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Mapping Engineering Outcomes to the Lean Launch Curriculum in the Context of Design

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Mapping engineering outcomes to the Lean Launch curriculum in a user-centered design context

Abstract

Although engineering graduates could once be successful through acquiring technical proficiency alone, modern engineers are expected to master a wider set of skills to succeed in the workplace. They must be able to communicate effectively, lead and work with interdisciplinary teams, and design unique and creative solutions for open-ended problems, while considering ethical standards and global implications. In response to these growing expectations, engineering programs are evolving to better prepare their students for the workplace. One way that engineering curricula are addressing this is by the inclusion of design-based courses or projects, that give students a chance to work in a more industrially-situated context to develop both technical expertise and non-technical skills.

Recently, entrepreneurship education has emerged as a means of supporting engineering professional development in the modern context. Although entrepreneurship has traditionally been a focus primarily in business curriculum, engineering programs have recently recognized its value for developing important skills in engineering students such as collaboration, communication, and creativity. However, unlike design, the implementation of engineering entrepreneurship into traditional engineering departments is not yet widespread, due to limited time and space within both curricula and individual courses, and due to difficulties adapting entrepreneurship education pedagogies to be useful in an engineering context.

In this work, we discuss Lean Launch, an entrepreneurship curriculum that can be easily implemented into engineering programs and which shares many parallels to engineering design. Rather than focusing on traditional business model development, Lean Launch incorporates an iterative hypothesis-testing model built around customer need and constraints, akin to that found in engineering user-centered design courses. Through this approach, Lean Launch offers students the skill sets needed to iterate and explore user needs. The use of a Lean Launch curriculum can also aid in the development of important skills needed by modern engineers, such as communication. This paper maps the Lean Launch curriculum to engineering design outcomes and behaviors and a typical human-centered design process, to identify how Lean Launch can be used in engineering courses to meet the ever-evolving needs of engineering education and better prepare students for the field. By identifying how the Lean Launch curriculum supports traditional engineering outcomes, it is possible to integrate entrepreneurship education into engineering curriculum. This will lead the way to providing a framework for instructors to encourage the non-technical skills required and recommended for engineers of the future.

Introduction

As the engineering field shifts and evolves, demands on engineering graduates have grown. Engineering students must be more well-rounded, needing more than technical prowess to succeed; they must also be able to collaborate, lead, communicate, and innovate.[1,2] As expectations on engineers have evolved, so has the engineering curriculum to aid students in meeting these expectations.

One type of course that encourages the development of these types of skills is the engineering design course. Engineering design courses have long been a mainstay of engineering curricula, requiring students to apply their engineering knowledge and skills to create a system, product or process.[2] In design courses, students work in teams in a more "authentic" environment, applying knowledge to solve an open-ended, "real world" problem.[3] Throughout the project, they practice and develop many important skills that they will need as a practicing engineer. However, given that design courses involve a time- and resource-intensive project that incorporate all of the content delivered in the past three years of a curriculum, there is little room to add in the development of more skills that the modern engineering student needs.

More recently, engineering colleges and universities have also explored other approaches to cultivating professional skills of engineering graduates, including entrepreneurship education. While entrepreneurship education originated from business schools, engineering schools have begun to establish their own approach to entrepreneurship education: taking a more active approach to student learning, blending business context with experiential learning.[4] This is most evident by the wide-spread adoption of Steve Blank's Lean Launch curriculum.[5] Lean Launch, a new entrepreneurship curriculum most prominently used by the NSF I-Corps Program[6,7] is a method for start-ups that involves iteration and extensive exploration of customer needs through Customer Discovery, leading to the development business model for a solution that has a proven market fit before being operationalized.

This study was founded on the hypothesis that engineering design courses are a platform for the integration of Lean Launch, to better develop entrepreneurial skills in our engineering students. More specifically, we investigated *how* the Lean Launch curriculum parallels that used in engineering design courses and exactly *why* it should be integrated, or, in other words, what benefits Lean Launch could bring to engineering design students. Through interviews with entrepreneurs who leverage Lean Launch in engineering contexts, we investigated how Lean Launch compares to engineering design in terms of the process that students engage in, the skills that students may practice, and the behaviors that students develop. The entrepreneurs were well-versed with Lean Launch, but not necessarily the engineering design curriculum, and thus, when prompted, they were able to objectively identify similarities and differences between the two contexts. These interviews enlightened many parallels between Lean Launch and engineering design, suggesting that an integration of the two would be seamless. Furthermore, analysis of the interviews revealed that the utilization of Lean Launch principles in engineering design courses could *strengthen* engineering design curricula, allowing for the teaching and assessment of many important engineering skills that may not be fostered in traditional engineering courses. From this work, we provide a foundation for determining how to integrate the teaching of entrepreneurship into existing engineering curricula, better preparing our students as entrepreneurs and as engineers.

