevere. I was also persistent with trying to keep the group well-connected outside of class and offered to help with anything pertaining to the course.*

The ability to work effectively as a team also requires good communication. This was included as a separate theme though, because communication also occurs outside of the team including with customers, clients, investors, and more.

4. Communicating Effectively

Communicating effectively with an attitude of friendliness, positivity, gratitude, and confidence emerged as an important theme in the design process. To communicate with clarity and be well understood are very important in understanding customer needs according to one reflection as seen in the following excerpt:

> *In the first listed task, it is important to be well understood about anything you are discussing with the target customer. This is more specifically eliminating language*

barriers and eliminating barriers to effective communication due to limits from the customer's perspective or due to limits from the engineer's perspective.

Clear communication is not the only key criteria for effective communication though. Demonstrating professionalism and having a good attitude were very important in achieving effective communication and therefore with navigating the design process according to a number of reflections. Reflections described demonstrating professionalism as, "courteous etiquette when dealing directly with the customer", "dressing appropriately when needed", and "speaking formally when justifying the value and developing a research question."

Having a positive attitude was discussed in eleven reflections. One student wrote, "Your attitude is important in all areas of the process. Whether it be the data collection, the developing stage, or the proposal/justification stage you need to always have a good attitude." Other reflections elaborated more specifically on what having a good attitude actually means. Examples that surfaced included treating customers with enthusiasm, positivity, friendliness, confidence, and gratitude. One student wrote, "Be enthusiastic when collecting data and feedback from your customer. They'll be more receptive to you because they will like you and want to help." In another reflection example, the student wrote, "Confidence is what sells the product, of course along with the research data as well as the testing data. If the producer is not confident in himself, the customer will not be confident in the proposed design solution." A third example describes the importance of gratitude as the student wrote, "I think we should appreciate for our customers with a grateful attitude. The customers give feedback and data mean that they trust you. So we should have a grateful attitude to analyze the feedback and data from the customers."

Maintaining a friendly, positive attitude in communicating also pertained toward teamwork. Several reflections discussed how maintaining a positive, friendly attitude led to comfortable environments where ideas and suggestions could be shared openly. One reflection even said, "Having a positive attitude is what I think will be one of the most important traits upon graduation. Having a positive attitude means being pleasant to work with, open to other's suggestions, and trusting other people to do their job correctly." Having a positive attitude was therefore a very important attitude to have during the design process.

5. Valuing Attitudes and Behaviors

Twenty out of the twenty-seven reflections explicitly state in their reflections that the behaviors and attitudes they thought were important in completing their respective projects would be useful in future work after graduating. Thirteen of these reflections even expand on this and express a desire to continue reflecting and improving these attitudes and behaviors. For example one student wrote:

Overall, I do believe that these behaviors and attitudes would be helpful in the workplace after graduation as there will be a need to work in groups in the workplace. The behaviors and attitudes that I found important in completing the project apply universally to any situation when working with others, especially punctuality and responsibility. I plan to continue to develop the behaviors and attitudes in the future through internships and research positions that are typically heavily dependent on teamwork.

Another example to illustrate the desire to keep improving these attitudes and behaviors can be seen in this excerpt of a student reflection:

In the end I have learned a lot. I can easily say that what I have learned will help me down the road. These attitudes and behaviors will help me in my work after graduation. These are the qualities people should have to be successful in the engineering field. I believe I have these. I will continue to work on improving these traits as I move on to higher level classes and work in groups more. I really enjoyed this class and I learned a lot.

A few students perceived the attitudes and behaviors they reflected on as useful not only in the design process, but in life as well. This can be seen in the following excerpt:

I definitely think these tools are going to help us not only in the workplace, but in life as well. The ability to keep an open mind will definitely translate onto and improve future employment opportunities. Just as group 9 was extremely diverse, so will my future employer's company be. Just as we had to put all differences aside and work together cohesively, we will definitely have to do the same in the future anytime we are working in teams- which is most of the time when you are an engineer. In my opinion, it will not only help us in the workplace, but life as well. If everyone in the world kept an open mind, words such as "segregation" or "discrimination" wouldn't be a part of the dictionary. This may have only been for a class, but I think you can take these lesson with you wherever you go.

Overall, the majority of the students perceived their self-identified behaviors and attitudes as important to their experience with the design process.

