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Article

Applying Authentic Learning through Cultivation of the Entrepreneurial Mindset in the Engineering Classroom

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Abstract: Higher education provides plenty of opportunity for theory and in many cases, even the ability to apply theory in a laboratory setting. Yet, there remains limited opportunity for students to learn by doing through participation in authentic learning experiences. The purpose of this paper is to provide one potential solution for integrating authentic learning into the engineering classroom by cultivating the entrepreneurial mindset. As entrepreneurship serves as an integral part of the economy, developing an entrepreneurial mindset through authentic learning experiences is essential for engineers. While online discussion prompts represent a useful way for educators to facilitate student learning, less is known about how to facilitate online discussions in a way that truly cultivates an entrepreneurial mindset for engineering students. In this paper, the key intentions of entrepreneurially-minded learning are reviewed, and a guide for creating online discussions applicable to any engineering course is presented. Example online discussion prompts incorporating the entrepreneurial mindset are then shared from an Introduction to Engineering course. Results from a mixed methods survey instrument suggests positive impacts towards student perceptions of online discussions and development of the entrepreneurial mindset. Recommendations for effectively and efficiently facilitating online discussions for entrepreneurially-minded learning in the engineering classroom are offered.

Keywords: entrepreneurship; innovation; writing across the curriculum; discussion prompts; inquiry; authentic; engineering; undergraduate

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1. Introduction

1.1. Problem Overview

"An authentic learning environment is a context that reflects the way knowledge and skills will be used in real life [1]." Higher education provides plenty of opportunity for theory and even the ability to apply theory in the laboratory setting, however, students are sometimes left with limited opportunity to learn by doing through participation in authentic learning experiences. This is particular problematic in theory heavy courses, often found in engineering disciplines. These courses tend to focus more on large amounts of rigorous content, equations, definitions, and other theoretical foundations of a topic and less on the practical application to workplace relevant skills around innovation and new product/process development. One of the five major shifts in engineering education from the last 100 years is noted to be "a shift from hands-on and practical emphasis to engineering science and analytical emphasis [2] (p. 1345)." As a result, many engineering courses, and engineering programs in general, have limited opportunity for students to participate in authentic learning experiences.

In response to this challenge, many engineering programs offer opportunities for students to participate in design courses [2]. This commonly occurs in an incoming Introductory Engineering course and outgoing Capstone Design course where hypothetical design challenges are developed as a way to work through the human-centered design process. These courses often guide students from problem identification through prototype, with a heavy focus on technical feasibility. Although these courses are extremely beneficial for offering students experiential-based design experiences, the authenticity of the experience varies [3,4]. Other attempts to integrate authentic learning include industry-sponsored projects, the use of innovations such as virtual labs [5], and service learning [6]. Yet, the exposure for engineering students are many times limited to a select, few courses. In order to gain an expertise in engineering, the engineering curriculum must "provide multiple opportunities for them to practice their skills on authentic tasks that require the integrated application of various knowledge and skills [7]."

The purpose of this paper is to provide one potential solution for integrating authentic learning more continuously into the engineering classroom. In recent decades, authentic learning has been looked upon in a favorable manner for entrepreneurship and innovation educators who view the pedagogical approach as a means to transfer theoretical knowledge to practical real-world applications [8,9]. Furthermore, writing and online discussions provide students the opportunity to collaborate, reflect [10], examine different perspectives, and use a variety of resources, all of which are characteristics of authentic learning experiences as identified in Table 1. Thus, the authors proposed an ideal method for integrating authentic learning into the engineering classroom through entrepreneurially-minded learning and online discussions. This paper offers two major contributions to the literature. First and foremost, it provides a much-needed guide for engineering educators, and general educators alike, to infuse authentic entrepreneurially-minded experiences into their coursework. Second, this paper provides several examples of online discussion prompts incorporating the entrepreneurial mindset and makes recommendations for effectively and efficiently facilitating online discussions in the engineering classroom.

1.2. Applying Authentic Learning through Development of the Entreprenuerial Mindset

Engineers play a critical role in the economy by addressing pressing problems and creating solutions that are new and innovative. This role is not played in isolation, but rather requires collaboration and leadership. It is a role that involves technical skills but also requires curiosity, an ability to connect pieces of knowledge to discover solutions, and a focus on value creation—which are all characteristic of entrepreneurially minded learning [11]. As noted by Wheadon and Duval-Couetil [12], entrepreneurially minded learning as a pedagogical approach has received increased interest within the engineering arena. Entrepreneurially minded learning is not just applicable for start-ups, and it is not a matter of simply repackaging business for engineering students; rather, it emphasizes the development of a mindset among engineering students that allows them to identify and solve problems. Because a mindset develops over time and requires practice, the role of engineering educators is to find opportunities throughout a student's coursework to infuse this entrepreneurially minded learning [13].

One way that has been suggested to integrate the entrepreneurial mindset is through the use of discussion prompts [14]. This methodology is helpful in that it offers a way to incorporate entrepreneurially minded learning into existing coursework throughout the curriculum, thereby offering multiple touch points for students as they progress in their degree program. Such prompts are relatively easy for educators to integrate, and they can be used in either online or face-to-face courses. To date, however, little is known about how to effectively develop discussion prompts that indeed encourage the entrepreneurial mindset. The knowledge gap relates not to the technical aspects of developing the prompts, but rather to the conceptual form of determining the appropriate content and objectives.