Background

Entrepreneurship Engineering Education

Entrepreneurship has traditionally been viewed as an area best-suited to business or management students, taught to those interested in starting or managing companies. In fact, "entrepreneur" is still defined by Merriam-Webster as one "who organizes, manages, and assumes the risks of a business or enterprise." However, in recent years, it has become clear that there are many benefits to implementing entrepreneurship more broadly into college curricula, particularly in an engineering context.

Most broadly, the skills that entrepreneurs embody – professionalism, communication, creativity, dynamism – are becoming more important for any engineering graduate. Engineers now are required to be curious, flexible, agile, creative, and empathetic[1,8], and must be able to work on interdisciplinary teams and communicate in a variety of contexts.[9,10] Graduating engineering students cannot simply be technically proficient; they must be able to develop innovative new products, but also explore customer needs, understand the market, and have the abilities to commercialize products or start-up businesses.[11–13]

However, traditional curricula do not sufficiently incorporate entrepreneurship skill development. Because entrepreneurship has been typically relegated to a business curricula, business students may be well-prepared to manage or start a business, but less prepared to develop a new technology, while engineering students are ready to innovate, but not equipped to market it or manage employees.[14] Students have reported that traditional college education inhibits creativity[15] and entrepreneurial thinking.[16] Some engineering students report that their curriculum was lacking in terms of teaching innovation or other entrepreneurship-related skills, including teamwork, communication, organization, creativity, and leadership.[14]

There are many proposed reasons as to why entrepreneurship is not yet broadly implemented into engineering curricula.[11] Duval-Couetil et al. note that the integration of entrepreneurship into engineering courses is a "relatively new movement."[11] Engineering faculty do not necessarily understand entrepreneurship or the entrepreneurial mindset.[17] Faculty also feel that the engineering curriculum is already overcrowded[9,18] and there is no space for entrepreneurship-related electives.[19] Also, there is not yet a broadly-agreed upon entrepreneurship curriculum for engineering students, in terms of course structure, student population or pedagogy.[11,17,19]

Engineering Design

Thus, it is clear that there is a need to have a better understanding of how to implement entrepreneurship into engineering curricula. We argue that, rather than isolating entrepreneurship within their own courses or academic programs, entrepreneurship could be integrated into the engineering curriculum or specific engineering courses. Engineering design, in particular, provides many opportunities for this integration, as design and entrepreneurship have many parallels.[20] Teaching engineering design, as in teaching entrepreneurship, is also about teaching a process or way of thinking. Co-curricular engineering design experiences, like the K-WIDE program, have already integrated the teaching of entrepreneurial skills within an engineering design experience[21] and have found that students do couple concepts from the two fields to form an overarching engineering mindset.[8]

In engineering curricula, accredited departments are required to offer an engineering design course in the final year of study, called a capstone design course.[2] In this course, students have the opportunity to apply previously-acquired knowledge and develop new skills in a more "real world" type of environment than that in their prior classes.[3] Design courses have more recently become engrained in other parts of the engineering curriculum; particularly, in the first year, to introduce students to the engineering career and engineering ways of thinking.[22]

In the consideration of how entrepreneurship parallels engineering design, we considered three aspects of engineering design: the *process* that engineers go through as they design, the learning *outcomes* associated with engineering design courses, and the *behaviors* that engineering designers embody.

Engineering Design Process

One goal of design courses is to teach students how to step through the engineering design process. In engineering design courses, students generally work in teams on an open-ended, less-defined problem that requires a culmination of their engineering knowledge. Students are typically expected to engage in an iterative, non-linear problem-solving process to generate ideas to a problem, and then to consider alternatives and constraints to decide on a best solution.[23] In a human-centered design project, students may spend more time re-defining the problem or doing more research to explore and understand user needs.

Engineering design has been an area of focus for engineering education researchers, both because of the unique learning experience for students but also because design is, in short, what engineers *do* in the real world. Thus, it is important to fully understand how students currently do and, ideally, *should* engage in the design process. There is a realm of research within the engineering design space on a concept called design thinking, which involves studying how a designer approaches, works through and solves design problems.[24] The research done on how experts utilize design thinking can be applied to determining the ways that we want students to engage in design. Specifically, studies on design thinking have identified typical steps that are employed in the engineering design process, derived from how experts design[23,25–27], presented in Table 1.

Table 1. Steps of the engineering design process.