Discussion

Link to Three Ways of Looking at Design

From the result under the emerged theme "Problem solving using the design process", we can see that students were able to break down the process of solving an engineering design problem into a series of steps. As is shown in Table 1, there is a striking similarity between the steps identified by students and the steps used by NCETE. This similarity demonstrates that

students had already understood the correct steps and the sequence in an engineering design process.

Table 1: A comparison of the steps identified by students and NCETE

	Students	NCETE
1.	Identifying the problem	Identification of a need (consumer, and company);
2.	Understanding customer needs	Definition of the problem / specifications (design problem)
3.	Research	Search (for existing design);
4.	Developing design specifications	Develop designs
5.	Evaluating potential ideas	Analysis (of alternative designs; may include simulations…);
6.	Prototyping	Decision (decision matrix);
7.	Testing and evaluating the design	Test the prototype and verify the solution (provide iteration as needed);
8.	Pitching your design	Communication (summarization report).

Furthermore, we can see that collectively the students understood the activities involved in the engineering design process based on their reflections. For example, students mentioned both the societal, economic, and environmental impact of an engineering design and the value of open-mindedness under the theme “Considering multiple perspectives”. These two points are important in the step “evaluating potential ideas”. Students also recognized the importance of communication with clarity and being well understood in the step “understanding customer needs” under the theme “Communicating effectively”.

As students can correctly identify steps in an engineering design process, the sequence between each step, and clearly understand the activities in each step, we can say that these students already had well mastered the engineering design process from the viewpoint of work process.

From the cognitive angle, we can see that students’ cognition of the skills relevant to the engineering design project had been enhanced through their reflection. They recognized that positive attitudes and behavior can help them understand, analyze, and solve an engineering design problem. Specifically, those attitudes and behavior include not being afraid of mistakes,

attention to detail, patience, determination, empathy, open-mindedness, trusting team members, and a grateful attitude to customers' feedback. Moreover, they emphasized those attitudes and behaviors were still helpful to them after graduation both in the workplace and in their personal life under the theme "valuing attitudes and behaviors". This demonstrates that those students could well connect what they had learned in class to their future career and life, and transfer the knowledge to broader application scenarios.

Lastly, we also can see that students had achieved progress from the social-process viewpoint. On one hand, they could consider engineering problems in a social context. They had considered the impact of their design solution to the technology, society, technology, the economy, and the environment in their design process; a well-justified design should improve life and be sustainable. They also recognized the purpose of an engineering project was to satisfy customers' needs. They emphasized effective communication with customers and appreciated customers' feedback. The students also emphasized the value of teamwork. Some students mentioned that everyone had different characteristics; cooperating well with others in the team could complete a project more effectively than they could individually. In addition, students distributed the work, trusted other team members, applied time management efforts, and supported others with showing appreciation and encouragement to their teammates. These skills enabled them to keep learning from each other throughout the design process.

Linking the Results to KERN's EM Framework

The attitudes and behaviors students perceived to be important while navigating the design process appear to align with KERN's 3Cs framework for EM. Although they were not usually explicitly described in the reflections, the 3C's relate closely to the five themes that inductively emerged. An argument can be made that the identified themes from this paper, considering multiple perspectives and problem solving using the design process, connect closely to "Curiosity". A curious person is more likely to have the desire to listen to others and truly understand their perspective. Someone that is curious is also more likely to go through the design process more effectively than someone who is not interested in what they are doing. They would be more likely to explore the entirety of the problem and consider the myriad of potential solutions they could use by making a strong effort to understand customer needs and conducting thorough research. The second C, "Creating value", can be associated with the themes, problem solving using the design process. The design process itself is a methodological approach with the goal of designing something of value that solves a problem. Therefore, the successful application of the design process should lead to the creation of value.

