Developing the Entrepreneurial Mindset in STEM Students: Integrating Experiential Entrepreneurship into Engineering Design

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Abstract

According to Neil Kane (2016), there is no better way to prepare students for the world of the 21st century, whether they aspire to work for a large company, start their own business, go into academia or devote themselves to public service, than through cultivating their skills in entrepreneurship. The entrepreneurial mindset has been defined as the set of atti-tudes, skills, and behaviors needed by students to succeed academically, personally, and professionally. It is the ability to see opportunities, marshal resources, and create value which are of high demand in both for-profit and not-for-profit organizations. Developing the entrepreneurial mindset requires a combination of critical developmental experiences and a well-coordinated combination of personal reflection, peer support, and expert mentoring. The article provides an overview of an approach incorporating these key elements, to develop the entrepreneurial mindset in engineering undergraduate students through a two-semester design lab course. It uses evidence-based entrepreneurship methodology, while involving faculty and local business mentors in the development of the students. The approach used in developing the entrepreneurial mindset in the students draws heavily from Process Education principles. Process Education (PE) has been defined as a performance-based philosophy of education which integrates many different educational theories, processes, and tools in emphasizing the continuous development of learning skills through the use of assessment principles in order to produce learner self-development. Process Education combines many components of both experiential education and problem-based learning (PBL).

Introduction

Entrepreneurial mindset has been defined as a specific state of mind that orients human conduct towards entrepreneurial activities and outcomes (Fayolle, 2012). According to Neil Kane (2016), there is no better way to prepare students for the world of the 21st century, whether they aspire to work for a large company, start their own business, go into academia or devote themselves to public service, than through cultivating their skills in entrepreneurship. The entrepreneurial mindset has been defined as the set of attitudes, skills, and behaviors needed by students to succeed academically, personally, and professionally. It is the ability to see opportunities, marshal resources, and create value, which are of high demand in both for-profit and not-for-profit organizations.

According to the Allan Gray Orbis Foundation (AGOF) (Commarmond, 2017), this state of mind is influenced by multiple factors. This includes what people know or do not know (their knowledge), what they have done or have not done (their experience), what they can do or believe they can do (their level of competency and self-belief), and finally, who they are (their personality, values, attitudes, and beliefs) (Krueger, 2015). The development of the entrepreneurial mindset and related entrepreneurial skills is critical for a person to be able to sense and leverage entrepreneurial opportunities (Nichter & Goldmark, 2009). Furthermore, it is a critical characteristic required for leaders to create sustained value for the future (Ireland, 2003).

Exploring Key Dimensions of the Entrepreneurial Mindset

Understanding what factors are the key dimensions of the entrepreneurial mindset is vital if the goal is to assist student mindset development. Lau et al. (2012) examined 23 earlier studies which explored the characteristics of entrepreneurs finding that the entrepreneurial attributes of innovativeness (14 counts), integration (7 counts), proactiveness (6 counts) and results orientation (5 counts) were the most dominant. Further, integration is defined as the ability to be involved in all aspects of a business and being a strong systems thinker who is able to make sense of complexity (Lau et al., 2012). Moreover, there is a cyclical nature to these attributes as depicted in Figure 1. An individual with an entrepreneurial mindset can identify and evaluate opportunities. Then gather the resources necessary to explore the identified opportunities. Followed by the ability to create their product and deliver its value competitively.

Research has shown that education, which is grounded more in generative approaches such as design thinking, more naturally fosters an entrepreneurial mindset (Krueger, 2015). In addition, highly experiential entrepreneurship programs, particularly those that are embedded within a local entrepreneurial community or ecosystem,

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promotes deep entrepreneurial learning via multiple avenues (Krueger, 2015). Effective programs exhibit co-immersion in which the entrepreneurial community highly involved within the program. Furthermore, the instructors need to be skilled at experiential learning. While evidence from problem-based learning and peer instruction models emphasizes the importance of domain expertise, expertise within a constructivist framework of education is even more essential (Krueger, 2015).

