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# Impact of Entrepreneurial Mindset Module Connecting Societal Consideration, Medical Interventions and Engineering Physiology

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Allison Lukas graduated in 2021 from Western New England University where she earned a bachelor's degree in Biomedical Engineering. She has plans to attend graduate school and eventually become a professor. In the meantime she will be working in the medical device industry to gain experience before pursuing further education. During her time at Western New England University she served as a supplemental instructor for two physiology courses, where she provided extra help to any student in need. This experience also allowed her to assist the professor in the implementation of modules within the class, and learn how to interact with various students.

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Dr.Devina Jaiswal completed Masters of Science degree in Biomedical Engineering from Pennsylvania State University in 2010. She completed her Ph.D. from University of Connecticut in 2017 where she worked on creating nano and micro devices that could interact with micro-tissue and cells. Her research interest lies in fabrication of micro-electronic devices that can be used to understand biological patterns and apply them to the field of tissue engineering. Other than research, she has a keen interest in best practices in education system. She was recently named KEEN Engineering Unleashed Fellow, 2020. She is trained through KEEN in inculcating Entrepreneurial Mindset (EM) in Undergraduate education and research. Since then, she has created several problems based, active learning EM modules for lecture based courses to enhance student learning.

# Impact of Entrepreneurial Mindset Module Connecting Societal Consideration, Medical Innovation and Engineering Physiology


## Abstract

Entrepreneurial mindset (EM) enables an engineer to analyze, sense and develop a solution to open ended problems based on the environment and needs of the society. Primarily, engineering education focuses only on technical skills that students can apply during employment. However, employers have identified a gap in the skillset that points towards limited EM skills in their engineering recruits. There is a need for introducing EM in engineering students due to the ever-changing demands of the job market. Engineering institutions and educators are now incorporating EM into their curriculum as a full course or embedded module. In this work, a four-stage EM module was developed focusing on 3Cs (curiosity, connections, creating value) based on the Kern Entrepreneurial Engineering Network (KEEN) model. The module was implemented in a lecture intensive course with an objective to inculcate EM through active learning techniques to improve student engagement. Students worked in groups to identify an opportunity and customer's needs, create a business model, brainstorm and communicate an engineering solution to an open-ended question. The quantitative results from student surveys showed significant advancement in technical and most of the EM skills. The qualitative responses indicated improved student engagement through hands-on product analysis. Therefore, improving the students' ability to solve problems of societal relevance and work cohesively as a team. After a successful implementation of this module, it is expected to make it more stakeholder centric for other engineering courses and universities.



**Keywords:** Entrepreneurial mindset, hands-on module, skillset, real-world problems, stakeholder, engineering, technical skills


## 1. Introduction

Entrepreneurial education is generally associated with start-ups, product commercialization or business studies. However, there is a clear distinction between being an entrepreneur and having an entrepreneurial mindset (EM). EM has been defined as cognitive behavior that allows engineers to be curious about an opportunity, make connections and create value for a broad range of stakeholders while recognizing their social and environmental responsibilities [1], [2]. Incorporation of EM in engineering education is driven by the dynamic nature of the current job market and the 'skills gap' recognized by the employers. Graduates are expected to be technical experts as well as have high quality 'professional skills' [3], [4]. Sighting this demand, engineering educators around the world are now making efforts to change the curriculum by adding an EM based course or incorporating associated modules into their courses. Students can explore EM concepts related to real-world social issues and expand 'professional skills' such as recognizing opportunities, creativity, communication, leadership and adaptability through experiential learning modules. Such modules can be easily integrated into design-based courses as well as laboratory courses to provide students with a hands-on experience and expose them to open-ended questions. However, it is challenging to incorporate EM modules in lecture intensive engineering courses such as engineering physiology (biomedical engineering), thermodynamics (mechanical engineering) and signals and systems (electrical engineering). Such courses present faculty with a great opportunity to create a learning environment where EM skills can be instilled through various experiential and active learning methods.