To address this gap, the authors first consider the key intentions when incorporating the entrepreneurial mindset into the existing engineering curriculum. These intentions are then integrated into a guide for online discussions that can be applicable to any engineering course. Each online discussion question involves a learning objective, hook, initial prompt, and response prompt. A design criteria form is offered to further guide the educator. Lastly, a set of online discussion prompts used in an Introduction to Engineering course taught in a medium-sized university in the Midwestern United States are shared, along with assessment data of the impact. This applied example is guided through the following research questions:

- How do student perceptions of blended and online learning change given the integration of authentic entrepreneurially-minded discussion sessions?
- How does participation in authentic discussion sessions impact student awareness and exposure to entrepreneurially-minded concepts?

Table 1. Assessment of Authentic Experiences within the Online Discussion Prompts.

10 Characteristics of Authentic Experiences [15]	*Online Discussion Prompts Used in Study*
Authentic activities have real-world relevance	The hook of the discussion prompts illustrates the relevance.
Authentic activities are ill-defined, requiring students to define the tasks and sub-tasks needed to complete the activity	The discussion questions tend to be open ended and could result in a variety of responses.
Authentic activities comprise complex tasks to be investigated by students over a sustained period of time	The discussion prompts are offered weekly throughout the semester.
Authentic activities provide the opportunity for students to examine the task from different perspectives, using a variety of resources	The student can determine which direction to take in responding to the prompt, and which resources to utilize.
Authentic activities provide the opportunity to collaborate	The response prompt requires the students to listen to, and build on, other student responses.
Authentic activities provide the opportunity to reflect	The response prompt allows the student to reflect on other viewpoints, as well as see how others reflect on their own.
Authentic activities can be integrated and applied across different subject areas and lead beyond domain-specific outcomes	The discussion prompts allow for the student to apply what is being learned in class to other contexts and outcomes.
Authentic activities are seamlessly integrated with assessment	The discussion prompts are integrated into class learning.
Authentic activities create polished products valuable in their own right rather than as preparation for something else	The discussion prompts allow the student to create a deeper understanding of the practical aspect of their education.
Authentic activities allow competing solutions and diversity of outcome	The discussion prompts are purposely open and allow for a diversity of solutions.

2. Materials and Methods

2.1. How to Develop Online Discussion Prompts for Cultivating the Entrepreneurial Mindset

Because entrepreneurship serves as the backbone of the US economy, it is critical for engineering educators to cultivate an entrepreneurial mindset in their students [16]. Yet, many engineering faculty members have not been trained in entrepreneurship. Moreover, in order to develop a mindset, which requires practice, there is a need to offer frequent opportunities for engineering students to be exposed to and develop their entrepreneurial mindset. For this reason, online discussion prompts can be a useful but easy supplement to a rigorous engineering course, thus offering an ideal starting point for incorporating the entrepreneurial mindset throughout an existing engineering curriculum. As noted by Watson [17], the creation of online discussions requires limited changes to a face-to-face course and have the potential to increase course learning outcomes with a relatively minor investment in preparation prior to deploying the discussion.

Existing research highlights the benefits of online discussions for both students and instructors. From a student perspective, online discussions provide low barriers to participation. Students can participate on their own schedules, while still having the opportunity to learn from others [18]. While peer discussions promote thoughtful reflection, complex engineering topics can be rather intimidating for students to discuss in a face-to-face setting. Online discussions afford participants the necessary time to craft a thought-provoking response and to consider other potential research or recent news media to support their response [19]. For this reason, online discussions have the potential to broaden participation. For some students, especially students who are hearing impaired or for whom English is not the first language, participating in a face-to-face environment can be difficult. Online discussions allow all students to be on a level playing field [20].

From an instructor perspective, online discussions provide an opportunity to assess how much students actually know (or don't know) about a topic. Online discussions give instructors the chance to provide immediate student feedback and ask further questions to dig deeper into the subject at hand [21]. Moreover, online discussions provide instructors the opportunity to "hook" students into a topic prior to going more in depth in the classroom. The online discussions can be used to establish the practical relevance of a topic so in-class time can be spent on more rigorous aspects [22]. Online discussions also promote accountability. In some classes, students can get away with just showing up (and not participating or engaging). Yet, the use of online discussions ensure that all student voices are heard [23].

When developing online discussion prompts for entrepreneurial minded learning, there are four major intentions of which engineering educators should be cognizant [24]. Intention 1 suggests the discussion prompt should include the implicit context of course content, the entrepreneurial process and the opportunity context. In this way, online discussions allow students to see value in the class topic by promoting pragmatic inquiry [25] and reflections that connect course concepts to concrete and tangible real-world design innovations. Intention 2 advocates that online discussions should require students to respond to peers' posts in order to hone the professional skills of collaboration and communication [26] while engaging in a collective conversation for the betterment of the group. Intention 3 promotes the development of a mindset, as initiating discussion prompts throughout the semester allow for continued practice during which students will naturally have the opportunity to reflect on course concepts and provide feedback to peers [27]. Intention 4 notes that discussions, like any other pedagogical approaches, need to be carefully planned to ensure the reinforce of learning goals, objectives, and assessment. We next elaborate on each of these four key intentions in order to develop a checklist for entrepreneurially minded curriculum design that helps engineering instructors leverage online discussion prompts [28].

2.1.1. Intention 1: Consider Implicit Context

Intention 1 focuses on identifying the implicit context for the online discussion prompt. To be a highly valuable learning activities, the online discussion prompt should incorporate the (a) entrepreneurial process, (b) opportunity context, and (c) engineering course content [24].

