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Developing a Semester-Long Project in a Biomechanical Engineering Course to Instill the Entrepreneurial Mindset in the Next-Generation Biomedical Engineering Students

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Abstract

Entrepreneurial-Minded Learning (EML) is an emerging pedagogy progressively gaining popularity in the engineering education community. Coincided with project-based learning (PBL), EML illustrates an essential dimension to the instruction of next-generation engineers, equipping them with various perspectives and approaches to relate societal challenges with technical concepts. Nationwide initiatives, such as the Kern Entrepreneurial Engineering Network (KEEN), have developed a learning framework specifically designed to create engineers such as these. The implementation of EML aims to stimulate connections, create value, and ignite curiosity. This study introduced a semester-long project based on these EML skillsets in a sophomore-level biomechanical engineering course. To evaluate the effectiveness of the project design, students were equally distributed randomly to different versions of the project. Version 1, or the experimental group, contained students participating in the project embedded with the target EML concepts - such as identifying an opportunity, investigating the market, communicating an engineering solution in economic terms, developing partnerships, and building a team. Version 2, or the control group, contained students who participated in the project without the embedded EML concepts.

At the completion of the project, an end-of-semester survey was administered to the students. The survey consisted of open-ended and 5-point Likert scale questions targeting students' development of curiosity, connections, and value creation. Analysis indicated, with statistical significance, an overall increase in students' development of an entrepreneurial mindset for those participating in the EML version of the course project. For the Likert scale questions, students participating in the experimental group averaged a response value of 4.32, indicating a

strongly agree (5) or agree (4) response for questions targeting a student's overall confidence in developing the specific EML skills targeted the project. Students who participated in the control version had an average overall response value of 3.93. Survey questions were further divided into EML target skills - curiosity, connections, and creating value. Across all three target skills, students participating in version 1 of the project demonstrated statistically significant increases in developing curiosity about the surrounding world, creating value, and establishing connections - thus generating an entrepreneurial mindset. Developing an entrepreneurial mindset is crucial to the next-generation engineers' long-term success in the workforce, with a potentially more significant impact on the national economy and societal benefits. With guidance from the study results, semester-long projects that employ the EML concepts will be incorporated into our institution's core curriculum of Biomedical Engineering.

1. Introduction

Over the past two decades, increased global competition, autonomation, and the progression of technology caused new challenges for engineering institutions, specifically in adapting to the evolving field of STEM and educating engineering students accordingly [1]–[4]. When hiring engineering graduates, firms seek engineers with sound knowledge of engineering fundamentals while also emphasizing the importance of creativity and innovation [5]. Although higher education provides the opportunity to learn theory and apply it, students can be left with a limited ability to learn through authentic experiences [6]. This proves to be particularly problematic in engineering disciplines. The curriculum tends to focus more on theoretical foundations and less on the practical application and skills needed in the workforce [6]. Studies have shown that to enhance the value of engineering graduates in the industry, they must acquire entrepreneurial abilities such as identifying an opportunity, solving problems, thinking creatively and generating societal value [1], [3]. Therefore, engineering institutions have begun to recognize the importance of teaching technical skills coincided with entrepreneurial skills to generate perceptive competent engineers [7]. As a result, increased attention has surrounded the development of what is known as an "entrepreneurial mindset" (EM). An entrepreneurial mindset can be defined as the cognitive strategies to think and apply different approaches to a given task [8], [9]. The Kern Entrepreneurial Engineering Network (KEEN) created a learning framework specifically designed to develop this mindset in engineering students known as Entrepreneurial Minded Learning (EML)[10]. EML is an emergent pedagogy that emphasizes discovery, opportunity identification, and value creation. The KEEN foundation created this learning style with one goal- to create a habit of mind geared towards action [10]. The implementation of EML aims to stimulate connections, create value, and ignite curiosity.

EML focuses on students' mind and skillset development, preparing them to identify problems and solve them in innovative ways. The overall goal of implementing EML in engineering courses is to develop an entrepreneurial mindset. This is essential in entrepreneurial education as this mindset of personal success coupled with engineering skills generates unprecedented value for others. Research indicates that academic goals can be assessed through learning outcomes that measure academic and individual development [8]. Literature assessments have divided learning outcomes into three measurable categories or learning domains. Category one is concerned with cognitive characteristics or the ability to evaluate, recall, and apply knowledge [8], [11]. Category two gives importance to content knowledge by developing business models, analyzing market forces, and performing different tasks. The third category emphasizes affective factors, which are the feelings one has, such as self-efficacy, intention, interest, or motivation [8], [11]. These domains are used conjointly when integrating learning course objectives with EML components. Furthermore, to implement an entrepreneurial mindset, students must acquire these affective factors in combination with learning the same framework and approaches as entrepreneurs [8]. These categories were referenced alongside the EML framework- curiosity, creativity, and connections- to identify skills shown in Table 1- that can be targeted to develop the traits and behaviors associated with an entrepreneurial mindset [12].

Table 1. EML Target Skills- adapted from [12].