In this work, a four-stage module was created for an engineering physiology course offered to junior level Biomedical Engineering (BME) students. The EM module was implemented in a class of 31 students who actively participated in all four stages. Technical and EM skills were evaluated to understand student learning during the module. Students participated in activities such as jigsaw, stakeholder identification, product innovation and a gallery walk to make connections between social issues, physiological health hazards and the role of biomedical engineers in solving problems. Pre- and post- surveys were collected and analyzed to assess the impact of the module. Additionally, special considerations were made to accommodate COVID-19 restrictions during the module execution.

## 2. Module Execution

Engineering physiology is a core course offered every year for Biomedical Engineering (BME) undergraduates. It is a lecture-based course with assignments related to modeling physiological systems in MATLAB. Primarily, students rely on memorization and computer programming to succeed in the course. This mindset creates a gap between instructional material and creative thinking applied to real-world situations. The EM module incorporated in this course had two distinct aims: (1) to inculcate an entrepreneurial mindset and skills in engineering students when exposed to open ended socially relevant problems and (2) to incorporate active learning instructional techniques to improve student engagement in a lecture-based course. To accomplish these goals, four (50 min each) class hours were dedicated to the module with four distinct activities.

Initially, students were given a lecture about skeletal muscles and the physiology of the neuromuscular junction. The lecture and affiliated discussion laid the groundwork needed for the success of the module. Students were introduced to a relatable scenario where they were asked to imagine themselves among friends, discussing a news article about a teenager who was diagnosed with the lungs of a 70 yr old man. Some of their friends agreed that smoking can be a health hazard whereas some of them supported occasional smoking. Being curious and socially responsible, BME students were asked to dig deeper into the topic to further understand the impact of smoking on the physiological system and addiction. They explored medical interventions that are currently available and how these medical technologies can be improved to create value for individuals who are trying to quit smoking. The module was divided into four stages: (1) understand how nicotine works and causes addiction, (2) identify stakeholders and pitch an engineering solution, (3) analyze a preexisting product and brainstorm innovation, and (4) communicate the idea to a broad audience.

*Stage 1 (Jigsaw):* A jigsaw is an interactive activity that promotes communication and leadership qualities among individuals. The class was divided into five core and four expert groups. Each expert group was assigned a topic such as ‘what is nicotine?’, ‘effect of smoking on muscles’, ‘how nicotine causes addiction’, and ‘effect of other addictions such as alcohol on muscles’. The class was given preparatory slides in advance. Students were allowed to research their topics using the slides as a starting point. During the class session, the first 20 mins were dedicated to the expert groups where each student was given 3-4 minutes to share their knowledge on the topic. Students took notes on a google document that they could refer to during the core group discussion. In the last 40 mins, students rearranged as per their core groups. Here, each member shared their expertise on the topic with their core group members. This allowed the students to fully comprehend the effect of nicotine and alcohol on the body as well as the specific contents that cause addiction.

*Stage 2 (Campus Stakeholder worksheet*): Stakeholder identification proved to be critical to this section of the module. As an engineer, it is imperative to understand ‘who’ and ‘why’ before finding an engineering solution [5]. Prior to coming the class, students were asked create a photo essay (Fig. 1) of the areas on campus that were a potential source of secondary smoking. Here, the university campus was selected as the background to capture the attention of the students. The class was divided into five groups and each spent 15 mins to select an area on campus from the photo essay, identify possible stakeholders and their needs. In context to this activity, a stakeholder was defined as the population that can be affected by secondary smoking areas. Next, 20 mins were spent developing an engineering solution to eliminate the hotspots on campus. The last section of the worksheet required students to brainstorm arguments that could be used to pitch their idea to the university administration. The corresponding deliverable was a completed worksheet with identified stakeholders, an engineering solution and a projected concept pitch.