Figure 1 Cyclical Nature of the Entrepreneurial Mindset

Moving Students from a Novice towards an Expert Entrepreneurial Mindset

The mindset of an expert differs significantly from the mindset of a novice (Krueger, 2015). What differentiates the expert mindset is not the knowledge content, but a significantly different way of looking at the world. Experts structure their domain knowledge very differently. Knowledge structures are based on deep underlying beliefs and changing the knowledge structures requires changing those deep beliefs, often in a discontinuous fashion (Krueger, 2015). This exemplifies constructivist learning as opposed to the traditional behavioristic learning model that emphasizes knowledge content (Krueger, 2009; Neergaard et al., 2012).

Changing the knowledge structure, however, is a difficult task (Krueger, 2015). Mindset change occurs through a combination of critical developmental experiences (CDE) (Krueger, 2015) and a well-coordinated combination of personal reflection, peer support, and expert mentoring (Goleman, 2013). The CDE are activities that are able to displace deeply rooted assumptions and beliefs in the mind. A deep exposure to models of the expert mindset is also critical for developing the expert mindset (Krueger, 2015).

Combining Experiential Education and Problem-Based Learning

The approach used in developing the entrepreneurial mindset in students draws heavily from Process Education (PE) principles. PE has been defined as a performance-based philosophy of education that integrates many different educational theories, processes, and tools in emphasizing the continuous development of learning skills using assessment principles in order to produce learner self-development (Burke et al., 2009). Process Education combines many components of both experiential education and problem-based learning (PBL) (Burke et al., 2009). According to Morgan and Williams (2010), the definition of PE aligns well with the findings of Woods (2000) and others concerning effective means of developing problem solving abilities in students. The skills identified for effective problem solving include self-management, problem solving, interpersonal and group skills, assessment as a foundation for growth, change management, and lifetime learning (Morgan & Williams, 2010).

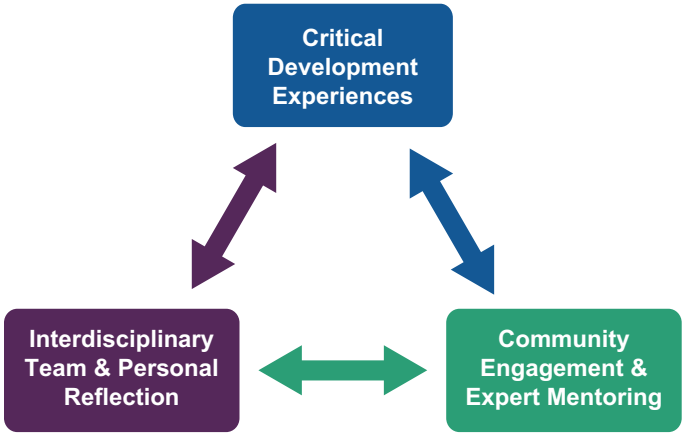
Experiential education emerged from the ideas of educational theorist David Kolb (Burke et al., 2009). According to the Association for Experiential Education, experiential education is defined as, "a philosophy and methodology in which educators purposefully engage with learners in direct experience and focused reflection in order to increase knowledge, develop skills and clarify values" (Association for Experiential Education, n.d.). PBL was introduced at McMaster University where Barrows and Tamblyn found that medical school graduates were often unable to apply the knowledge they learned to the experiential challenges they faced when working as interns in a hospital environment (Burke et al., 2009). Constructivist research shows that students learn more effectively, and remember longer (Dochy et al., 2003), if they are guided to construct their own knowledge such as in problem- or project-based learning (Morgan & Williams, 2010). Students in problem-based learning are better at applying their knowledge than students trained in lecture classes (Dochy et al., 2003). With PBL, the students are presented with an ill-defined problem and they work cooperatively to solve the given problem, while accessing resources as needed. PBL, like experiential education, is student-centered, with the students, rather than the instructor, managing the problem-solving process. The instructor's role is simply that of a facilitator of learning (Burke et al., 2009).