EML Skill	**3 C's**
Identify an opportunity	Curiosity
Investigate the market	Curiosity
Create a preliminary business model	Create Value

Evaluate technical feasibility and customer value. Societal benefits, or economic feasibility	Connections
Test concepts quickly via customer engagement	Create Value
Communicate an engineering solution in economic terms	Create Value
Develop partnerships and build a team	Connections
Persist through and learn from failure	Create Value
Communicate an engineering solution in terms of societal benefits	Curiosity

Entrepreneurship is vital to higher education systems as it has proven to stimulate the economy, increase job opportunities, and encourage technological progress [13], [14]. The importance of incorporating entrepreneurship within the classroom has been gaining recognition in engineering communities. Nearly 50 universities across the nation have partnered with KEEN to implement EML into their curriculum [10]. A study conducted in an engineering physiology course examined the impacts of EML in a module involving global markets for medical devices [12]. The study used pre-and post-surveys to track the changes self-reported by students. Results showed that the module increased various EML skills tested in the study, such as investigating the market and building partnerships [12]. A study at the University of California, Irvine, modified a senior capstone course to stress professional skill and entrepreneurship development [15]. Researchers witnessed improvements in student confidence, with 39% of students having provincial patents for their projects, highlighting the efficiency of the course in entrepreneurship and innovation. These studies have shown the dramatic impact of introducing entrepreneurial-minded learning modules in the classroom.

Although these studies show the positive effects of adding EML-based modules in engineering courses, it cannot be determined if these effects were a primary result of the EML modules or the course itself. This is attributed to the fact that data was collected using pre-and post-surveys and the studies lacked control groups. The input of a control group ensures that a difference in EML development solely relies on the additional EML elements, not other elements of course delivery. This study developed two versions of a project (control Vs. experimental) in a sophomore-level biomechanical engineering course based on EML concepts. One post-survey was administered after completing the project. The scope of the current work did not require a pre-survey since the objective was to identify possible differences using a control group (which lacks EML components) as a reference rather than individual starting points. The survey was designed to gather data where specific skills could be compared in both groups. We hypothesized that the experimental project (EML-embedded) would show higher instances of EML development compared to the control project.

2. Methods

2.1 A Modular Approach to Entrepreneurial Minded Learning

Biomechanical Engineering is an introductory course into biomedical processes and the basic concepts of biomechanics- viscoelastic properties, cardiovascular dynamics, gait analysis, etc. Traditionally, as freshmen and sophomore engineers, students lacked the emphasis on entrepreneurial processes to establish the background information crucial to technical engineering. This research aimed to introduce EM concepts into a sophomore-level biomechanics course and examine the outcomes. A semester-long project was developed to add real-world applications to the course. This project was used as a platform to add EML modules with embedded target skills. Two versions of the project were created. Version 1 is the control

group with no EML concepts, while Version 2 is the experimental group containing these EML skills. This study investigates whether the EML project modules increased the students' ability to create connections, ignite their curiosity, and create value. A total of 46 students participated in this study resulting in a sample size of n=23 for each version. Students were randomly organized into groups of 2 or 3 to execute the modules for their assigned version. Specific EML-based instructions were incorporated for Version 2 so that a clear division could be seen between the student groups. This division was critical for establishing the control group that would serve as the reference when comparing student responses. This course schedule included two lecture times for the student teams to solely work on the project while the instructor and teaching assistants were available to answer their questions. Student groups had to utilize other available times outside of lectures to ensure the completion of the project. Patient profiles were given to each group to incorporate contributing factors when solving real-world problems. The profiles describe two orthopedic injuries that the students used to answer the modules. Profiles 1 and 2 are described below.

Patient Profiles

(1) Chris P. Bacon is a 65-year-old man who has been experiencing pain in his left hip. Dr. Pepper decided that the wear and tear on his hip joint were too extensive and that he needed a complete hip replacement to treat it properly.

(2) Pear E. White is a 35-year-old woman who is a marathon runner. She has been experiencing knee pain for a while, and at her last race, she fell and has been experiencing server pain in her knee ever since. Upon meeting with her doctor, Dr. Fizz, they examined the damage and found early to the mid-stage formation of

osteoarthritis, causing severe damage to the knee joint. Dr. Fizz decided that the best plan of action was a total knee replacement.

2.2 Biomechanical Engineering Project

The semester-long project consisted of three modules. The experimental version was integrated with additional entrepreneurial components. The proposed modules are defined below.

Part 1: Module 1- Treatment Plan Research Paper

Using their assigned patient profiles, student teams were asked to survey the available treatment options, including details about two options, and then choose one treatment option over the other while providing a rationale for their choice. Those in the experimental version were given additional information in the format of notes gathered from initial conversations with each patient. These notes are shown below. They were asked to consider these notes and answer the questions when choosing their preferred treatment plan. The students participating in the experimental or EML-based project are tasked with relating any current worldly issues ranging from diseases to politics to the treatment plan. Lastly, they were asked to create a general idea for a treatment plan not yet approved by the FDA based on the needs of their assigned patient. The expanded patient profiles for the EML version of the project are shown below:

(1) Mr. Bacon is a retired naval officer that gets a slight skin reaction to metal when he touches it. Will his VA benefits cover the cost of his treatment? Is there an implant option available that does not contain metal? Is this the best option? If not, what can he do to combat the side effects? Mr. Bacon also has six grandchildren that he loves to take hiking, fishing, and hunting. He values his time with his grandchildren and wants to continue to do so. How will this surgery affect his time with his grandchildren?