*Stage 3 (Product innovation):* The first two tasks made students socially aware of their surroundings. They were able to solve an open-ended question specifically for their campus during stage 2 of the module. The activity for the third stage was designed for them to apply previous and new knowledge to find an engineering solution for the population who is addicted to nicotine. The students were asked to research medical interventions available on the market that assist in quitting. Further, a nicotine patch was provided to each group for analysis. They were given an option to improve the patch or come up with a novel idea that could overcome the limitations of current medical interventions. The deliverable of this activity required active discussion within groups as well as developing a presentation strategy. The strategy included creating a poster that would allow students to relay the information to a wider audience, including technical and non-technical groups.

Fig. 1: An example of a student’s photo-essay, highlighting smoking around campus which would be used to further investigate the stakeholders and aid in developing an engineering solution to the real-world problem.

*Stage 4 (Gallery Walk):* A gallery walk is an effective way to present concepts and receive immediate feedback from experts and peers. This activity required students to create a poster in the first 15 minutes of the class (Fig 2A). Students were supplied with scissors, blank white posters and glue. In addition, students were allowed to bring their own supplies such as printouts and markers. Each group gave a 2 min pitch and were assessed based on the innovation, poster layout, and presentation skills. All the groups were encouraged to ask questions during the gallery walk as well as vote for their favorite product. This gave students an opportunity to provide constructive feedback and learn from the work of their peers.

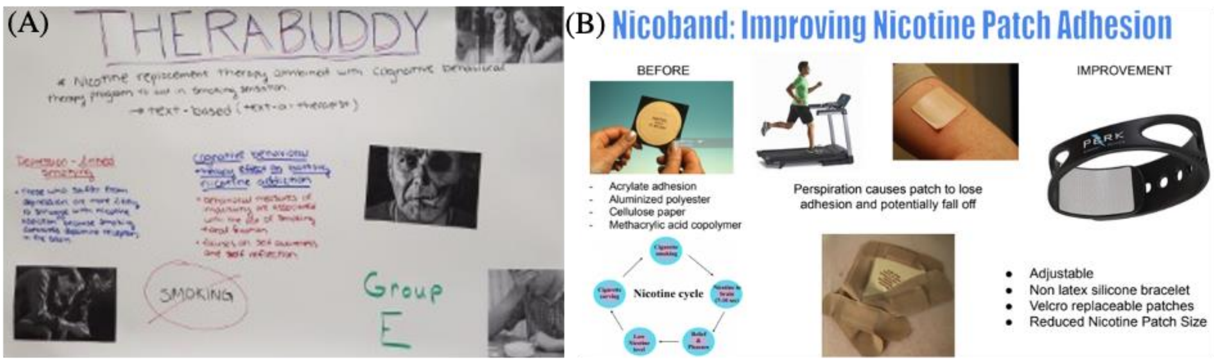

Fig. 2: Student posters displaying product innovation. (A) Poster created in 2019 by students presenting a concept to help quit smoking by providing a therapy program (text-a therapist). (B) Slide created in 2020 by students showcasing improvements to the nicotine patch, specifically targeting the adhesion of the device.

## 2.1 COVID-19 Accommodations

This module was implemented in an engineering physiology course for two consecutive years, 2019 and 2020. The module description in the above section was executed in 2019. For the year 2020, the activity was modified to accommodate social distancing (SD) due to COVID-19. As a result, the in-class jigsaw and stakeholder activities were transferred to Zoom. The instructor and supplemental instructor (SI) created breakout rooms and were able to relocated to each virtual room to monitor the conversation, answer questions, promote active discussion and assess the participation of each student. The product analysis (stage 3) activity was conducted in class while following SD protocol. Each student was provided with their own nicotine patch to prevent cross contamination. Students wore masks and stayed 6 ft apart throughout stage 3. Office 365 PowerPoint was utilized to document and discuss ideas allowing students to collectively work on the poster. Finally, a gallery walk was conducted on Zoom to prevent violation of SD regulations. All of the groups presented their work as if they were part of a product booth at a conference and spoke to a broader audience (Fig 2B).