The learning activity should focus on the entrepreneurial process because the development of opportunities happens over time, fluxing from discovery to evaluation to exploitation of an opportunity [29]. The discovery phase focuses on exploration and investigation, taking into consideration alternate ways to accomplish tasks. The evaluation phase promotes assessment, analysis, and interpretation of data and information relevant to the potential success of an opportunity. Finally, the exploitation phase encourages strategic thinking to take the opportunity from idea to implementation and beyond. It is realized that the process is not always linear, but nevertheless, represent different phases in the development of an opportunity.

The learning activity should also consider the opportunity context. In some cases, this can include the creation of a new organization, yet this more holistically implies new means-ends relationships in that an opportunity must create value. Thus, entrepreneurial activity can also take place within an existing organization. From an engineering innovation and design perspective, the most valuable design encompasses *attributes* related to customer desirability (Do they want this?), business viability

(Should we do this?), and technology feasibility (Can we do this?) [30]. Furthermore, the design can result in a variety of *applications*, including emotional innovations (e.g., implementing customer loyalty programs), process innovations (e.g., installing robots in the manufacturing process), and functional innovations (e.g., developing graphical user interfaces). These opportunity contexts are visually depicted in Figure 1.

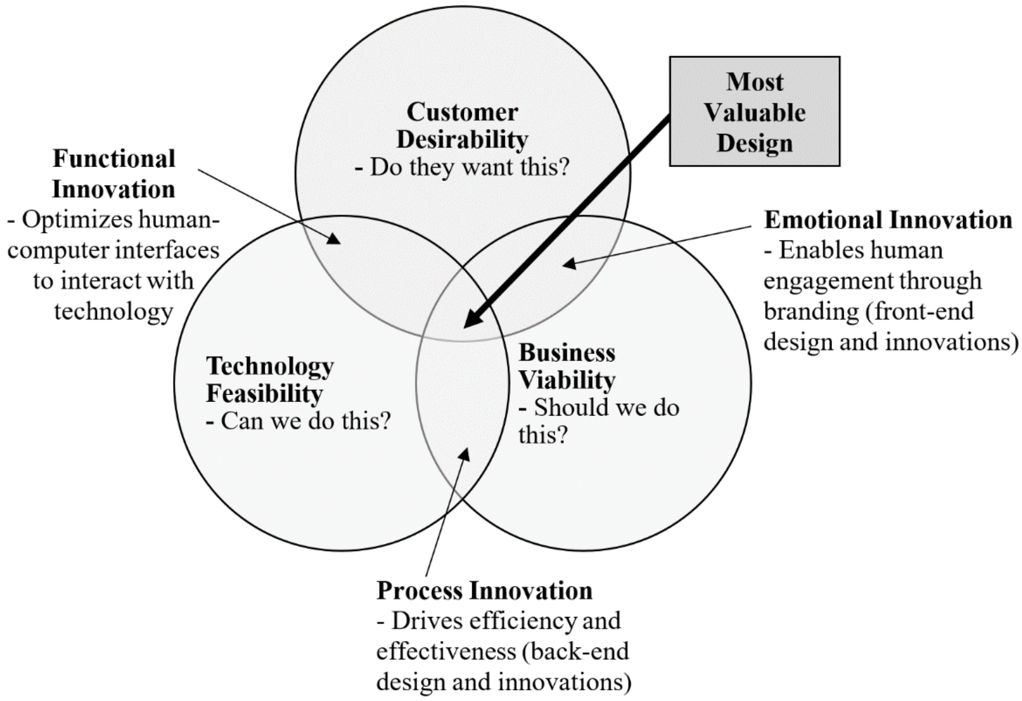

Figure 1. Most Valuable Design [30].

Last, the learning activity should incorporate the engineering course content. From a pragmatic perspective, the students should be completing learning activities that connect the course topics to real-world applications of opportunity context and the entrepreneurial process. When developing entrepreneurially minded discussion prompts, instructional faculty should first determine if their engineering course content is more applicable to design attributes (e.g., customer desirability, business viability, and technology feasibility) or design applications (e.g., emotional, process, and functional innovation).

In general, the *design attributes* approach is more appropriate for design courses (e.g., Introduction to Engineering, Senior Capstone courses) that spend the majority of the course completing a design project. Although there are multiple approaches to the engineering design process, it typically includes the following iterative steps: (1) Gather customer needs, (2) Identify problem, constraints, and requirements, (3) Brainstorm solutions and evaluate design options, (4) Create a prototype, and (5) Test design and get feedback. Typically, in these types of design-oriented courses, students apply the engineering design process throughout the course, culminating in a real-world design project. This allows the student to consider connecting class topics to Brown's [30] concept of most valuable design in an effort to encompass customer desirability, business viability, and technology feasibility within the design project.

On the other hand, the *design application* approach is typically more relevant to engineering foundation courses (e.g., Linear Systems, Thermodynamics, Statics). Here, online discussions can serve as a forum for better understanding how the course content applies to real-world innovation designs, such as emotional, process, and functional innovations.

Once an approach (design attributes or design application) is decided upon, instructional faculty should start brainstorming how specific class topics connect to opportunity context— either the design attributes (validating customer desirability, verifying business viability, confirming technology feasibility) or the type of design application (emotional, process, function). Finally, instructional faculty should consider how the course content and opportunity context apply within the entrepreneurial process of discovery, evaluation, and/or exploitation.