Holistic Entrepreneurial Mindset Development Approach

The engineering program at the R. B. Annis School of Engineering (RBASOE) combines the identified critical ele-

ments in moving students from the novice entrepreneurial mindset to the expert entrepreneurial mindset. The approach, depicted in Figure 2, centers on the interaction of three key components: 1) Critical development experiences based on the Lean Launchpad and Design for Six Sigma methodologies, 2) Peer support through an interdisciplinary team and personal reflection, and 3) Community engagement and expert mentoring.

Figure 2 Critical elements for moving students from the novice entrepreneurial mindset to the expert entrepreneurial mindset

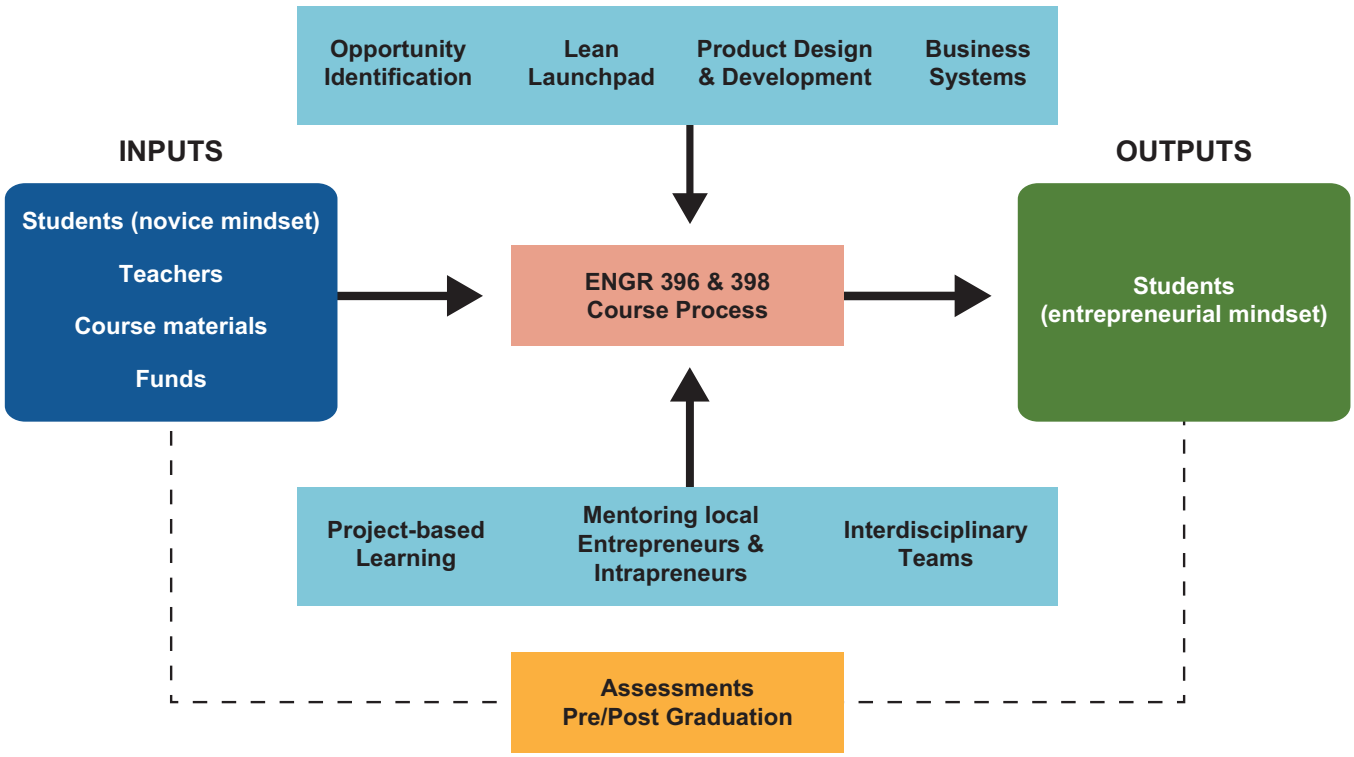


Students are provided with multiple critical developmental experiences through the *venture creation* approach (Krueger, 2015) and engineering design process using the *Design for Six Sigma* methodology. The venture creation approach does not necessarily involve students actually starting business ventures. It is, however, a highly structured process with all the elements of constructivist learning (Krueger, 2015) and all the tools for nurturing a startup in line with the lean Launchpad startup methodology (Blank et al., 2014).

At the RBASOE, interdisciplinary project teams, comprised of students from different engineering disciplines, work on real-life design projects from external stakeholders beginning in their sophomore year and continue through their senior year. This innovative project-based curriculum is referred to as the DesignSpine sequence as detailed in Olawale et al. (2018). It is in the junior year where the focus is on the development of the student's entrepreneurial mindset utilizing the Holistic Entrepreneurial Mindset Development Approach. This approach, depicted in Figure 3, is used to transition the students from a novice entrepreneurial mindset towards an expert entrepreneurial mindset.

At the beginning of junior year, the inputs are the students, their teachers, course materials and funds for developing their product. The students will be enrolled in ENGR 396 and ENGR398 during the academic year. The course design includes the incorporation of project-based learning for students in interdisciplinary teams. These students will receive mentoring from local entrepreneurs and intrapreneurs while exploring opportunity development through the use of Lean Launch Page, Product Design and Devel-

Figure 3 Holistic Entrepreneurial Mindset Development Approach



opment and Business Systems. The integration of these methods and tools will assist in developing the student's mindsets.

The ENGR 396 and ENGR398 course objectives as they relate to entrepreneurial mindset development include:

1. Develop the entrepreneurial mindset in engineering undergraduates through practical, hands-on exposure to the process of identifying business opportunities and creating competitive solutions and value to the customers
2. Develop the skills needed to communicate with and understand potential customers and stakeholders in order to create effective and competitive solutions
3. Learn from and be mentored by business professionals on the intricacies of engaging customers and being successful in the business world
4. Exposure to local business leaders with the opportunity to attract investment and support for viable business ventures
5. Assess and gain insights on the development of the entrepreneurial mindset in the engineering students for onward dissipation to the STEM education community.

The two-semester course sequence is divided into four phases each with a specific focus, as highlighted in Table 1. During the first semester, the interdisciplinary student teams will spend the first 8 weeks identifying a commercially viable opportunity and validating it using the customer discovery process of the Lean Launchpad methodology. The remainder of the semester is spent designing a minimum viable product (MVP). At the beginning of the second semester, the student teams will build and test product prototypes using the Design for Six Sigma Methodology. The students finish their junior year validating the design, finalizing their business model and developing their product pitch. While each of the stages has a *gate review* to ensure appropriate progress, the two-semester sequence concludes with the teams presenting in a business pitch competition in an attempt to secure funding from investors (judges) for their product commercialization.

Mentors

The interdisciplinary engineering student teams work with mentors consisting of faculty, entrepreneurs, and business leaders in the community for the two semesters (academic calendar year). The entrepreneurs and business leaders (intrapreneurs) serve as business mentors to the student teams, focusing on the commercial viability and success of the student teams' ideas and design solutions. Each team is assigned business mentor(s) from an organization in the community.

Assessment and Evaluation

There are weekly assessments of the teams by the faculty. These provide opportunities for immediate feedback and learner growth. In the first semester course, the weekly assessment included weekly status reports that were reviewed by the faculty team with the project teams. There were also weekly five minutes presentations from each team during the customer discovery phase of the course. In the second semester course, the weekly assessment included class discussion on assigned book reading as well as the weekly status report.