## 2.2 Impact Analysis

The effectiveness of the module was assessed using a pre- and post-survey. The surveys were approved by the Institutional Review Board (IRB) prior to their use. The confidentiality of the participants was maintained by assigning a random number to each survey allowing the pre- and post-surveys to be matched. The survey used in 2019 did not include technical questions, while the survey was updated for use in 2020 and consisted of two technical questions related to general knowledge concerning addiction and current medical interventions that help users quit smoking. In addition, the survey included 5-choice Likert-scale questions rating seven critical

EM skills (see description in Table 1). The data analysis was conducted using statistical tools such as 2-way ANOVA.

### 3. Results

Pre and post IRB approved surveys were completed by 5 out of 23 (N=5) in 2019 and 22 out of 31 students (N=22) in 2020. The average score on technical questions in 2020 improved 2.5 times between the pre- and post-module (p-value=$0.006\times10^{-3}$). Likewise, a statistically significant improvement was measured in most of the EM skills in both the years. The results from Likert-scale questions (Table 1) from the pre- and post-surveys are shown in Fig. 3. In 2019, even though students liked the module, survey participation was low. This could be attributed to lack of communication regarding the importance of the survey to the students. In 2020, students were informed of the importance of the survey, how it would help them to reflect on their skillset improvement and how dissemination of the results would help the educational community. Considering the low sample number from 2019, the discussion in this article is focused on results from the year 2020.

Table 1: Entrepreneurial mindset skills evaluated during the pre- and post-surveys.

| # | Criteria Description |
|---|---|
| 1 | Identify an opportunity |
| 2 | Investigate the Market |
| 3 | Create a Preliminary Business Model |
| 4 | Evaluate Technical Feasibility, Customer Value, Societal Benefits, or Economic Feasibility |
| 5 | Communicate an Engineering Solution |
| 6 | Communicate an Engineering Solution in Terms of Societal Benefits |
| 7 | Develop Partnerships and Build a Team |

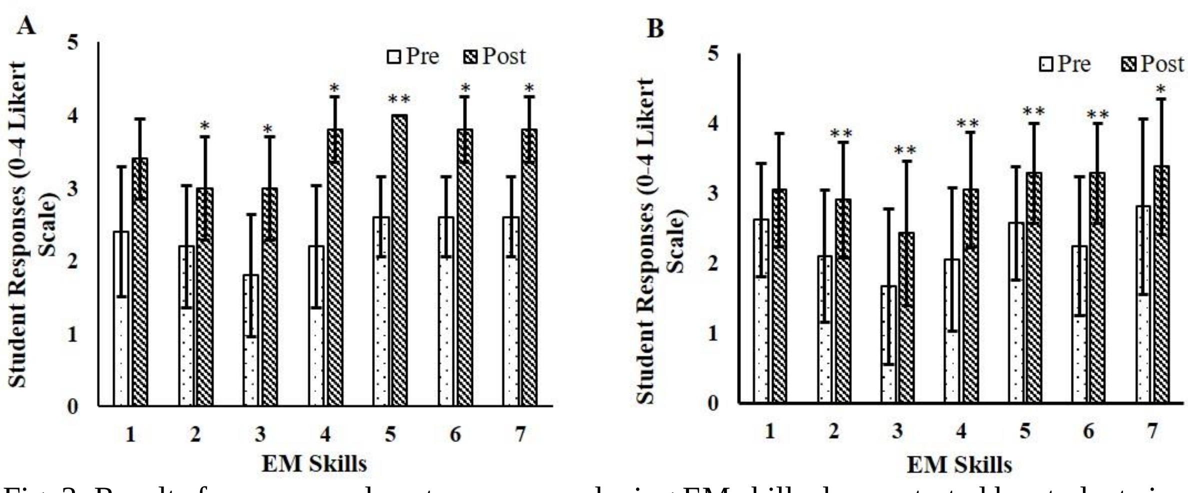


Fig. 3: Results from pre- and post-surveys analyzing EM skills demonstrated by students in (A) 2019 (n=5) and (B) 2020 (n=22). Descriptions for each skill are presented in Table 1. A significant improvement can be seen for most of the skills with the exception of the first skill (**p-value < 0.005, *p-value < 0.05) after the completion of the module.