The third C, "Connection", as described by KERN has to do with students habitually pursuing knowledge and integrating it with previous discoveries to reveal potentially new insights that can lead to innovative solutions. Based on this definition, the themes, working effectively as a team, communicating effectively, valuing attitudes and behaviors, and

considering multiple perspectives, can all be linked to connections. As discussed in the results, effective communication is an important criterion to teamwork. Teams composed of members that communicate well and have a good working relationship with each other are more likely to have productive discussions in which ideas can be shared and connections can be made. Exceptional communication skills can also be used to share information with greater clarity, which can lead to more useful feedback that can be integrated to improve a design. In order for this feedback to be integrated, a student must be willing to consider other perspectives. Open-mindedness, a code under the theme of considering multiple perspectives, is vital to being able to consider new ideas, and thus making connections. Finally, the theme, valuing attitudes and behaviors, is an example of how students made connections in their reflections. A strong majority of the students made a connection between specific attitudes and behaviors that were important in successfully going through the design process. A number of students also expressed a desire to improve on these attitudes and behaviors, and in some cases, even made the connection that these attitudes and behaviors can be applied to other life situations.

Conclusion

With the increasing interest in integrating entrepreneurship into engineering education comes the need to explore how it fits with other well-established priorities (e.g., an emphasis on engineering design). Such interest also fortifies the need for scholarship on meaningful ways to approach integrating it in engineering education and ways to assess the impact of doing so. This study contributes to a growing body of literature on this topic by adding a qualitative study to a body of EML assessments that been largely quantitative thus far. In short, the results of this study include five themes emerged from analyzing twenty-seven students' reflections about an engineering design task they had recently completed. The five major themes that emerged from the reflections were: problem solving using the design process; considering multiple perspectives; working effectively as a team; communicating effectively; and valuing attitudes and behaviors. In many ways, the details associated with each of them help demonstrate the alignment between engineering design and the entrepreneurial mindset.

We recognize the one limitation of this work is its scope. Namely, the results of this work are based on one project that happened in one section of a course. Expanding this work to include other sections and other design activities would help generalize the findings beyond its original context. Moreover, we also recognize that the wording of the prompts may have influenced what was included in the reflection. For example it is unclear to what extent the attitudes and behaviors students described as important were developed from the course. The use of mixed methods or other forms of qualitative data collection in a future study can help to mitigate the effects of the prompt. Lastly, we recognize that conducting qualitative analysis of students' submissions is more feasible with some class sizes and is impractical for others. Exploring ways to perform this type of thematic analysis at a larger scale is worth exploring before this approach can become a mainstream assessments approach in engineering education.

References

Atman, C., Eris, O., McDonnell, J., Carbella, M., & Borgford-Parnell, J. (2014). Engineering Design Education: Research, Practice, and Examples. In *Cambridge Handbook of Engineering Education Research* (pp. 201–225). incollection, New York, NY: Cambridge University Press.

Bell-Huff, C., Carpenter, D., & Gerhart, A. (2016). Fostering an Entrepreneurial Mindset through a Sophomore-Level , Multi-Disciplinary, Engineering Design Studio Experience. In *ASEE Annual Conference and Exposition*.

Braun, V. and Clarke, V. (2006). Using Thematic Analysis in Psychology. *Qualitative Research in Psychology*, *3*(2), 77–101.

Condoor, S., & Mcquilling, M. (2009). Incorporating an Entrepreneurial Mindset in Freshman Engineering Students. In *ASEE Annual Conference and Exposition*.

Cook, K., & Cuper, J. (2010). Building the entrepreneurial mindset in senior projects. In *ASEE Annual Conference and Exposition*.

Creswell, J. (2016). Analyzing and Validating Data. In *30 Essential Skills for the Qualitative Researcher* (pp. 151–203).

Criteria For Accrediting Engineering Programs. (2017). Retrieved from http://www.abet.org/accreditation/accreditation-criteria/criteria-for-accrediting-engineering-programs-2016-2017/

Davis, G. W., Hoff, C. J., & Riffe, W. J. (2011). Incorporating Entrepreneurship Into Mechanical Engineering Automotive Courses: Two Case Studies. In *ASEE Annual Conference and Exposition*.

Draper, S. (2009). Engineering Design Process. *Technology and Children*, 8–11. Retrieved from http://books.google.es/books?id=4EQAK2eLxLgC

Duval-Couetil, N., Shartrand, A., & Reed, T. (2016). The role of entrepreneurship program models and experiential activities on engineering student outcomes. *Advances in Engineering Education*, *5*(1), 1–28.

Erdil, N., Harichandran, R., Nocito-Gobel, J., Carnasciali, M.-I., & Li, C. (2016). Integrating e-Learning Modules into Engineering Courses to Develop an Entrepreneurial Mindset in Students. In *ASEE Annual Conference and Exposition*.