Engineering Design Process	Definition
Understand, define, reframe a problem	Exploring the problem space; revising the problem statement based on new information
Do research	Investigating the problem and relevant solutions; enhancing the knowledge and understanding needed to form solutions[23]
Explore user needs	Determining what the customer or

	consumer requires from the product
Identify constraints	Determining societal, economic, environmental, legal or other restrictions on the design
Generate ideas	Avoiding fixation on a single idea; utilizing different strategies to come up with a variety of solutions[28]
Prototype/represent your idea	Demonstrating your design via a model, sketch, or 3D representation[23,26,27]
Conduct experiments	Running tests to consider hypotheses, gain new information and learn "how prototypes behave"[23]
Revise and iterate	Revisiting the design, using new information or feedback[23]
Reflect on the process	Thinking about challenges, failures, and successes; considering what contributed to or hindered progress[23,29]
Execute the final solution	Creating a prototype of the final design, considering research, experimental results, and user needs[30]

Engineering Design Learning Outcomes

Engineering design courses serve to teach students how to engage in the design process, as discussed in the previous section, but students also can learn many other important engineering skills from design courses. With their team-based, project-based pedagogy, design courses serve as opportunities for students to practice and develop skills that are crucial to the engineering profession. Students develop teamwork or leadership skills by working in groups and written and oral communication skills by reporting progress through presentations and reports. They practice creative problem solving, developing ethical standards, and analyzing ideas or solutions. Because of this, the learning outcomes of engineering design courses typically mirror – or are the same as – outcomes identified for engineering students in general,[3,31,32] such as those defined by the Engineer of 2020 report,[1] listed in Table 2.

Table 2. Engineer of 2020 outcomes.

Attributes of the Engineer of 2020	Definition
Strong analytical skills	Applying math science, and design principles; consider social, economic, legal, and political constraints; practice core engineering design activities
Practical ingenuity	Identifying problems and finding solutions
Creativity	Synthesizing knowledge to solve complex and diverse problems

Communication	Working with interdisciplinary teams and different stakeholders
Business and management skills	Being leaders of change considering interdependence between technology and communities
Leadership	Performing public service
High ethical standards, strong sense of professionalism	Considering implications and social, economic, and environmental factors
Dynamism, agility, resilience, flexibility	Working in a changing and uncertain context
Lifelong learning	Constantly seeking and amending knowledge

Engineering Design Behaviors

Typically positioned at the very end of the student's curriculum (or very beginning, in the case of first-year design courses), engineering design courses can also serve to help students develop into engineers. Situated within an authentic problem-solving context, students are expected to make the leap from being students to being functional engineers. They learn the process of approaching an open-ended design problem and develop important skills, as discussed in the previous sections, but they also begin to form as an engineer by practicing and developing certain behaviors, attitudes, or mindsets. A branch of research focusing on engineering designers has identified certain behaviors that are practiced by successful designers.[23,24,26,33] Table 3 presents behaviors that were identified in multiple papers as being present in engineering designers. These behaviors are also what are, ideally, being developed in engineering students as they engage in the engineering design process.

Table 3. Behaviors, attitudes or mindsets common to engineering designers.

Engineering Design Behaviors	Definition
Empathy	"Taking others' perspective";[26] understanding and considering consumer needs in the development of their design
Comfort with uncertainty, failure and risk	Working under ambiguity, taking strategical risks[26]
Creativity	Inventing, innovating; solving problems in unique or novel ways
Collaboration	Working in interdisciplinary, diverse teams
Iteration	Cycling between convergent and divergent thinking[24]
Curiosity	Needing to know or learn something
Critical questioning	Keeping "an open mind about possibilities;" questioning "bias and beliefs"[33]

Lean Launch

Lean Launch is an entrepreneurship curriculum developed by Steve Blank at Stanford University[5] and used by the NSF I-Corps Program.[6] Lean Launch is an iterative, fast-moving development process to aid entrepreneurs in identifying product market fit and key activities and resources to develop a scalable and repeatable business model, before launching a venture, thus ensuring more success for new start-up companies.

Lean Launch operates on the foundation of "evidence-based entrepreneurship." In the past, business founders wrote a business plans to seek investor funding to launch their business. Under this model, however, entrepreneurs would need to make assumptions that they can't necessarily support and they may not obtain adequate feedback from potential users until the product is on the market. Steve Blank, author of the Lean Launch curriculum, argues that this traditional business plan approach neglected the voice of the customer and these plans fail because founders never confirmed a product need before launch.[34] In Lean Launch, entrepreneurs are challenged to hypothesize the critical components necessary to develop their business model and seek confirmation or opposition to their hypotheses through talking to potential stakeholders. Rather than using the traditional business plan model, entrepreneurs use the Business Model Canvas (BMC) as a guiding principal to identify the fundamental components of an actionable business model based on Customer Discovery, in which entrepreneurs get feedback from potential customers and stakeholders on their product and business strategies. As entrepreneurs collect data from stakeholders, they are encouraged to also create a Minimum Viable Product (MVP), a low-level prototype that has the minimum level of detail needed to present their vision and gain feedback. The iterative feedback gained in Customer Discovery is used revise the BMC and MVP; this process is referred to as Agile Development, in which entrepreneurs are developing their product "iteratively and incrementally."[34]

Research Questions

The purpose of this study was to identify similarities and differences between engineering design and Lean Launch and examine how Lean Launch can be utilized in current engineering curricula. Engineering design and Lean Launch were analyzed and compared in terms of *process*, course *outcomes*, and changes in *behaviors* that students exhibit throughout the course. Four research questions guided this research:

1. How does the Lean Launch process compare or contrast to the engineering design process?
2. What engineering learning outcomes are also outcomes in the Lean Launch curriculum?
3. What types of engineering design behaviors do instructors believe students develop by engaging in the Lean Launch curriculum?
4. What benefits could the Lean Launch curriculum bring to engineering design curricula?