(2) Mrs. White is an account executive at Walmart with private health insurance. At the age of 24, she was diagnosed with Tomophobia, the fear of surgery; how will this affect your choice of a treatment plan? What will her post-op life look like? How will her running be affected?

EML skills provided in Table 1 associated with Module 1 are listed below.

- Evaluate technical feasibility, customer value, societal benefits, or economic feasibility
- Investigate the market
- Communicate an engineering solution in economic terms
- Develop partnerships and build a team

Students participating in the non-EML version of the project were given the same patient profiles. They were tasked to choose a treatment plan based on current literature for their patients; however, they were not given additional information about their patients nor explicitly told to address these different societal issues.

Module 2 – Presentation of Treatment Plan

After detailing their preferred treatment plan from Module 1, students were tasked to present their findings. Students created a video presentation for fifteen minutes through a video recording software such as Zoom. Students participating in the EML project version were informed to present their findings as a business pitch. Students were tasked to create their own company to sell their chosen treatment option. This included a company name and logo design. They were asked to address current technology issues and determine solutions or modifications their product/treatment can offer. Students participating in the EML version of the project were asked to address the following questions in their presentation:

i. Why does the joint need to be replaced?
ii. How does your patient's background affect your treatment plan?
iii. What are the different options for your patient?
iv. Which of these is the best option to treat the patient? How is your treatment plan going to address current limitations?
v. What are the advantages and disadvantages of your option?
vi. From the material, you learned in class, which skills did you use to complete this project?
vii. Are all the patient's physical and mental health considerations met?
viii. Considering your patient's values, how this treatment plan might affect them.
ix. Is the process of getting a hip/knee replacement a sustainable process for your patient?
x. Is there a non-surgical alternative for the replacement?

Similar to Module 1, the additional components of the experimental version were associated with specific EML attributes. The skills targeted when comprising Module 2 are described below.

- Identify an opportunity
- Investigate the market
- Create a preliminary business model
- Test concepts quickly via customer engagement
- Evaluate technical feasibility, customer value, societal benefits, or economic feasibility

Students in the non-EML version of the project were asked to complete the same task- presenting their treatment plan in a video presentation through recording software. However, they were not tasked with presenting their findings as a business case or creating a company. Instead, students participating in the non-EML version of the project were asked to consider the following questions when creating their presentation:

i. Why does the joint need to be replaced?
ii. How does your patient's background affect your treatment plan?
iii. What are the different options for your patient? Which is the best option to treat the patient (including brand, implant name, and cost)?
iv. What are the advantages and disadvantages of your option?
v. From the material, you learned in class, which skills did you use to complete this project?

Module 3 – Force Diagram and Calculations

The second part of the project focused more on the technical skills needed for the course and how to make pertinent connections. First, students were required to create force diagrams of their implants based on the assigned patient profile. Then, using their research, they were required to choose a scenario, walking, sitting, or jogging, and draw force diagrams determining all the forces and moments applied to the implant. Students then solved the force diagrams for the compression/tensile active force, joint reaction force, moment joint reactions, and bearing stress. Next, using their research and calculations, the students were tasked with generating the elastic portion of the stress vs. strain curve for their chosen scenario. The curve included Youngs' modulus, yield strength, and appropriate axis labels. They were then asked to discuss the material properties of the implant and how different materials can alter the response of the implant. Finally, the experimental groups had to create a scenario where their implant failed due to a design flaw and state the possible reasons why it failed and what they learned from it.

While creating this module, we considered the skills that needed to be emphasized in the experimental version to see EML impactfully. The skills targeted when comprising Module 3 are described below.

- Investigate the market
- Evaluate technical feasibility, customer value, societal benefits, or economic feasibility
- Communicate an engineering solution in economic terms
- Communicate an engineering solution in terms of societal benefits.
- Persist through and learn from failure

Students in the non-EML version of the project were tasked with completing the same technical skills; however, they were not asked to create a scenario in which their implant failed due to a design flaw and what they learned from it.

2.3 Survey Design

A survey was developed to assess how the EML skills and behaviors were strengthened or developed by completing the previously described modules. Institutional Review Board (IRB) protocol (IRB protocol #2012306631) was developed and approved by the University of the board. By analyzing Likert-scale questions from the survey, the quantitative responses of the control and experimental groups were compared to conclude the effectiveness of this learning framework. Questions were carefully composed to target the overall EML competencies- curiosity, connections, creating value- and the specific EML skills. In addition, open response questions were designed to further analyze student responses to EML. These questions were categorized based on the three C's and specific entrepreneurial skills. Students were asked to answer the following statements in Tables 2 and 3.

Table 2. 5-Point Likert Scale Questions categorized into the KEEN EML 3 C's (Curiosity, Creating value, and Connections)

Curiosity	**Creating Value**	**Connections**
The project allowed me to show more curiosity about worldly engineering problems.	How confident are you in your ability to succeed as an engineer?	The project allowed me to experience making connections between what I learned in class and real-world engineering problems.
The project has fostered my ability to think in more innovative ways.	How confident are you in your ability to create value for a customer?	Explored alternatives or encourage forming contrarian views of accepted solutions.
The project has taught me the importance of learning new skills.	How confident are you in your ability to create value in different situations?	Collaborated in a team setting.
Applied to learning in a new context.	How confident are you in your ability to persist through and learn from failure?	Communicated engineering solutions in economic terms.
Furthered learning beyond the course content curriculum.	Understood the motivations and perspectives of customers.	Substantiated claims with data and facts.