Estell, J. K., Reeping, D., & Sapp, H. (2016). Curiosity , Connection , Creating Value : Improving Service Learning by Applying the Entrepreneurial Mindset. In *ASEE Annual Conference and Exposition*.

Ferguson, D. M., Cawthorne, J. E., & Streveler, R. (2013). Designing an introductory entrepreneurial thinking course. In *ASEE Annual Conference and Exposition*.

Froyd, J. E., Wankat, P. C., & Smith, K. A. (2012). Five major shifts in 100 years of engineering education. In *Proceedings of the IEEE* (Vol. 100, pp. 1344–1360).

Fry, C., Jordan, W., Leman, G., Garner, B., & Thomas, B. (2010). Bringing Innovation and the Entrepreneurial Mindset (Back) Into Engineering: The KEEN Innovators Program. In *ASEE Annual Conference and Exposition*.

Fry, C., & Van Treuren, K. (2016). Encouraging Student Innovation in a Freshman-Level Computer Science Course. In *ASEE Annual Conference and Exposition*.

Gerhart, A. L., & Carpenter, D. D. (2013). Campus-wide course modification program to implement active & collaborative learning and problem-based learning to address the entrepreneurial mindset. In *ASEE Annual Conference and Exposition*.

Gerhart, A. L., Carpenter, D. D., Fletcher, R. W., & Meyer, E. G. (2014). Combining discipline-specific introduction to engineering courses into a single multi-discipline course to foster the entrepreneurial mindset with entrepreneurially minded learning. *ASEE Annual Conference and Exposition, Conference Proceedings*, *1058*(248).

Gerhart, A., & Melton, D. (2016). Entrepreneurially Minded Learning : Incorporating Stakeholders, Discovery, Opportunity Identification, and Value Creation into Problem-Based Learning Modules with Examples and Assessment Specific to Fluid Mechanics. In *ASEE Annual Conference and Exposition*.

Gettens, Robert, Riofrio, Jose, Spotts Jr., H. (2015). Opportunity Thinktank : Laying a foundation for the entrepreneurially minded engineer. In *2015 ASEE Annual Conference and Exposition* (p. 26.1208.1-