Assessment and learner's growth are core principles of PE (Burke et al., 2009). The gate review presentations and reports are key components of the assessment strategy. PE requires that learning and facilitation of learning take place within an assessment culture, rather than a culture of evaluation (Burke et al., 2009). The traditional educational model focuses on evaluation in which an educator judges a student's efforts and performance against objective criteria with standards. PE however requires that learning and facilitation of learning take place within an assessment culture where the students can continually improve the quality of their performance and develop into self-growers. Self-grow-

Table 1 Overview of program phases and timeline

Phase & Gate Review	Focus	Expected Timeline
1	Opportunity identification and customer discovery (tests customer perception of the problem and customer's need to solve the problem)	Week 1-8
2	Design of a Minimum Viable Product (MVP)	Week 9-15
3	MVP development (Build a Prototype)	Week 1-8
4	Validate the design and establish a business model	Week 9-15

ers are learners who seek to improve their own learning performance; can create their own challenges; serve as leaders and mentors to others; take control of their own destiny, and self-assesses and self-mentors to facilitate their own growth (Burke et al., 2009). The weekly assessments help the students to continually improve their presentation and writing skills through their communication with not only the faculty, but with their business mentors. In addition, two personal reflection exercises were incorporated to promote active learning and personal applications of new insights from learning opportunities. The students are required to keep a personal journal for the courses where they document the lessons learned (new things learned, why it is important, and how to apply the lessons learned to their studies, life, and career). There is a reflection essay submission at the end of each phase focusing on questions that address the theme of each phase. At the end of each gate review, the students complete a peer survey to assess their own performance and that of their teammates.

Important Lessons

Customer Discovery

Based on the analysis of student reflections, the customer discovery phase was the most challenging for the students. Particularly, as engineering students, they found it different and challenging to have to go out of the classroom and speak to the different customer types, week after week. The hands-on experience of leaving the classroom and engaging in customer discovery provided both experiential education and problem-based learning opportunities (Burke et al., 2009). While 12 out of 13 of the students expressed the lessons learned and benefits of leaving the classroom to engage potential customers and work with business mentors, some saw it all as a waste of their time because they are engineers. They would rather do design and fabrication. They tended not to understand and appreciate the relevance of engaging multiple customers through interviews before embarking on design and prototype development for commercialization.

The students' observations point to the importance of focusing on entrepreneurial mindset development and not just entrepreneurship (a focus only on business creation). There is a tendency to shut down from engaging and learning for the majority of the STEM students who may not have a desire to start a business if we focus only on entrepreneurship. The entrepreneurial mindset is broader. Faculty were able to explain to the students on several occasions that the goal is entrepreneurial mindset development, which includes entrepreneurship (starting a business) and intrapreneurship (being an employer). During the two courses, it was emphasized that an entrepreneurial mindset involves developing the thought process and ability to recognize and exploit opportunities to meet needs and create value for different stakeholders. The proper messaging is critical if we want to engage the students and cause a transformation in their mindset.

Faculty Training and Organization

It is imperative to note the importance of faculty training in the customer discovery process. Most engineering faculty have little or no exposure to entrepreneurial training. This lack of experience caused their expectations during gate review 1 to be contrary to the goals for the class causing frustration for the students. The lead faculty member took the responsibility for this issue with the students. To rectify the issue, a short training was organized during the faculty weekly meeting to review the customer discovery process, the phases for the courses and the course expectations. In addition, to prevent contrary and multiple feedback from different faculty to the teams, the faculty created faculty team committee (FTC). Each FTC consisted of three faculty members with different engineering backgrounds. Each were assigned to mentor three student teams. They met weekly with each team for 15 minutes to assess their work, assist with team progress and provide guidance. The faculty role in coaching and assessing the students is critical for success because part of the skills identified for effective problem solving include assessment as a foundation for growth, change management, and lifetime learning (Morgan & Williams, 2010).