Methods

Interview Protocol Development

An interview protocol was developed to investigate how Lean Launch is taught in various engineering contexts and also determine the parallels that exist between Lean Launch and engineering design curricula.

The interview protocol first consisted of general warm-up questions that involved asking the participants about their entrepreneurial, engineering and Lean Launch backgrounds.

Next, the interview was segmented into three parts, to probe the parallels that exist between engineering design and Lean Launch in three aspects.

1. **Process**: The steps that students go through when engaging in the Lean Launch curriculum or engineering design processes.
2. **Outcomes:** Learning outcomes that are identified and assessed in the Lean Launch curriculum or engineering design courses.
3. **Behaviors:** Behaviors that are developed in the Lean Launch curriculum, or identified as being present with expert engineering designers.

In each of these three parts, interview participants would first be asked an open-ended question about their experience with Lean Launch (i.e. "what are the learning outcomes of your Lean Launch course?").

Next, participants would be prompted to compare Lean Launch with elements of engineering design. For each of the three parts of the interview, a checklist existed that listed elements of engineering design (Table 4). Participants would be asked to "check" items that they believed were also present in the Lean Launch curriculum, provide examples, and were prompted to annotate the list further if they desired. The checklists were developed from the items presented in Tables 1, 2 and 3. Some checklist items also included a definition based on that found in design literature, as the interview participants had varying familiarity with the engineering design space or with a typical engineering design curriculum. The definitions that were provided to the participants are intact in the table below.

Table 4. Checklists provided to interview participants.

Engineering Design Process Checklist	**Engineering Design Learning Outcomes Checklist**	**Engineering Design Behaviors Checklist**
☐ Understand, define, reframe a problem ☐ Do research ☐ Explore user needs ☐ Identify constraints ☐ Generate ideas ☐ Prototype ☐ Conduct experiments ☐ Revise and iterate ☐ Reflect on the process ☐ Execute the final solution	☐ Strong analytical skills ☐ Practical ingenuity = identifying problems and finding solutions ☐ Creativity ☐ Communication ☐ Business and management skills ☐ Leadership ☐ High ethical standards ☐ Strong sense of professionalism ☐ Dynamism, agility, resilience, flexibility	☐ Empathy = understanding and considering consumer needs in the development of their product ☐ Comfort with uncertainty, failure and risk ☐ Creativity ☐ Collaboration ☐ Iteration = revising solutions ☐ Curiosity = a need to know or learn something ☐ Critical questioning = reflecting on and revising

	☐ Lifelong learning	solutions

The project team co-developed the interview protocol. The second author, with extensive experience in entrepreneurship education, then responded to each question to ensure relevance to the Lean Launch curriculum. These responses were used to both revise the interview protocol and provided preliminary perceptions that informed development of a coding rubric used to analyze research interviews.

Participants and Setting

Interviews were conducted with three entrepreneurs who also teach entrepreneurship to engineers at a large Midwestern university in a course that leverages the Lean Launch curriculum, although each entrepreneur teaches or utilizes the curriculum in different ways. All three entrepreneurs hold degrees in engineering. Each person had founded at least one technology-based company before beginning to teach. The contexts in which the entrepreneurs taught or utilized the Lean Launch curriculum included several undergraduate engineering entrepreneurship courses, one graduate engineering entrepreneur course, I-Corps, and through mentoring engineers who start up their own companies.

Data Collection

Each interview was conducted by the first author of this paper and audio recorded. Following the interview protocol described above, participants first discussed their entrepreneurial and engineering backgrounds. The interview was then divided into three parts, focusing on the (1) process that students engage in, the (2) skills that students develop, and (3) behaviors that students embody throughout their Lean Launch course. In each of the three parts, they discussed their own course context; and were prompted to consider how their course compared to the engineering design process, by reading and annotating the three checklists containing the engineering design steps, learning outcomes, and behaviors described in Table 4. The participant checked if the item (step, outcome, or behavior) was also included, assessed, or integrated into the Lean Launch curriculum.

The audio recordings of the interviews were later transcribed for analysis.

Data Analysis

The analyzed data included the interview checklists and transcriptions.