## 4. Discussion

Engineering education is evolving and focus is now shifting towards the needs of the employers [6]. It is not enough to just acquire technical skills. Students are expected to master technical as well as professional skills. With this goal in mind, the EM module was designed for a lecture intensive BME course. The objective of this module was to improve EM skills, such as identification of the market, creating business models, finding engineering solutions for an open-ended problem, communication and teamwork. Throughout the module the faculty fostered an active learning environment to enhance student engagement and learning. This module requires at least 4 class hours without compromising on regular course content. Even though the assignments from this work were not used for ABET assessment, components from the deliverables can be used to assess ABET outcomes such as '*An ability to communicate effectively with a range of audiences'* and *'An ability to acquire and apply new knowledge as needed, using appropriate learning strategies'*.

As seen from the technical assessment, students' knowledge of physiology and its connection to smoking addiction was improved from 30% to 74%. This was also validated by keywords from student's qualitative responses such as *"learned how nicotine impacts the body", "How nicotine affects the neuromuscular junction was what I found most interesting"* and *"how nicotine is released into the body and how it affects your muscles".* As per Bonwell and Eison, active learning is about physical interaction with the environment and engaging students in higher-level thinking processes to improve learning [7]. Generally, students consider memorization of facts the way to understand anatomy and physiology. Even though engineering physiology has elements of mathematical modeling, it still falls under a basic science course. There is evidence that active learning methods can significantly improve content knowledge, make students independent learners and inculcate a positive attitude towards human physiology courses [8]. A similar trend was seen in this study as students took responsibility and explored the topic in depth allowing them to discuss, teach and learn the content during the jigsaw and product innovation activities.

### 3.1 EM Learning Objective

As per the Kern Entrepreneurial Engineering Network (KEEN) model, student engagement and entrepreneurial mindset should focus on the 3Cs: Curiosity, Creating value and Connection. Universities across the United States are incorporating KEEN EM model in their curriculum to prepare undergraduate students for a dynamic professional environment [9], [10]. This module targeted the three Cs embedded within active learning techniques to improve the entrepreneurial skillset of students [11], [12].

**Connection:** The jigsaw was used to make connections between the course content and a real-world problem. Students integrated information from various sources and associated it with nicotine and its influence on the neuromuscular junction. The significant improvement in technical knowledge of the students indicates the success of the jigsaw activity. In addition, this exercise enhanced communication (EM skill 5, 6) and partnership development (EM skill 7) skills significantly as seen in Fig. 3.

**Creating Value:** Activities such as (1) identifying stakeholders on campus and (2) medical product innovation encouraged students to create value in two different scenarios. During the first activity, students became cognizant of their environment which motivated them as entrepreneurs. Here socio-cognition was applied as it is the first step in the meta-cognitive model suggested by Haynie et al. for an entrepreneur [13]. In this activity, students were able to identify a problem in their surroundings, come up with an engineering design solution for their stakeholders, and create a business model that could be communicated to the administration in terms of societal benefits. This is validated by significant improvement in EM skills 1, 3 and 6 (Fig. 3). The second activity targeted creating value for broader stakeholders across different age groups. The needs of the users were identified by sources such as customer product reviews, cost comparisons, product descriptions and journal articles.

**Curiosity:** The third EM learning objective was targeted using a homework assignment in which students had to investigate the market for commercially available medical interventions that help others to quit smoking. This was the foundation for the product innovation section. Additionally, providing nicotine patches immediately engaged the students and made them curious about the design, mechanism of drug release, dosage, cost and user interface. EM skills 2, 4 and 5 were directly affected by this activity and show significant improvement as reported by students through the survey (Fig. 3). Students were able to evaluate a previously existing solution, assess its technical feasibility and devise an alternate solution. Engineered concepts were then successfully communicated to a broader audience during the gallery walk activity (Skill 5).