126.1208.21).
Gettens, R., Zimbroff, A., Spotts Jr., H., Houser, C., Taylor, A., & Schoonmaker, M. (2016). An Intensive Experiential Entrepreneurship Program (3-Day Startup). In *ASEE Annual Conference and Exposition*.
Greeno, J., Collins, A., & Resnick, L. (1996). Cognition and learning. In R. Calfee & D. Berliner (Eds.), *Handbook of eductional psychology* (pp. 15–46). incollection, New York, NY: Macmillan.
Huberman, M., & Miles, M. (1994). Data management and analysis methods. In *Handbook of qualitative research* (pp. 428–444). Thousand Oaks: Sage Publications, Inc.
KEEN Engineering Unleashed. (2017). Retrieved from http://engineeringunleashed.com/keen/
Kim, C., Cheville, A., Jablonski, E., Prince, M., Nottis, K., Siegel, N., … Tranquillo, J. (2016). Instilling an Entrepreneurial Mindset through IDEAS Studio Courses. In *ASEE Annual Conference and Exposition*.
Kirkpatrick, S. R., Watt, A., & Bernal, A. (2016). Developing an Entrepreneurial Mindset in Engineers: An Application of the Three C's (Creativity, Curiosity, and Connections) in a Collaborative Summer Mega-Course. In *ASEE Annual Conference and Exposition*.
Kuratko, D. F. (2007). *Entrepreneurship : theory, process, practice* (7th ed.). book, Mason, OH: Thomson South-Western.
Lave, J. (1991). Situated learning in communities of practice. In S. D. Teasley, L. B. Resnick, & J. M. Levine (Eds.), *Perspectives on socially shared cognition* (pp. 63–82). incollection, Washington, DC: American Psychological Association.
Lazear, E. P. (2005). Entrepreneurship, *23*(4), 649–680. article.
Lord, S., & Chen, J. (2014). Curriculum Design in the Middle Years. In A. Johri & B. Olds (Eds.), *Cambridge Handbook of Engineering Education Research* (pp. 181–200). New York: Cambridge University Press.
Mallory, J. (2015). A Module to Introduce the Entrepreneurial Mindset into Thermodynamics - a Core Mechanical Engineering Course. In *ASEE Annual Conference and Exposition* (p. 26.69.1-26.69.12).
Mallory, J., Romoser, M., & Keyser, T. (2016). Inclusion of Entrepreneurially Minded Learning (EML) Modules in 2nd-Year Core Engineering Courses. In *ASEE Annual Conference and Exposition*.
Meyer, E. G., & Nasir, M. (2015). Fostering the entrepreneurial mindset through the development of multidisciplinary learning modules based on the "Quantified Self" social movement. In *ASEE Annual Conference and Exposition* (p. 26.794.1-26.794.17).
Michigan Engineering Interdisciplinary Minors & Programs. (2017). Retrieved from http://www.engin.umich.edu/college/academics/undergrad/minors/interdisciplinary-minors-programs
NAE. (2002). *Diversity in Engineering: Managing the Workforce of the Future*. Washington, DC: National Academies Press.
NAE Grand Challenges for Engineering. (2017). Retrieved from www.engineeringchallenges.org
Nezami, F., Tavakoli, M., & Torfeh, M. (2016). Developing Entrepreneurial Mindset in Industrial Engineering Classes: A Case Study. In *ASEE Annual Conference and Exposition, Conference Proceedings*.
Rayess, N. (2016). Instilling an Entrepreneurial Engineering Mindset through a Freshman Design Course. In *ASEE Annual Conference and Exposition*.
Reid, K. J., & Ferguson, D. M. (2011). Work in progress - Enhancing the entrepreneurial mindset of freshman engineers. *Proceedings - Frontiers in Education Conference, FIE*.
Rensselaer Polytechnic Institute Entrepreneurship. (2010). Retrieved from http://rpi.edu/academics/entrepreneurship.html
Riofrio, J. A., Gettens, R., Santamaria, A. D., Keyser, T. K., Musiak, R. E., & Spotts Jr., H. E. (2015). Innovation to Entrepreneurship in the First Year Engineering Experience. In *ASEE Annual Conference and Exposition* (p. 26.969.1-26.969.17).
Singh, P., Klingler, J., Dougherty, E., & Moncada, M. V. (2015). Instilling the Entrepreneurial Mindset by International Development Project Work. In *ASEE Annual Conference and Exposition* (p. 26.973.1-26.973.13).
The Kern Family Foundation. (2016). Retrieved from www.kffdn.org
Thoroughman, K. A., Hruschka, A., & Widder, P. (2014). Engineering virtual studio: KEEN modules to foster entrepreneurial mindset in an integrative, first/second year online course. *American Society for Engineering Education*.
Woolfolk, A. (2016). *Educational Psychology* (13th ed.). book, Pearson Education, Inc.
Yeager, D. S., & Dweck, C. S. (2012). Mindsets that promote resilience: When students believe that personal characteristics can be developed. *Educational Psychologist*, *47*(4), 302–314.
Zhu, H., & Trowbridge, A. (2016). Assessing the Impact of Incorporating the NAE Grand Challenges for Engineering as a Multidisciplinary Hands-On Design Project into the Introduction to Engineering Course. In

ASEE Annual Conference and Exposition.

Appendix:

Engineering Design Process Reflection

The purpose of this activity is for you to reflect on the engineering design process that you and your team went through for the final design project.

First, think about the work that was involved in:

- Collecting feedback/data from your target customer
- Developing a well-researched and well-tested design solution
- Justifying the value of your design solution from multiple perspectives

(e.g., technological, economical, societal, environmental, etc.)

Then, write and submit a 1-2 page personal reflection that includes responses to each of the following questions:

- What behaviors do you think are important in accomplishing each task above? Consider behaviors to be specific actions that you perform as part of completing a particular activity.
- What attitudes do you think are important in accomplishing each task above? Consider attitudes as views, ideas, or ways of thinking that you bring to bear on a particular activity.
- Among the behaviors and attitudes you mentioned, which of these behaviors and attitudes do you think you have? Which of these behaviors and attitudes do you think you still need to work on? Give specific examples from working on the final project to support your answers.
- Do you envision these behaviors and attitudes being helpful in your work after graduation? Explain why you do or do not. How might you continue to develop these behaviors and attitudes in the future?

There are no right or wrong answers to these questions, so please answer honestly.