Each checklist item was noted as having being checked by each participant (thus representing that the interview participant believed that that item was also present in the Lean Launch curriculum). The transcripts were analyzed to determine how the participant perceived the item to exist in the context of the Lean Launch curriculum, by considering the examples they gave.

A coding schema was established by one author based on the engineering design literature related to the design *process*, course *outcomes*, and engineering design *behaviors* and the elements of Lean Launch curriculum. The three authors revised the coding schema until agreement was reached. One author coded the interviews using the schema. Discrepancies were discussed between two authors and the codes were revised until agreement was reached.

Results and Discussion

Analysis of the interview data led to a determination of the elements of engineering design that are also present in Lean Launch curriculum. Interviewee's insights also enlightened the ways that the integration of Lean Launch could benefit engineering design students.

How does the Lean Launch process compare or contrast to the engineering design process?

During the first part of the interview, participants were prompted to discuss the process that students engage in throughout Lean Launch and the parallels between a typical engineering design process, presented in Table 1. Overall, the interviewees agreed that steps that are common to both engineering design and Lean Launch are **doing research**; **conducting experiments**; **exploring user needs**; **understanding, defining, and reframing the problem; revising and iterating;** and **prototyping**. Lean Launch students are not formally required to **execute the final solution, identify constraints, generate ideas** or **reflect on the process.**

In Lean Launch, **doing research** occurs in two main areas: throughout the process of Customer Discovery and by looking into competing products or businesses. Interviewees noted that these research processes are different than research in engineering aspects because they are researching "businesses, not technical papers" and must actually engage personally with customers, even though "there's not a lot of time that's actually spent on teaching them how to identify their customers." Students are not **conducting experiments** in the stereotypical, laboratory-situated way, but instead through Customer Discovery: students are "testing [their] hypothesis" by talking with and gathering feedback from customers. **Exploring user needs** is the foundation of the entire Customer Discovery process, to determine the value proposition, or the "value" that customer will derive from the product's use. As one interviewee said, "once you understand the value, then later you can transform that into your requirements, documentation to conduct research, [you can] build product, whatever."

Interviewees agreed that Customer Discovery is also when students **understand, define and reframe the problem**. Ultimately, by gaining and considering customer feedback, students may rework their original problem statement that they are trying to address with their product, in order to better meet consumer needs. This also means that students are **revising and iterating** throughout the entire process. All interviewees agreed that iteration is the core of Lean Launch, in that students are "constantly [correcting] the way they present the information." One interviewee noted that the concept of iteration is similar to that of "pivot" in the Lean Launch process, but instead of "refining the problem at hand" they are "taking something in a new direction."

If **prototype** is defined as any representation of the students' idea, then this is exemplified by the Minimum Viable Product, which is what students show to potential customers to gain feedback.

However, students rarely develop a detailed prototype as a part of the class and thus are not typically **executing the final solution**. One interviewee noted that this is because "most of them don't actually care about the final solution, they're just trying to make enough money to get an A in the class" but more broadly, interviewees noted that the final solution is not the point of the Lean Launch process. Students are gaining valuable experiences by participating in the process, and the main point is to prove that their product could work on market, not to actually develop a product that can be sold. This, again, is similar to many design courses, in which student must create a "proof-of-concept" type of prototype, but it is not necessary to have a final, detailed product.

One engineering design step that is not assigned explicitly in Lean Launch is **identifying constraints**, although interviewees agree that this step happens "implicitly." Students ideally "identify constraints based on [the] conversations" with potential customers or by making assumptions," or by "always putting a boundary on the problem." In this context, specifically, in which it is students engaging in Lean Launch within a classroom environment, students are constrained by time and resources, because "it's pretty clear that they're not going to have the time or money to [create their product]." Students who are also not used to this type of project may not even consider time or money constraints when constructing their MVP, as described by a team who wanted to create and market a new type of candle, without researching how expensive candle wax was.

Students also do not engage formally in **generating ideas.** In many engineering design courses, ideation is also not a formal step; students may be assigned a project statement from their instructor or an industry partner, and there may be little room for innovation or creativity in the types of solutions they can create. In the classes that utilize Lean Launch, there is "no formal brainstorming" but the students do need to have an idea that is the foundation of their BMC. Typically, even in a Lean Launch scenario outside of the classroom, ideation does not occur because the "idea already exists" and the entrepreneurs are engaging in the process to get the idea to market.

Similarly, just as in most undergraduate engineering design courses, **reflecting on the process** is not formally assigned in undergraduate courses that utilize Lean Launch. In I-Corps, participants must "reflect on their journey" as part of their final presentation.

What engineering learning outcomes are also outcomes in the Lean Launch curriculum?