Interactions with Business Mentors

The general trend is that the students are learning about the real world of business from their interactions with their business mentors. It is surprising, however, that they voiced the opinion that they would like to have more interactions with their business mentors. A number of students also mentioned that they preferred more face-to-face interactions with their business mentors. Surprisingly, we found out based on feedback from mentors that they also wanted more interactions with their student team.

Student Learning and Course Credit

Many students stated in their reflections that they learned more about themselves, about working in interdisciplinary teams, about project management, about what it actually takes to begin a start-up company, as well as growing in their confidence and communication skills.

A number of students noted that they have decided to pursue a career in project management because of their experience in the class and one reportedly acquired an internship because of the experience she gained in project management throughout the course. A number of students stated that prior to the class, their entrepreneurial knowledge was practically non-existent but now their knowledge has grown. They complained, however, about the amount of work required for the course and the associated one credit per semester. The one credit assigned for the course has been a major demotivating factor.

Projects and Team Member's Program of Study

It is very important that each student team choose and work on a project that enables each student to use their expertise from their field of study. Appropriate project selection is particularly important to prevent teams with a domineering member from imposing his or her project ideas on the team without considering how the other team members will contribute or gain from working on the project. It is important that when there is a team member like a software engineering student, purely mechanical projects should not be pursued. The team needs to deliberately choose a project that has a software engineering component or find ways to incorporate software engineering into the project.

Combining Engineering Design with Entrepreneurial Studies

The majority of the engineering students who participated in the class reported that they were better engaged, enjoyed and learned more during the second semester course, ENGR 398. While the first semester course dealt largely with the customer discovery process, the second semester involved actual design, fabrication and testing coupled with storytelling/entrepreneurial activity. Further, they reported that they enjoyed the second semester class more because they were able to do design (CAD) and prototyping (fabrication) which they love. They also mentioned that the readings from Kiyosaki (2012) helped by showing them why being entrepreneurial was important.

An important insight was garnered from this experience. To promote the development of an entrepreneurial mindset effectively, particularly in STEM students, the learning needs to be incorporated into technical skill development and learning activities. This approach, supported by constructivist research, indicates that students learn more effectively and remember longer (Dochy et al., 2003), if they are guided to construct their own knowledge. Which they do in the project-based learning that occurs in the course sequence (Morgan & Williams, 2010).

As this was the first cohort of the two semester entrepreneurship classes, an extended number of weeks was spent on opportunity identification and evaluation as well as customer discovery leaving only about four weeks for the design phase. In subsequent cohorts, it will be important to keep the opportunity identification and evaluation as well as customer discovery of phase 1 to be within the first 7-8 weeks. This will provide adequate time for the students to move quickly into the design phase, which is something they like doing. They can continue with the customer discovery while doing design in which they have more interest.

Conclusion

The approach described in this article in developing the entrepreneurial mindset in students draws heavily from Process Education principles. Process Education combines many components of both experiential education and problem-based learning (PBL), both of which are integrated into the framework of the two-semester sequence. Utilizing assessment for the student's growth is also core to PE. The students' reflections show that their perspective towards entrepreneurial mindset learning during the second semester course (ENGR 398) is much better than that of the earlier first semester course (ENGR 396). The students attributed the change to both the readings (Kiyosaki, 2012) which discussed why the entrepreneurial mindset was important as well as moving into design, fabrication and testing instead of the customer interviews that dominated the first semester course. Their response shows that establishing and communicating the motivation for the entrepreneurial mindset learning is critical for the successful development of this mindset in STEM students. Combining core STEM activities, in this case, engineering activities like design and fabrication, with entrepreneurial learning, is critical for successful student engagement and learning.

This research provides some qualitative assessment of the impact of a holistic approach for developing an entrepreneurial mindset in STEM students. The process employed and the lessons learned are documented through this research to improve future as well as provide a framework for others to implement. Further research is necessary to evaluate the impact the different components and interactions have on students' entrepreneurial learning and growth.

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