2.1.2. Intention 2: Target Professional Skills

Intention 2 targets professional skills and focuses on the development of collaboration and communication [24]. Mainstream media and engineering education research, alike, often focus on industry's demand for engineering graduates to enter the market with the "soft skills" of collaboration and communication, among others [31–34]. In addition, under the 2016–2017 Criteria for Accrediting Engineering Programs from the Accreditation Board for Engineering and Technology (ABET), bachelor's degree student outcomes within accredited college and university programs must include an ability to function on multidisciplinary teams and an ability to communicate effectively [35].

In developing entrepreneurially minded discussion prompts, the hook, initial prompt, and response prompt can be used to promote collaboration and communication within the online learning community. The hook is a quick and engaging introduction to the learning objective and initial prompt. Through an attention-getting device, such as a striking statistic, joke, or personal story, the hook allows the instructional faculty to establish relevance and credibility, while providing students with a preview of expectations laid out in the initial prompt and response prompt. The initial prompt provides direction on expectations for student communication. To inspire a wide variety of responses and discussion, initial prompts should focus on open-ended questions that promote exploration and encourage curiosity. To keep the online discussion manageable and within scope, they should be limited to one or two questions. To encourage communicating in different formats to a variety of audiences, instructional faculty may want to consider requiring responses that use an assortment of communication formats beyond text. For example, students could be required to reply to an initial prompt using media such as a homemade video, narrated presentation slides, photos, or infographics to visually explain a response. The response prompt provides direction on expectations for student collaboration, through giving feedback and encouraging reflection among peers. Some instructional faculty find it more beneficial to use a standard prompt for all online discussions, such as "Respond to a peer's initial post, comparing and contrasting your own post to your peer's post." Others find it useful to customize the prompts for each online discussion.

2.1.3. Intention 3: Promote a Mindset

Intention 3 states that learning activities should incorporate multiple experiences to practice, reflect, and provide feedback [24]. Simply put, these types of experiences help mold routines into habits, and habits into a mindset. As summarized by Gupta and Govindrarajam [36], our mindsets evolve and are developed based on our histories and the information and experiences that we are exposed to. This entrepreneurial mindset will only be embraced when students start to act and think entrepreneurially about given tasks on a regular basis [37]. It is recommended that instructional faculty initiate the online discussions at least six to eight times throughout the typical course semester. To ease the potential time burden on faculty, students can be assigned as discussion leaders to promote respectful debate and meaningful sharing throughout the individual online discussions.

2.1.4. Intention 4: Align with Course Design

Intention 4 specifies that the learning activity should be purposefully designed to be in alignment with the course and/or content learning goals, objectives, and assessments [24]. Here, the backward course design process, Figure 2, modeled by Wiggins and McTighe [28] can be applied to ensure that the broad learning goals (i.e., incorporating the entrepreneurial mindset into the engineering curriculum) are connected to specific learning objectives, which are assessed using tool(s) or method(s) to measure student learning, and that they support the learning process through the proposed learning activity.

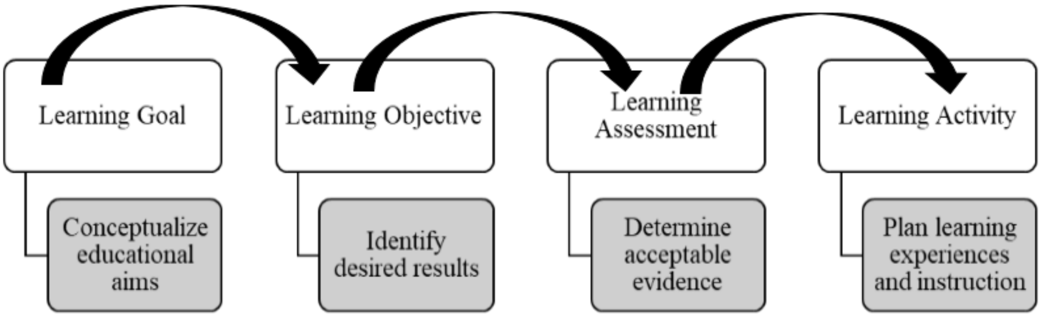

Figure 2. Backward Course Design.

For entrepreneurially minded assignments, the learning goal focuses on incorporating the entrepreneur mindset into the engineering curriculum; as a result, the most valuable learning activities should incorporate the entrepreneurial process, opportunity context, and engineering course content.

Second, the learning objective should be written in alignment with the learning goal. Two key attributes of effective learning objectives are clarity and observability [38]. Clarity implies that the learning objective must provide clear expectations to the students, and observability implies that it must be observable by the instructor. As a rule of thumb, Bloom's Taxonomy of Educational Objectives [39] can be used to identify different levels of observable actions.

Finally, the learning activity (in this case the discussion prompt) and learning assessment should line up with the learning objective and learning goal. Following the first three intentions will help guide the alignment of the learning activity. As for an approach to the learning assessment, rubrics are an excellent option. There are many writing rubric resources available [40–43], and in addition to providing instructor assessments, students can also participate in the assessment process through self- and peer assessments [44–47].

Figure 3 provides a checklist for online discussions within entrepreneurially minded curriculum design. This checklist offers instructional faculty an opportunity to assess the development of the online discussions prior to deploying them in the engineering course.