Next, interviewees discussed which outcomes from engineering design courses, shown in Table 2, are also outcomes for Lean Launch courses. Interviewees agreed that Lean Launch strongly emphasizes the development of **dynamism, agility, resilience, flexibility; lifelong learning; strong analytical skills; practical ingenuity;** and **communication**. Students that engage in Lean Launch may develop **creativity**, **business and management skills** and **leadership**, but are unlikely to develop a **strong sense of professionalism** or **high ethical standards.**

Interviewees unanimously agreed that Lean Launch helps students develop **dynamism, agility, resilience, flexibility** and **lifelong learning**. Dynamism, agility, resilience, and flexibility are core skills required to engage in Lean Launch successfully. Flexibility, in particular, must be exhibited or the student teams will "break." Students must be able to change their ideas and revise; they must be able to “avoid curve balls." Lifelong learning is another skill that was identified as being developed throughout the Lean Launch process, due to both the Lean Launch philosophy and also the pedagogy used in Lean Launch. Lean Launch instructors have found that students aim to implement Lean Launch principles even outside of the course: they look "for ways to apply what they've learned to other aspects of their life: their education, their jobs, teaching, things like that." Because the Lean Launch curriculum employs a flipped classroom model, students are responsible for learning concepts on their own before coming to class. Even outside the classroom, throughout the Customer Discovery process, students are responsible for their own learning, because "no one is guiding them" at every step of the process.

The interviewees agreed that Lean Launch is integral to teaching students **communication** skills. Interviewees agreed that the Customer Discovery aspect of Lean Launch is the most difficult for engineering students. For "technologists… talking to people that aren't in the same space is hard for them." Students are learning "proper communication and presentation form" and how to "[present] themselves in a way that is well-received...I don't think that you would present yourself to [a supply truck driver] the same way as to a VP of customer acquisition or purchasing." Another interviewee noted that students, in fact, "can't stop communicating" – they are always on social media, talking with friends, going to social events – "the question is... is it useful communication?" This interviewee noted that although her engineering students seemed very social, they "hated" engaging in Customer Discovery and talking with "strangers:"

> *They don't like doing this one. They hate this, that whole talking to strangers thing. It's really funny. Here are all these people who ... Some of them like to talk to strangers but even the ones who are big in Greek life and all that, most of them hate it.*

She described an incident in which a student group clearly recruited their own friends to play the roles of “strangers” in their Customer Discovery process.

Most interviewees agreed that students in Lean Launch are developing **strong analytical skills**. Engineering design students may be developing strong analytical skills by working with data from laboratory experiments, test runs, or calculations. Students in Lean Launch are analyzing the "feedback they are getting from people," or the "results of their field work," to "identify certain patterns" and to "get from the data to the why." In other words, students are using the feedback from customers to determine exactly why their product would be viable or provide value. Students in Lean Launch practice **practical ingenuity** by prototyping, or developing Minimum Viable Products. Another interviewee noted that this skill is developed by students "[focusing] more on value," or in other words, focusing on how to identify the actual problem rather than executing the final solution.

Although entrepreneurship is typically viewed as a business concept, interviewees agree that Lean Launch does not necessarily teach **business and management skills**. Students will not learn a typical business vocabulary or typical business skills from engaging in Lean Launch, but instead, will learn how to engage with those in different business realms: they "should be able to speak to someone with a marketing focus and have a real conversation and exchange the right information."

Interviewees agreed that students who are typically leaders or already practice creativity will continue to do so in the Lean Launch class, but it is unlikely that these skills will be specifically developed in the course. Rather than exhibiting **creativity** in their product or solution, students in Lean Launch are creative in Customer Discovery. They must have "creative ways [to try] to get to the customers and get their attention." Students also practice creativity by "[thinking] in new ways about new topics." Although **leadership** is not explicitly taught in Lean Launch, it was agreed that "students get empowered by being able to be leaders in this context."

Interviewees agreed that Lean Launch does not teach **high ethical standards**, but actually could be seen as teaching students to disregard rules or some ethical standards. In Lean Launch, students are:

> *...pushed to break the rules...Not that they do anything unethical. They learn that some rules should be broken or normal ways of engagement should be broken in order to collect the data, right? For example, bypassing the receptionist and going straight down the hall to find the person you want to talk to. Okay, that's not unethical but that's not a typical rule that you would break unless you're encouraged to, right? Sometimes it's the only way to get the data ... I don't think there's an improvement in high ethical standards.*

Similarly, a **strong sense of professionalism** is likely to not be developed in Lean Launch, although interviewees agreed that it depends on how professionalism is defined. Students do gain the "ability to interact with people across an organization" and may engage with industry but are unlikely to learn "industry standards of norms of behavior."

What types of engineering design behaviors do instructors believe students develop by engaging in the Lean Launch curriculum?