Formulated questions and generated own inquiries.	The project allowed me to learn the importance of creating value while conducting engineering problem-solving.	How confident are you in your ability to understand the motivations and perspectives of customers?
How confident are you in your ability to exercise curiosity about the surrounding world?		How confident are you in your ability to make connections?

Table 3. Open Response Questions

Open Response Questions	**What is being measured?**
How has this project impacted your mindset? Have you gained any new mental habits? Explain.	All EML components (curiosity, connections, creating value)
Has this project equipped you with the tools needed to create value in any context? Give examples and explain.	Value creation
How has this project affected how you make connections about the surrounding world? Give examples and explain.	Connections

Based on this project, in what ways are you more curious about the surrounding world?	Curiosity
Please provide any suggestions/comments you may have about the course project.	N/A

2.4 Data Analysis

The online survey software (Qualtrics) collected students' responses. Survey responses were stored in cloud storage software with access restricted to the research team. Paired t-tests were conducted within Excel to analyze the obtained data. The qualitative open response feedback data were used to compare/contrast to the quantitative 5-point Likert data.

3. Results and Analysis

In this study, we developed a three-module semester-long project for a sophomore-level biomechanical engineering course. To test how the project can aid in instilling entrepreneurial-minded learning into Biomedical Engineering students, two versions of the project prompt were created, with one (control) lacking target EML skills compared to the experimental project.

The overall data analyses from the survey indicated that the students participating in the EML version of the project exhibited significantly higher instances of curiosity, connections, and value creation as measured by the quantitative 5-point Likert questions referenced in Table 1. With five indicating strongly agree and one strongly disagree. The addition of the control group can confirm that the increases in EML skills - curiosity, connections, and creating value - were due to the incorporation of EML target skills in the experimental version of the project. Figure 1 compares the overall average rating of EML and non-EML versions of the project for twenty 5-

point Likert scale questions. Statistical analysis indicated that the average rating of the EML project was higher compared to the control project ($n=23$, $p < 0.001$).

Furthermore, the EML skill-based questions were grouped based on curiosity, value creation, and connections, as given in Table 2. Figure 1 depicts the average rating of student responses from both experimental (EML) and control groups for each category, including the overall average rating of EML and non-EML versions of the project for twenty 5-point Likert scale questions. Statistical analysis indicated that students participating in the EML version of the project showed an increase in each section category, as described in Table 4.

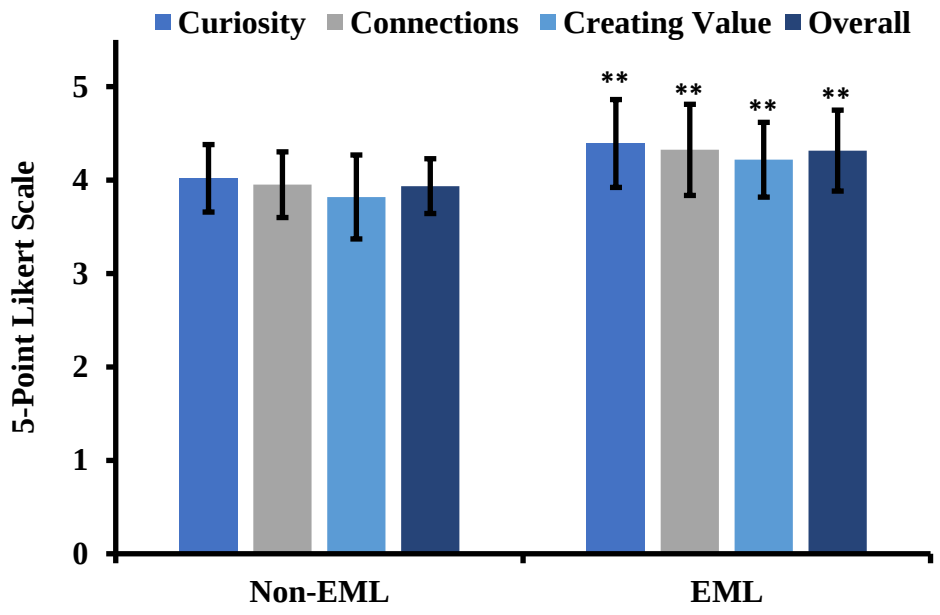

Figure 1| Average rating of student responses to the end-of-semester survey. They are separated into curiosity, connections, creating value, and overall grouping. ** indicates statistical significance ($P < 0.01$).

Table 4| Statistical Analysis of Figure 1.