2.2. Data Collection and Assessment

The study was deployed at a medium-sized university in the Midwestern United States. Online discussion prompts were developed for a freshman-level 3-credit course on Introduction to Engineering offered in Fall 2016. There were 140 students enrolled in the course. This course is mandatory for all general and mechanical engineering undergraduate students, and used to engage students in the engineering discipline and showcase how engineering is applied in the real world. Generally, students are introduced to the engineering design process and get the opportunity to apply the process to a real-world project throughout the course. Appendix A provides example discussion prompts developed and deployed in the Introduction to Engineering course using the online learning management system, D2L. In additional to participating in fourteen discussion sessions, student participants completed both a pre- and post-survey including quantitative and qualitative assessment. All participants gave their informed consent for inclusion before they participated in the study. The study was conducted in accordance with the Declaration of Helsinki, and the protocol was approved by the University Institutional Review Board (IRB) under identification code HR-3200.

An assessment was given at the beginning and end of the semester for students enrolled in the Introduction to Engineering course, as shown in Table 2. The assessment was distributed, collected, and analyzed to better understand student perceptions of how incorporation of online discussions *impacts student learning outcomes* and *develops the entrepreneurial mindset* when applied to the engineering classroom. Both the pre- and post-assessment included three open-ended qualitative questions used to explore student perceptions related to student learning outcomes. The post-assessment included a quantitative component to explore student perceptions related to the entrepreneurial mindset in addition to student learning outcomes. One hundred and forty students completed the pre-assessment, and sixty students completed post-assessment. The smaller number of students completing the post-assessment is due to the voluntary nature of the survey.

Intention 1: Implicit Context

The Discussion Prompt includes the implicit context of:

- ❑ Course content.
- ❑ Entrepreneurial process (discovery, evaluation, exploitation.
- ❑ Opportunity context (design attributes vs. design applications).

Intention 2: Target Professional Skills

The Discussion Prompt requires communication and collaboration as explained in the:

- ❑ Hook and initial prompt.
- ❑ Response prompt.

Intention 3: Promote a Mindset`

The engineering course promotes ongoing practice, reflection, and feedback by requiring:

- ❑ Several Discussion Prompts throughout the learning experience (e.g. semester).

Intention 4: Grounded in Backward Course Design

The Learning activity (Discussion Prompt) aligns with the:

- ❑ Learning goal(s).
- ❑ Learning objective(s).
- ❑ Learning assessment(s).

Figure 3. Checklist for Entrepreneurially Minded Curriculum Design [24].

Table 2. IRB Approved Survey Instrument [14].

Open-Ended Questions (Both Pre- and Post-Assessment)

1. Identify the top three factors that are most important for student learning and success.
2. Blended learning occurs when a student learns at least in part through digital and online engagement with some element of student control over time, place, path, or pace. What is your perception of blended learning in comparison to face-to-face learning?
3. How might you further your skills/knowledge after this class is over?

Scaled Comparison (Only Post-Assessment)

In comparison to other courses, how much has your coursework in this course emphasized the following? (5 = Very Much; 1 = Not at All)

- Applying learning in new contexts
- Learning beyond the curriculum
- Formulating questions and generating own inquiries
- Exploring alternatives
- Encouraging diverse perspectives
- Understanding diverse perspectives

The open-ended questions and the first two scale questions explore student perceptions related to learning outcomes. The latter four scale questions explore student perceptions related to the entrepreneurial mindset, as defined by several entrepreneurial focused frameworks. "Formulating questions and generating own inquiries" is similar to the Innovator's DNA [48] Questioning and Associating; the Knowledge-seeker attribute of the Entrepreneurial Strengthsfinder [49], the Reflection aspect of the "Teaching Entrepreneurship: A Practice Based Approach" [50], and promoting Curiosity within the KEEN framework. "Exploring alternatives" is similar to Experimenting in the Innovator's DNA [48] and "Teaching Entrepreneurship: A Practice Based Approach" [50], as well as promoting Curiosity in the KEEN framework. "Encouraging and understanding diverse perspectives" comparable to Empathy in "Teaching Entrepreneurship: A Practice Based Approach" [50] and encouraging Connections in the KEEN framework.

3. Data Analysis and Results

3.1. Data Analysis

The methods provided by Koro-Ljungberg and colleagues [51] was used to guide the research and analysis process. Specifically, a mixed methods approach was used to analyze the data. Both the pre- and post-surveys each included a combination of open-ended questions and numerically scaled questions. The NVivo 11 qualitative analysis software was used to analyze the qualitative open-ended questions. All data documents were imported into NVivo and the researchers read through the documents several times. Two researchers completed the analysis independent, then compared results, re-read the documents, and came to a consensus. Analysis of the documents led the researchers to identify major themes, quotes, and takeaways related to the research questions, which are identified in the next session. The Statistics Package for Social Sciences (SPSS) was used to analyze the quantitative numerically scaled questions. Descriptive statistics, graphical techniques, and hypothesis testing using the Student's t-test for a difference in means was used to quantitatively analyze the data.

3.2. Open-Ended Questions (Pre- and Post-Assessment)

3.2.1. Top 3 Factors Impacting Student Success

Students were asked to "Identify the top three factors that are most important for student learning and success."

Common responses for both pre- and post- assessment included: teacher effectiveness, student study habits, and course schedule. The response to this question did not change much from pre- to post-assessment, and as a result, offers limited insight into the research question.

3.2.2. Perceptions of Blended Learning

Students responded to the following question: "Blended learning occurs when a student learns at least in part through digital and online engagement with some element of student control over time, place, path, or pace. What is your perception of blended learning in comparison to face-to-face learning?"

The responses to this question changed quite a bit from pre- to post-assessment. In the pre-assessment, 57% of the students preferred blending learning (incorporating online discussions into the classroom) over face-to-face learning. However, in the post-assessment, 66% of the students preferred blended learning (incorporating online discussions into the classroom) over face-to-face learning. This suggests that students see blended learning and online discussions as a viable method to meet student learning outcomes, although there may be some initial hesitation.