Finally, interviewees discussed how Lean Launch encourages the development of certain mindsets, attitudes or behaviors that are associated with engineering designers. Interviewees agreed that Lean Launch helps to develop all of the presented engineering design behaviors in students. Interviewees believed that **collaboration, iteration, critical questioning, empathy,** and **comfort with uncertainty, failure and risk** were integral to Lean Launch**.** They also believed that students developed **creativity** and **curiosity**, but to a lesser extent.

Lean Launch is centered on **collaboration**: students are working in teams, and also must work to understand customers in order to improve their product. **Iteration** is also core to Lean Launch; "the whole program builds on constant iteration" as students are revising their product based on feedback from customers.

Critical questioning is a key mindset embodied by Lean Launch participants. During Customer Discovery, students "learn how to ask more open-ended questions and dig and try to get more value out of their interactions." They realize that asking the right questions to the right people is what allows them to gain feedback on their product, and ultimately make it better for the market.

Empathy also comes from engaging in Customer Discovery. With a focus on discovering and understanding customer needs, students must be empathetic to their customer in order to make their product best fit the market. One interviewee noted that students who are "more empathetic coming in tend to do better."

All interviewees believed that students do gain a **comfort with uncertainty, failure and risk** through Lean Launch, but recognize that comfort is subjective. One interviewee said that it would be more apt to say that they gain a "familiarity" with uncertainty, failure and risk:

> *I don't know if they get comfortable with it but I do feel like this is valuable. They do get exposed to this in a way nobody's there to like, 'Okay, go out there and sell something. You've got to make $150. Figure it out. I'm not your mom.'*

Students engaging in Lean Launch do not necessarily gain **creativity** in the traditional sense of the word, but as mentioned previously, they do have to be innovative in the ways that they reach out to and engage with customers. Similarly, they note **curiosity** is a natural part of Lean Launch, although they agree that they are unsure how to assess or measure that. One interviewee noted that, just as with creative students, students who already are curious "thrive" in Lean Launch, because they are more interested in doing research and talking with customers.

What benefits could the Lean Launch curriculum bring to engineering design curricula?

Beyond determining what parallels exist between engineering design and Lean Launch, analysis of the interview transcripts also allowed us to determine what benefits Lean Launch could bring to engineering students.

There are many clear lessons that engineering students can learn from engaging in a Lean Launch course: how to write value propositions, how to develop a Business Model Canvas, about bringing a product from idea to market. These direct lessons can help prepare engineering students to be competent in both innovating and creating new technologies, and in ensuring the success of those technologies in the market.

However, there was one core aspect of Lean Launch mentioned repeatedly by interviewees in terms of transforming their engineering students: *Customer Discovery*. The process of Customer Discovery parallels that of the design process in that students are **conducting experiments** and **doing research** to gather information that allows them to **reframe problems**, **explore user needs, revise and iterate**, and refine their **prototype.** However, Customer Discovery differs from a typical engineering design process in that students are engaging with and analyzing data from many different people, rather than simply considering data garnered from laboratory experiments. Although some design courses do focus on the human-centered aspect of design, it can be difficult to integrate human-centeredness into design projects, given the limited scope and time-intensive nature of engineering design projects already. Students must focus on doing the most direct path to get their technology to simply work – because their grade depends on it – and they may not be as focused on ensuring that it would actually be successful on the market. Students may engage with a few potential stakeholders, or, more likely, someone in industry who has worked in a similar area, but they are not forced to engage with (and integrate the feedback of) up to a hundred people in different fields, with different viewpoints and beliefs. Thus, integrating the Customer Discovery aspect of Lean Launch into an engineering design course could not just supplement the traditional design curriculum, but greatly improve upon it.

Engaging in Customer Discovery would benefit students in several ways: by formalizing the human-centered aspect of the design process, fostering the application and development engineering skills in a different context, and simplifying the teaching and assessment of vague (but important) engineering skills.

Formalizing the Human-Centered Aspect of Design

A core difference between typical engineering design projects and Lean Launch is that in Lean Launch, instead of using only calculations or results from laboratory experiments, students are also utilizing qualitative feedback from potential customers. This data is what is causing students to go back and revise their problem statements or product, and ultimately is what is causing their product to improve and be a better fit for the market. Ultimately, engaging in Lean Launch's Customer Discovery could better formalize the human-centered aspect of design: it provides a clear structure and process for students to follow when **exploring user needs**. Rather than simply researching customer needs via technical papers or internet searches, students are *required* to seek out and interview a variety of potential customers, ensuring that their product would actually bring value to their users. Thus, they are not simply creating a product that functions; they are creating a product has been proven to serve a real human need.

Fostering the Application and Development of Engineering Skills in a Different Context

The interactions done in Customer Discovery allow students to better meet outcomes that are necessary for engineering graduates and to develop behaviors that have been found to be important for engineering designers.