EML Competency	**Averages**		**Standard Deviation**		**P-Value**
	Non-EML	*EML*	*Non-EML*	*EML*	
Curiosity	4.1086	4.3913	0.3612	0.4703	0.0043
Connections	3.9503	4.3229	0.3515	0.4877	0.0007
Creating Value	3.8188	4.2174	0.4492	0.4002	0.0027
Overall	3.9348	4.315	0.2932	0.4331	0.0011

Figure 2 represents individual EML target skills as described in Table 1, tested at the end of the semester survey. Table 3 illustrates the statistical analysis of Figure 2. Although only communicating an engineering solution in economic terms and testing concepts quickly via customer engagement showed statistical significance, the EML version of the project consistently showed higher self-evaluations and ratings in all tested EML skills. For instance, EML-specific skills such as developing partnerships and building a team, identifying an opportunity, and communicating an engineering solution in societal terms showed a higher average rating than the control group results, but this was not statistically significant. Conceptually, this is logical due to the nature of the project because, for example, in both groups, students worked in teams and created a treatment plan for their patients and how it is innovative.

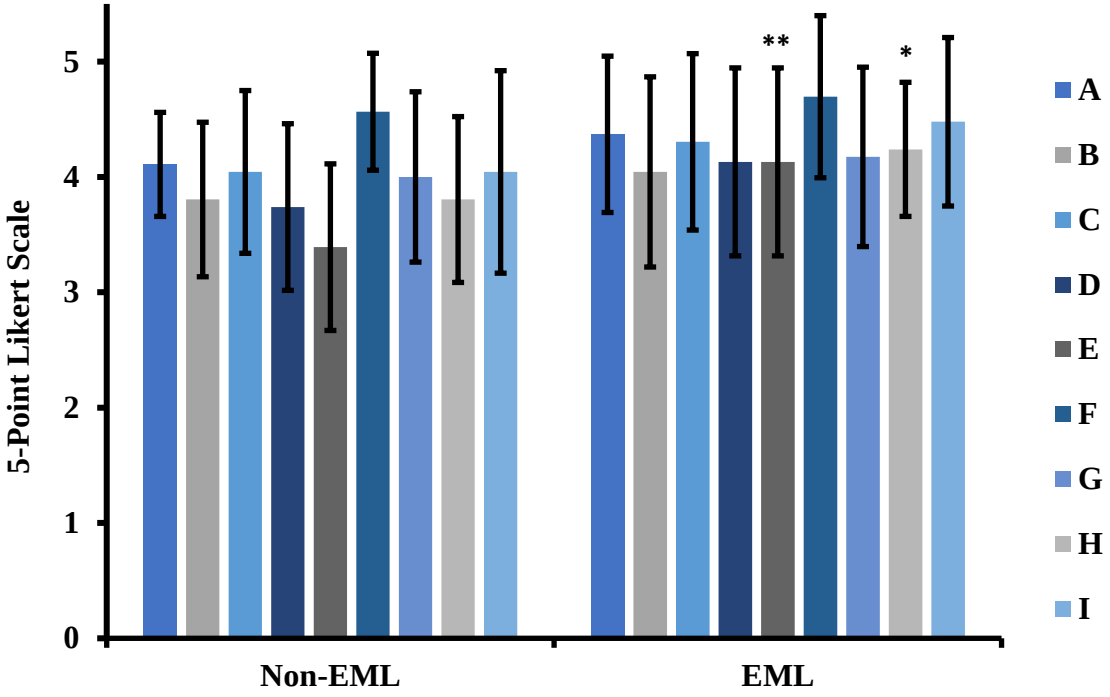

Figure 2| Average rating of student responses to the end-of-semester survey. Survey questions are grouped and separated by EML skill as given in Table 2 below. * Indicates statistical significance (P< 0.05). ** Indicated statistical significance (P < 0.01).

Table 3| Statistical analysis of Figure 2.

Legend	**EML Skill**	**Averages**		**Standard Deviation**		**P-Value**
		Non-EML	*EML*	*Non-EML*	*EML*	
A	Identifying an Opportunity	4.1086	4.3695	0.4511	0.6778	0.1315
B	Investigate the Market	3.8043	4.0434	0.6697	0.8245	0.2862

C	Create a preliminary business model	4.0434	4.3043	0.7057	0.7648	0.2357
D	Evaluate technical feasibility, customer value. Societal benefits, or economic feasibility	3.7391	4.1304	0.6887	0.7570	0.0734
E	Communicate an engineering solution in economic terms	3.3913	4.1304	0.7223	0.8148	0.0021
F	Develop Partnerships and build a team	4.5652	4.6956	0.5068	0.7029	0.4742
G	Communicate an engineering solution in terms of societal benefits	4	4.1739	0.7385	0.7776	0.4409
H	Test concepts quickly via customer engagement	3.8043	4.2391	0.7188	0.5813	0.0291
I	Persist through and Learn from Failure	4.0434	4.4782	0.8779	0.7304	0.0746

Open response questions supported the quantitative data with students demonstrating changes in their mindset. Representative verbatim comments from the students included, “This project has impacted my mindset by showing me that the solution is not going to fix every problem. I have gained new mental habits of having to think outside of the box to come up with different solutions that the original solution doesn't solve. I have also learned that as engineers, we need to

tailor our designs to the customer". Another student mentioned, "The project helped me visualize how a biomedical engineer would approach a real-world situation. It made me go from a broad picture to a narrow one". In response to the (Has this project equipped you with the tools needed to create value in any context? Give examples and explain.) question, a student answered: "Yes, the open-endedness really made me have to come up with my own answers to solutions instead of what I thought was expected of me." Another student mentioned, "This project has equipped me with tools like team communication, brainstorming, and many others. With team communication, we can work together to provide value in any context. It is often hard to come up with solutions on your own, but with the help of a team, the number of solutions increases. With brainstorming, I had to think outside of the box and figure out how to solve the situation given to us. This will provide value in any context because sometimes the solution isn't always right in front of you, and coming up with multiple ideas can be beneficial".