3.2.3. Life-Long Learning

Students were asked "How might you further your skills/knowledge after this class is over?"

The responses to this question changed quite a bit from pre- to post-assessment. In the pre-assessment, students' responses centered around resources provided by the instructor and within the institution. Sample pre-assessment responses are as follows:

- "Going to TA's and professors for help."
- "Reading the textbook, seeking practice opportunities."

- “Reading, and understanding more of the theories that are coming along with the work.”

However, in the post-assessment, students’ responses centered around keeping up with real-world examples (e.g., current events, trends, news, research) to further skills and knowledge. This suggests that students are starting to recognize online discussions as a viable to further skills outside the classroom while still promoting student learning outcomes.

- “By applying myself to situations in the real life world that I learned how to do in this class.”
- “By reading in academic articles of the subject.”
- “Research on related topics, keeping up to date on engineering innovations.”

3.3. Scaled Comparison (Post-Assessment Only)

Table 3 provides results for the scaled comparison questions relating to student perceptions of the online discussions. The average scores are all relatively high. The first two items (Applying learning in new contexts; Learning beyond the curriculum) focus on the student learning outcomes. The high scores suggest, from the students’ perceptive, the entrepreneurially minded online discussions were especially effective as an aid to student learning outcomes. The latter four items (Formulating questions and generating own inquiries; Exploring alternatives; Encouraging diverse perspectives; Understanding diverse perspective) focus on the perceived development of the entrepreneurial mindset. The high scores suggest, from the student’s perspective, the entrepreneurially minded online discussions were especially effective as an aid to develop personality traits, behaviors, and skills previously linked to the development of the entrepreneurial mindset.

Table 3. Results—Student Perceptions of the Online Discussions.

In Comparison to Other Courses, How Much Has Your Coursework in this Course Emphasized the Following? (5 = Very Much; 1 = Not at All)	Average Score
Applying learning in new contexts	4.2
Learning beyond the curriculum	3.9
Formulating questions and generating own inquiries	3.9
Exploring alternatives	4.2
Encouraging diverse perspectives	3.9
Understanding diverse perspectives	3.9

3.4. Summary of Results

In summary, the purpose of the study was to respond to the following research questions.

- How do student perceptions of blended and online learning change given the integration of authentic entrepreneurially-minded discussion sessions?
- How does participation in authentic discussion sessions impact student awareness and exposure to entrepreneurially-minded concepts?

The qualitative results suggest that student perceptions of blended and online learning did change given the integration of authentic entrepreneurially-minded discussion sessions. Positive student perceptions of blended learning improved from 57% to 66% (pre- to post-). This suggests that students see blended learning and online discussions as a viable method to meet student learning outcomes, although there may be some initial hesitation. Furthermore, when considering how students might further their skill development once the class is over, students became cognizant that life-long learning is attainable through keeping up with real-world examples such as current events, trends, news and research. Furthermore, the quantitative results suggest that participation in authentic discussion sessions impacted students’ awareness and exposure to entrepreneurially-minded concepts. Specifically, students sensed that this particular course offered the opportunity to *apply learning in new contexts* and *explore alternatives* more so in comparison to other courses.

4. Discussion

4.1. Additioanal Resources and Applicability

There are also many resources available that offer best practices in facilitating online discussions efficiently and effectively [52–54]. Among other useful starter recommendations, first, establish clear instructor and student expectations up front. For example, instructional faculty should specify when he or she plans to check in to the online discussion, including days and times during the week (e.g., an instructor might decide to limit participation to M/W/F 9–10 a.m.). If the online discussion is being deployed in a large class, the instructor may want to consider assigning student facilitators weekly to help promote the discussion. As for setting clear student expectations, in addition to providing students with a rubric, research and anecdotal evidence suggest that setting a weekly routine is best. For weekly asynchronous discussions, instructors can require that students reply to the initial prompt by Thursdays and reply to the response prompt by Sundays. It's important to keep in mind that designing, managing, and assessing online discussions can be completed effectively and efficiently with minimal time investment from the instructor's perspective [55–57].

In addition, there are multiple ways in which the guide on online discussion prompts can be varied and/or extended to cultivate an entrepreneurial mindset for students in other settings. For example, other pedagogical methods could leverage this guide: the discussion prompt and process could be used to facilitate in-class discussion, serve as essay prompts, guide research papers, initiate end-of-class "minute papers" [58], provide individual student journal prompts, or promote topics for poster sessions.

Furthermore, the use of online discussion prompts can also be applied to courses beyond the Introduction to Engineering course shared in this article. To exemplify the applicability, we consider what an example prompt might look like in a calculus class (Table 4). Some working engineers use calculus on an everyday basis, and others use software applications that embed calculus within the program. Regardless of actual engineering application in the real-world setting, ABET criteria require a minimum of 2.5 years (80 credits) devoted to engineering, math, and science courses [35]. This typically results in engineering students taking three or four calculus classes throughout the bachelor's degree program. Although engineering faculty typically do not teach calculus, it is a course that most engineering faculty can find relatable. Yet we posit that there is additional applicability beyond engineering settings. Indeed, the entrepreneurial mindset is becoming more and more a necessity for all students. Thus, it is possible that the engineering course content could be exchanged with other disciplines, such as courses focused around the sciences, education, and the humanities.

Table 4. Example Discussion Prompt for Calculus.