Essentially, in Customer Discovery, students are practicing the same principles inherent in engineering design, but in a different context. As opposed to simply conducting experiments in a theoretical vacuum or only considering technical or scientific data, students must consider qualitative information from real potential customers that would use their product. This would, of course, best serve students who will later be working in industry and creating new technologies, because they will be better prepared to consider real market fit. But considering a wider variety of data types can benefit any students, preparing them to have **stronger analytical skills** and **practical ingenuity** when improving their design.

During Customer Discovery, students are engaging with a diverse range of people and considering all types of feedback, developing **empathy** as they consider different human needs. Students will enter industry not only ready to conduct and interpret laboratory experiments, but also, to **communicate** and **collaborate** with all types of colleagues – from operators to marketing representatives to CEOs – and to utilize their feedback in improving their own work. Students also improve their **critical questioning skills,** as they must hone the questions they need to ask to get the information they need to improve their product. As students use the customer feedback to change their design, they are practicing **iteration**, and also becoming more

dynamic, agile, resilient, flexible and **comfortable with uncertainty, failure and risk**: they accept that they need to make changes to their design to make the product the best that it can be.

Simplifying the Teaching and Assessing of Engineering Skills
Furthermore, Lean Launch also could benefit engineering students by providing a clear way to practice important engineering deliverables that are currently difficult to teach or assess in typical engineering courses. For example, despite being a requirement for ABET accreditation, it can be difficult for engineering instructors to teach **lifelong learning** in their courses and to assess if students are acquiring this skill. All of the interviewed entrepreneurs agree that lifelong learning is a key skill that students develop in Lean Launch, by requiring students to be responsible for their own project and own learning. The increased authority and accountability forces students to seek out and discover information on their own, rather than waiting for their instructor to deliver it to them. Furthermore, rather than designing a product for users without actually seeking or considering their input, the act of Customer Discovery requires students to center their product on the user. This shift in thinking would continue to allow for a development of technical expertise but would also encourage students to develop a myriad of other "professional" or "soft" skills that are now necessary for the engineering career, but are difficult to teach, such as **flexibility**, **iteration, comfort with uncertainty** and **empathy.**

Conclusions and Recommendations

In more recent years, there has been a push to integrate entrepreneurship pedagogy into engineering curricula. Engineering students can no longer succeed solely using technical expertise; they need to embody many non-technical skills, such as communication, collaboration, teamwork, resilience; skills that are important in both engineering and in entrepreneurship. Engineering design courses have long been used to foster these types of skills in students, by requiring them to work in teams in a "real world" project environment, but these design courses are already over-loaded, requiring students to apply knowledge from the prior three or more years. The integration of Lean Launch into engineering courses could better improve the development of these important engineering and entrepreneurial skills in our students.

In this paper, we have demonstrated that there are many similarities between the Lean Launch and engineering design curricula; thus, Lean Launch could be integrated into engineering design courses without making significant changes to existing curricula. Furthermore, we found that the integration of Lean Launch has the potential to *improve* engineering design curricula.

We conducted interviews with entrepreneurs that teach using the Lean Launch curriculum. We interviewed entrepreneurs who leverage the Lean Launch curriculum in various settings, and asked them to compare the curriculum with that of a typical engineering design courses. It was found that there are many similarities between Lean Launch and engineering design, in terms of the process that students go through, the skills that students practice, and the behaviors that students develop. Thus, this work suggests that it would be relatively easy to integrate Lean Launch into the engineering curriculum without having to drastically alter the students' engineering design process or change deliverables that the students complete. This implementation would, of course, encourage entrepreneurial thinking in undergraduate students and also provide them with a rewarding, collaborative, realistic product design experience.

But beyond that, the interviewees' responses also revealed just how *beneficial* it would be to integrate Lean Launch into engineering design courses. Clearly, integrating Lean Launch into engineering courses would introduce entrepreneurship to a wider range of engineering students. But the differences between the two curricula demonstrates that the integration is *necessary*. The Customer Discovery aspect of Lean Launch, in particular, can provide structure for students to follow to engage in the human-centered aspect of the design process, foster the application and development engineering skills and behaviors, and simplify the teaching and assessment of vague engineering skills. Incorporating Lean Launch into an engineering design course would allow students to better develop skills that are imperative in both design and in entrepreneurship, and ultimately, in their career. Students would be better prepared for ensuring that their technology would succeed on the market; they would be prepared to interact with, collect feedback from, and empathize with a diverse range of people; and they would be able to collect and analyze different types of data to improve their product design. Furthermore, the use of a Lean Launch curriculum would allow engineering design instructors to teach and assess important engineering skills that are otherwise difficult to develop throughout the curriculum, such as empathy, flexibility, comfort with failure, and lifelong learning. As evidenced by the parallels discussed in this paper, the integration of Lean Launch into engineering design courses would be more than seamless; it would be highly advantageous.

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