In response to the (How has this project affected how you make connections about the surrounding world? Give examples and explain.) question, a student answered: "It has always been kind of challenging for me to apply in-class knowledge to real-world situations, and this project has helped me learn how to. I've learned that when working with a patient, there are multiple external factors that must be considered when making decisions". Another student added: "In the middle of the course, I did not understand how the material we learned in class was going to benefit us with our majors. The examples in class would be about cables and beams and inanimate objects, but then the project helped connect the puzzle. They allow us to see what a classic real-world scenario is and how to approach it." In terms of connecting to patient /customer needs, a student mentioned: "This project has affected how I make connections about the surrounding world by allowing me to see a wider range of issues. For example, I had the

project for the hip replacement, which sounds easy enough to pick a hip implant and discuss. This would have been easy if our patient didn't have a metal allergy. We then had to make sure the hip implant was tailored to what our patient needed. Before this project, I saw the surrounding world as one solution that fits all types of things. This is not the case, and there are many issues we need to take into account with engineering". In response to the (Based on this project, in what ways are you more curious about the surrounding world?) question, a student mentioned: "I would like to see how different our results are from an actual biomedical engineer in the industry. That is, how far off are we from the real "answer". Another student mentioned, "I am more curious about all the underlying issues in medicine that are still being discovered. I am also more curious about what the surrounding world can come up with to solve the underlying issues which present themselves".

Biomolecular Engineering

Moving forward, EML will be included in a junior-level biomolecular engineering course. This study will be similar in format to the biomechanical engineering project. This study will be in a more advanced course targeting more EML learning skills, as shown in Table 4.

Table 4| EML Target Skills for the biomolecular engineering project.

Number	EML Skill	3 C's
1	Identify an opportunity	Curiosity
2	Investigate the market	Curiosity
3	Create a preliminary business model	Create Value
4	Evaluate technical feasibility and customer value. Societal benefits, or economic feasibility	Connections

5	Test concepts quickly via customer engagement	Create Value
6	Assess policy and regulatory issues	Connections
7	Communicate an engineering solution in economic terms	Create Value
8	Validate market interest	Connections
9	Develop partnerships and build a team	Connections
10	Identify supply chain distribution methods	Curiosity
11	Protect intellectual property	Create Value
12	Communicate an engineering solution in terms of societal benefits	Curiosity

Two different versions of the same project will be used- an experimental and a control project. However, as seen from the results of the biomechanical engineering project, both versions yielded high response averages. They indicated strong similarities between the two projects. To achieve better distinctions between the two-course projects, the EML version will contain more open-ended modules. This project will include four EML modules- learning from failure, market analysis, interviews, and future improvements. The control project will not contain any aspects of these modules. This experiment will also include a pre-semester survey and an end-of-semester survey. The addition of the pre-semester survey will track the specific changes made for EML skills per student and measure a student's entrepreneurial mindset (EM) prior to the course and project. Implementing the pre-semester survey and control group will aid in data analysis clarity and ensure the changes in a student's mindset were due solely to the project. We hypothesize that students participating in the EML version of the project will develop an entrepreneurial mindset by showing an increase in EML target skills as well as connections, creating value, and demonstrating curiosity about the surrounding world.

Conclusions

In this study, we developed a semester-long three-module project and investigated the impacts of incorporating a target EML skillset on the students' mindset. Two versions of the project (control vs. experimental/EML) were provided to the students, with twenty-three students randomly assigned to each version. After completing the project deliverables, data gathered from students' surveys demonstrated a higher increase in the experimental group's entrepreneurial mindset compared to the control group. Furthermore, the responses to the open-ended qualitative questions further validated results from the Likert-scale survey questions. This study guided the decision to offer the EML version of the project in the following course offerings and develop a similar project in the other Biomedical Engineering courses currently offered.

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Appendix I: Informed Consent

Developing Entrepreneurial Minded Learning in a Second Year Biomechanical Engineering Course
Consent to Participate in a Research Study
Principal Researcher: Loren Hedgecock
Principle Investigator: Mostafa Elsaadany

INVITATION TO PARTICIPATE
You are invited to participate in a research study about Entrepreneurial Minded Learning (EML) in a Biomechanical Engineering course at the University of Arkansas's Biomedical Engineering Department. You are being asked to participate in this study because you are a Biomedical Engineering student who is currently enrolled in the University of Arkansas Biomedical Engineering Department.