Calculus	Example—Commercially Available Innovations
Learning Objective	Demonstrate a basic understanding of how integration and differentiation are applied to engineering design and innovation.
Hook	Calculus, defined as the mathematical study of change, was developed independently by Isaac Newton and Gottfried Wilhelm von Leibniz in the 17th century. The Merriam-Webster dictionary defines engineering as "the application of science and mathematics by which the properties of matter and the sources of energy in nature are made useful to people". Some engineers directly use calculus in their daily practice and some use computer programs based on calculus that simplify engineering design. Two methods of calculus, differentiation and integration, are particularly useful in the practice of engineering, and are generally used for optimization and summation, respectively.
Initial Prompt	Use the Internet to find an example of a commercially available innovation (product or service) that requires the use of calculus techniques to work effectively and efficiently. Identify the value proposition and customer segment(s). Explain the role calculus plays in the innovation. What alternative solutions are available?
Response Prompt	Respond to a peer's initial post. State the pros and cons of the innovation in comparison to alternative solutions. Identify alternative solutions not mentioned.

4.2. Limitations and Future Research Directions

While this study offered significant insight, it is not without its limitations that subsequently offer a series of future research directions. In terms of generalizability, there is a need to explore the applicability of using online discussion prompts within universities in other parts of the world and of varying class sizes. Moreover, in our study, only 60 of the original 140 students participated in the posttest due to the voluntary nature of the survey. Replication studies would be welcome to ensure that the smaller subset of students responding did not impact the results.

The additional workload for the students is estimated at thirty minutes per question prompt. In terms of the additional workload for the instructor, the majority of time was spent ahead of time crafting the questions. This is consistent with existing research that suggests the creation of the discussion prompt is a critical driver of its effectiveness [59]. Indeed, the use of discussion prompts is suggested to help develop relatedness among the students [60] as well the practical importance of the topic [17], which can offset the invested time. While the responses were monitored by the instructor, future research is needed to tease out whether additional interaction between the instructor and students is needed and/or if the peer to peer interaction is sufficient. Extremely large class sizes may benefit from smaller group discussion boards.

4.3. Conclusions

This paper set out to provide a guide for cultivating the entrepreneurial mindset in engineering students through online discussion prompts. In doing so, we reviewed the key intentions for teaching the entrepreneurial mindset as well as the benefits of online discussion prompts. It is our hope that this paper will continue to guide and spur engineering educators in preparing students for success in real-world occupations. Fostering student voice through online discussions encourages all students to participate, and connect what they have learned in the classroom to their own personal real-life experience (also known as 'authentic learning').

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Appendix A (Reprinted with Permission [24] (pp. 68–72))

Example Discussion Prompts to Connect Course Topics to Real World Applications: Engineering Discovery and Innovation Exploration

Course: Introduction to Engineering

Learning Activity Approach: Discussion Prompts to Connect Course Topics to Real World Applications

Description: This course is a requirement for all engineering majors. Some of the objectives include providing an overview to a variety of engineering disciplines, exploration of the many roles engineers play in society, application of professional skills, and lays the foundation for innovation and the engineering design process. This course used a variety of discussion prompts to connect real world applications to the course objectives.

Learning Objectives: (1) Describe the varying roles of engineering disciplines within society. (2) Critique and explore new developments in the field of engineering.

Learning Activities: Each week of the sixteen-week semester, with the exception of midterm and final exam weeks, students were required to reply to a variety of discussion prompts. All discussion prompts required an initial post and a response to a peer's post, which needed to be completed within a week.

Week 1: Introduction

Hook: Welcome to the class. Let's get to know your peers.
Initial Prompt: Upload a profile picture of yourself. Create a post answering these questions: (1) Why do you want to be an engineer and/or study engineering? (2) What type/kind of engineer do you want to be (in the future)? (3) What's your goal as an (future) engineer?
Response Prompt: Respond to a peer's post welcoming them to the class.

Week 2: Historical Engineers

Hook: Many of the greatest advancements in history have come about as the direct result of those working as engineers. Engineers provide us with practical solutions for a host of problems, as well as advance practical science and technology. They take theories and ideas, and often turn them into working principles and products that better our lives. From the compound pulley system invented by the great Greek engineer Archimedes, to the tall buildings and air conditioned comfort we enjoy today, engineers have been at the forefront of our technological advancement.
Initial Prompt: Identify whom you believe to be one of the greatest engineers and state why.
Response Prompt: Select two great engineer posted in the discussion. Assuming they were alive at the same time and capable of collaboration, what could they have accomplished?

Week 3: Math Importance

Hook: Calculus is the study of how things change. It provides a framework for modeling systems in which there is change, and a way to deduce the predictions of such models.
Initial Prompt: Provide an example of where an engineer might use calculus in a real world application and explain how it is used.
Response Prompt: Select a peer's post. Respond with a prediction of how calculus might be used in this real world application 20 years from now.

Week 4: Nuclear Engineering

Hook: Nuclear engineers research and develop the processes, instruments, and systems used to derive benefits from nuclear energy and radiation. Many of these engineers find industrial and medical uses for radioactive materials—for example, in equipment used in medical diagnosis and treatment. Nuclear engineers typically work in offices; however, their work setting varies with the industry in which they are employed. Most nuclear engineers work full time.
Initial Prompt: Search the internet to find a nuclear engineering focused design you think is especially innovative. Explain the product or service and how it adds value to the customer.
Response Prompt: Select a peer's post and comment on how current market trends might impact the innovation in the future.