### 3.2 Qualitative Survey

The qualitative open-ended questions were asked in order to gauge the skills that students developed, and take note of their likes and suggested improvements. As per the students, there were three categories of skills that were mentioned in their comments. At least 50% of the participants stated that the module helped in understanding the physiology behind the harmful effects of nicotine on the neuromuscular junction. Statements such as "*enhanced my understanding of the harmful effects of nicotine by looking at what it directly does to the body" and "learned a lot about how nicotine is released into the body and how it affects your muscles*" shows that the active learning method enhanced understanding of the content [14]. Out of 22 participants, 91% students talked about improvement in entrepreneurial skills such as identifying the problem and stakeholders, market analysis, product innovation, creating a business model, communication and collaboratively working in teams. Selected students' comments such as "*I gained knowledge in identifying a problem and creating a solution within a team", "Ability to brainstorm new ideas and improvements on already existing solutions"* and *"Looking at customer reviews is a good way to identify problems and generate a solution"* validate the quantitative results.

Overall, students were engaged and felt this module gave them a break from the traditional didactic lectures. It also gave them an opportunity to work as teams and innovate a product that they were able to physically analyze. Most of the students mentioned that the hands-on experience and ability to interact with the nicotine patch helped them to understand different aspects of the product that they could improve. This showed that such activity triggered curiosity and lead to innovation. At least 50% of the students listed teamwork and presenting their work in the form of a poster as their favorite part of the module. Additionally, comments such as "*liked group work/discussion because its good practice for jobs that require teamwork*" shows that module participation helped students to recognize the importance of EM skills, influencing their future endeavors.

3.3 Social Impact
Conceptualizing future technology and services that create value for society is an important aspect of the entrepreneurial mindset [13]. Societal and environmental motivation leads to cognitive awareness which is about finding the needs, exploring ideas, and applying available resources to create a business model. This module was able to connect the students to a social issue as evidenced by their comments: "*relevance to college students, many of my friends either smoke or vape so this issue of quitting smoking connected"* and *"project opened up awareness for everyone and I even informed some friends when they were vaping around me".* This impact is consolidated by significant improvement in skills 4 and 6 (Fig. 3). The results show that students care about innovation more when they understand the difference they would make in society.

3.4 COVID-19 Impact
The presence of COVID-19 affected the way classes were organized and delivered. Even though in-person classes were conducted, there were strict SD protocols in place. This made execution of hands-on activities and student engagement a challenge. With initial preparation by the instructor, the transfer from hands-on to hybrid models can have a high impact on students as seen by the results of this module. It also shows that instructors should not be discouraged in carrying out hands-on modules during the pandemic. Students appreciated the use of Zoom breakout rooms and familiarized themselves with collaborative technologies such as Office 365. However, some comments such as *"module was not the same as in years past" and "Corona makes anything like this difficult to do"* showed that the hybrid model lessened the enthusiasm of a few students.

## 4. Conclusion

In conclusion, active learning methods were successfully utilized to introduce students to socially relevant open-ended problems, and enhance an entrepreneurial mindset and skills in a lecture driven course (KEEN Card: https://engineeringunleashed.com/card/377). In addition, there was a significant improvement in technical knowledge related to the physiology of the neuromuscular junction and how nicotine works to cause addiction. EM skills such as identification of stakeholders, product innovation, communication, collaboration and mindset (curiosity, create value and connection) were significantly enhanced. Even with COVID-19 regulations, the module was successfully implemented and showed significant student engagement during each of the four activities within the module. In the future, the module will be modified to make it stakeholder centric allowing students to fully explore the 'who' and 'why' behind the development of new products, further instilling the EM mindset. The goal is to create a structure that can be used across all engineering disciplines and universities. In turn, this will help students become well-rounded and more appealing to potential employers after graduation.

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