WHAT YOU SHOULD KNOW ABOUT THE RESEARCH STUDY
Who is the Principal Investigator?
Dr. Mostafa Elsaadany
Email: mselsaad@uark.edu

Who are the principal Researchers?
Loren Hedgecock
Email: lghedgec@uark.edu

Kaitlin Hall
Email: kjh029@uark.edu

What is the purpose of this research study?
The students enrolled in the Biomechanical Engineering course will be assigned with a semester-long project that tasks the students to create a treatment plan and solve different problems in order to find the best way to treat their patients. The project is embedded with Entrepreneurial Minded Learning (EML) skills. These skills will be used to start developing students' entrepreneurial mindset, or a mind geared towards action.

Who will participate in this study?
Approximately 70 students enrolled in the Biomechanical Engineering course at the University of Arkansas.

What am I being asked to do?
Your participation will require filling out a survey at the end of the semester. Your grades, class participation, homework assignments, projects, and exams will be collected and analyzed anonymously.

What are the possible risks or discomforts?
The risks are leakage of participants' grades or their demographic information. Different measures will be taken to ensure the security of the participant's data. The data will be stored in

a secure platform with only access granted to the principal researchers and the PIs. The participant's name will not be included in any reported or published data.

What are the possible benefits of this study?
By participating in this study, all students will be able to problem solve as a team and work on real-world problems related to biomechanical engineering. These problems are intended for students to investigate the proper treatment plan for their "hypothetical" patients based on their group. For students participating in the entrepreneurial-minded learning (EML) aspect of this project, they will start building an entrepreneurial mindset and creating a mind geared towards action. There are many benefits to EML learning; it enables students with the tools to identify opportunities and create value in any context. EML's ultimate goal is to supply engineers with the learning tools needed to not just succeed but thrive in today's society. The young engineers in BMEG 2813 will participate in the semester-long project that will demonstrate many different EML skills. The modules will equip students with the ability to evaluate a situation, determine the values of the customers, build teams, explain societal and economic benefits, and respond to failure. Ultimately, this project should form engineers that are able to create value, curiosity, and connections.

How long will the study last?
This study will take place during the spring semester of 2021.

Will I receive compensation for my time and inconvenience if I choose to participate in this study?
Yes, you will receive extra credit in the course. If you decided not to participate in this study, alternative opportunities will be provided to receive an equivalent extra credit.

Will I have to pay for anything?
No, participation in this study will **not** cost you any payment.

What are the options if I do not want to be in the study?
If you do not want to be in this study, you may refuse to participate. Also, you may refuse to participate at any time during the study. Your grades and academic standing in the classes will not be affected in any way if you refuse to participate. If you decide not to participate in this study, alternative opportunities will be provided to receive an equivalent extra credit.

How will my confidentiality be protected?
All information will be kept confidential to the extent allowed by applicable State and Federal law. All the data collected will be kept in a secure domain. The participants' names will **not** be included in any reported or published data. Collected data will not be deleted at the end of the semester. However, data will continue to be secured as above.

Please note that grades and class assignments will be included in the research data. Confidentiality will be protected as above.

Will I know the results of the study?

At the conclusion of the study, you will have the right to request feedback about the results. You may contact, Dr. Mostafa Elsaadany (mselsaad@uark.edu). You will receive a copy of this form for your files.

What do I do if I have questions about the research study?
You have the right to contact the Principal investigator as listed above for any concerns that you may have.

You may also contact the University of Arkansas Research Compliance office listed below if you have questions about your rights as a participant, or to discuss any concerns about, or problems with the research.

Ro Windwalker, CIP
Institutional Review Board Coordinator
Research Compliance
University of Arkansas
109 MLKG Building
Fayetteville, AR 72701-1201
479-575-2208
irb@uark.edu

I have read the above statement and have been able to ask questions and express concerns, which have been satisfactorily responded to by the investigator. I understand the purpose of the study as well as the potential benefits and risks that are involved. I understand that participation is voluntary and extra credit is available whether I decide to participate or not participate in the study. I understand that significant new findings developed during this research will be shared with the participant. I understand that no rights have been waived by signing the consent form. I have been given a copy of the consent form.

Appendix II: Biomechanical Engineering Project

BMEG 2813 EML

Biomechanical Engineering Project

Patient Profile 1

- Chris P. Bacon is a 65-year-old man who has been experiencing pain in his left hip. After a visit with his orthopedist, Dr. Pepper decided that the wear and tear on his hip joint were too extensive and that he needs a complete hip replacement to properly treat.

Patient Profile 2

- Pearl E. White is a 35-year-old woman who is a marathon runner. She has been experiencing some pain in her right knee for a while now, and at her last race, she fell and has been experiencing server knee pain ever since. Upon meeting with her doctor, Dr. Fizz, they examined the damage and found early to the mid-stage formation of osteoarthritis, which has been causing server damage to the knee joint. Dr. Fizz decided that the best plan of action is to do a total knee replacement.

Module 1

Goal: Write a research paper outlining your plan to treat **either patient 1 or patient 2**. Research and discover all types of treatment options. Choose two different treatment options and discuss why one is better than the other to treat your patient. The guidelines to follow are listed. You meet with your patient and take notes of your conversation listed below. Keep these in mind when creating your treatment plan and answer the questions in your report.