Week 5: Biomedical Engineering

Hook: Biomedical engineers combine engineering principles with medical and biological sciences to design and create equipment, devices, computer systems, and software used in healthcare.
Initial Prompt: Search the internet to find a biomedical engineering focused design you think is especially innovative. Explain the product or service and how it adds value to the customer.
Response Prompt: Select a peer's post and comment on how current market trends might impact the innovation in the future.

Week 6: Industrial Engineering

Hook: Industrial engineers find ways to eliminate wastefulness in production processes. They devise efficient systems that integrate workers, machines, materials, information, and energy

to make a product or provide a service. Depending on their tasks, industrial engineers work either in offices or in the settings they are trying to improve. For example, when observing problems, they may watch workers assembling parts in a factory. When solving problems, they may be in an office at a computer, looking at data that they or others have collected.
Initial Prompt: Search the internet to find an industrial engineering focused design you think is especially innovative. Explain the product or service and how it adds value to the customer.
Response Prompt: Select a peer's post and comment on how current market trends might impact the innovation in the future.

Week 7: Civil Engineering

Hook: Civil engineers design, build, supervise, operate, and maintain construction projects and systems in the public and private sector, including roads, buildings, airports, tunnels, dams, bridges, and systems for water supply and sewage treatment.
Initial Prompt: Search the internet to find a commercially available civil engineering focused design you think is especially innovative. Explain the product or service and how it adds value to the customer.
Response Prompt: Select a peer's post and comment on how current market trends might impact the innovation in the future.

Week 9: Chemical Engineering

Hook: Chemical engineers apply the principles of chemistry, biology, physics, and math to solve problems that involve the production or use of chemicals, fuel, drugs, food, and many other products. They design processes and equipment for large-scale manufacturing, plan and test production methods and byproducts treatment, and direct facility operations. Chemical engineers work mostly in offices or laboratories. They may spend time at industrial plants, refineries, and other locations, where they monitor or direct operations or solve onsite problems. Nearly all chemical engineers work full time.
Initial Prompt: Search the internet to find a chemical engineering focused design you think is especially innovative. Explain the product or service and how it adds value to the customer.
Response Prompt: Select a peer's post and comment on how current market trends might impact the innovation in the future.

Week 10: Mechanical Engineering

Hook: Mechanical engineering is one of the broadest engineering disciplines. Mechanical engineers design, develop, build, and test mechanical and thermal sensors and devices, including tools, engines, and machines.
Initial Prompt: Search the internet to find a mechanical engineering focused design you think is especially innovative. Explain the product or service and how it adds value to the customer.
Response Prompt: Select a peer's post and comment on how current market trends might impact the innovation in the future.

Week 11: Agricultural Engineering

Hook: Agricultural engineers attempt to solve agricultural problems concerning power supplies, the efficiency of machinery, the use of structures and facilities, pollution and environmental issues, and the storage and processing of agricultural products. Agricultural engineers work in a variety of industries. Some work for the federal government, and others provide engineering contracting or consultation services, or work for agricultural machinery manufacturers. Although they work mostly in offices, they also may spend time traveling to agricultural settings.

Initial Prompt: Search the internet to find an agricultural engineering focused design you think is especially innovative. Explain the product or service and how it adds value to the customer.

Response Prompt: Select a peer's post and comment on how current market trends might impact the innovation in the future.

Week 12: Electrical Engineering

Hook: Electrical engineers design, develop, test, and supervise the manufacturing of electrical equipment, such as electric motors, radar and navigation systems, communications systems, and power generation equipment.

Initial Prompt: Search the internet to find an electrical engineering focused design you think is especially innovative. Explain the product or service and how it adds value to the customer.

Response Prompt: Select a peer's post and comment on how current market trends might impact the innovation in the future.

Week 13: Computer Engineering

Hook: Computer hardware engineers research, design, develop, and test computer systems and components such as processors, circuit boards, memory devices, networks, and routers. These engineers discover new directions in computer hardware, which generate rapid advances in computer technology. Computer hardware engineers usually work in research laboratories that build and test various types of computer models. Most work in high-tech manufacturing firms.

Initial Prompt: Search the internet to find an agricultural engineering focused design you think is especially innovative. Explain the product or service and how it adds value to the customer.

Response Prompt: Select a peer's post and comment on how current market trends might impact the innovation in the future.

Week 14: Engineering Impact

Hook: Team building is important in any environment which requires the coordination and integration of multiple activities. It is especially crucial in a technical engineering environment where projects are often highly complex and require the integration of many functional specialties. For these projects, it is necessary for the managers and their lead engineering personnel to cross organizational boundaries and work with resources and personnel over whom they have little or no formal authority. Such a team must have a capacity for innovatively transforming a set of technical objectives and requirements into specific products, system concepts, or services that compete favorably against other available alternatives.

Initial Prompt: Take into consideration your role in the final project and identify how your role contributed to the team's success.

Response Prompt: Select a peer's post where you have played a similar role but in a different setting (e.g., job, family, club, sports, extracurricular activities, etc ...) and describe your experience.

Week 15: What is engineering?

Hook: Unfortunately, engineers haven't done a good job in getting the word out about what they really do (perhaps because they're too busy doing it!). As a result, a lot of misconceptions exist about what engineering is and what engineers do, with people believing engineers to be anything from locomotive train operators to mechanics/ technicians, to construction supervisors, to NASA personnel, to generic "computer people".

Initial Prompt: Explain how you would describe the role of engineers to an adult? To a child?

Response Prompt: Select a peer's post. Assume you are that unknowing adult or child. What types of follow-up questions would you ask to learn more about engineering?

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