Patient Profile 1: Mr. Bacon is a retired naval officer that gets a slight skin reaction to Metal when he touches it. Will his VA benefits cover the cost of his treatment? Is there an implant option available that does not contain Metal? Is this the best option if not what can he do to combat the side effects? Mr. Bacon also has six grandchildren that he loves to take hiking, fishing, and hunting. He values his time with his grandchildren and wants to continue to do so. How will this surgery affect his time with his grandchildren?

Patient Profile 2: Mrs. White is an account executive at Walmart with private health insurance. At the age of 24 she was diagnosed with Tomophobia, the fear of surgery, how will this affect your treatment plan? What will her post-op life look like? How will her running be affected?

Outline guidelines:

1. 12-point font, times new roman, and double spaced.
1. Structure:
    a. Introduction
        - This section should include an introduction and background to your patient and the problem you are trying to solve.
    a. Treatment plan
        - This section should include your plan to properly treat this patient. In this section, you should list the different types of implants most commonly used and the reasons why you chose the ones that you did. **Take into consideration allergies, fears, socioeconomic status, and post-op lives (per patient profile)**.

- List out the risk factors associated with this type of surgery and the materials used.
- Google search, identify, and define "shelf-life" and discuss how it connects to your treatment plan.

a. Connections
   - Use this section to connect what you have done during this module to what you have learned thus far in class. Make sure you include specific examples of how what you have learned in this course has helped you create your treatment plan.
   - **Find a connection to current real-world issues (e.g. COVID-19 and its effect on hospital policy … other examples that connect with real-life examples are encouraged). This can be anything ranging from infectious diseases to economic or political issues.**

a. Conclusion
   - Briefly conclude your treatment plan. In this section, you should review the factors that helped you decided on this treatment and why this is the best plan.
   - **Introduce an experimental -Biomechanical- replacement option that has not yet been approved by the FDA. This does not have to be a thorough plan for total knee replacement.**

a. References
   - There should be correctly cited sources in APA format.

Module 2

Using the information gathered in Module 1, your team is going to create a PowerPoint presentation. To present this, your team will create a zoom meeting and record the session then upload the link to Blackboard. This presentation is going to be a sales pitch. You and your team already researched different orthopedic companies (e.g. Zimmer Biomet, Depuy Synthes, Smith and Nephew) and chose the best implant option available. You are then going to take that company implant and enhance it in some way. Out of this, you will create your own company. The presentation should include the company and implant your enhanced design is based on as well as your company and how you enhanced the implant. The first slide of your presentation should include your company name and logo. Your goal is to convince your audience and the patient that this is the best treatment plan option available. Each member should have equal time speaking. Use the criteria listed below to guide you.

Helpful links:

- https://www.youtube.com/watch?v=YA6SGQlVmcA - Zoom Screenshare Tutorial
- https://www.youtube.com/watch?v=lZHSAMd89JE - Zoom Recording Tutorial (Make sure to enable "uploading to the cloud" option). Share the link to the cloud video.
- https://www.freelogodesign.org/ - logo creation website

Guidelines:

1. As done in Module, make any appropriate assumptions. Educated guesses (decisions) are very encouraged.
    - We know for sure that you are not experts in the field.
    - This is an open-ended problem … there is no absolute right or wrong.
    - Have fun, be creative, and think out of the box.
1. Show logical decision-making.
1. This is a continuation of Module 1 … topics researched on module 1, need to be incorporated.
1. Every group member needs to equally participate in presenting their presentation
1. Students must create a company name and logo and include them on the first slide.
1. Slides need to be organized.
1. The format must be consistent for all the slides.
1. Use the presentation space (Avoid too much white "unused" space).
1. Include visual aids.
1. Avoid lengthy text and complete sentences.
1. Use concise and "to the point" words.
1. You must rehearse "as a team" before you record the presentation.
1. Show enthusiasm while you present.
1. DO NOT read from the slides.
1. Prepare well … rehearse again.
1. The video must be 5-7 minutes long.

<u>Questions to consider when creating your presentation:</u>

- *Why does the joint need to be replaced?*
- *How does your patient's background affect your treatment plan?*
- *What are the different options for your patient? Which of these is the best option to treat the patient? How is your implant going to be enhanced?*
- *What are the advantages and disadvantages of your option?*
- *From the material that you have learned from class, which skills did you use to complete this project?*
- *Are all the patient's physical and mental health considerations met?*
- *Consider your patient's values, how might this surgery affect them.*
- *Is the process of getting a hip replacement a sustainable process for your patient?*
- *Is there a non-surgical alternative for the replacement?*

Module 3

Patient Profile 1

- Chris P. Bacon is a 65-year-old man who has been experiencing pain in his left hip. After a visit with his orthopedist, Dr. Pepper decided that the wear and tear on his hip joint were too extensive and that he needs a complete hip replacement to properly treat.

Patient Profile 2

- Pearl E. White is a 35-year-old woman who is a marathon runner. She has been experiencing some pain in her right knee for a while now, and at her last race, she fell and has been experiencing server knee pain ever since. Upon meeting with her doctor, Dr. Fizz, they examined the damage and found early to the mid-stage formation of osteoarthritis, which has been causing server damage to the knee joint. Dr. Fizz decided that the best plan of action is to do a total knee replacement.

Using the images below create a force diagram labeling all the forces and the moment at the loads listed below.

<u>Patient 1</u> Chris P Bacon weighs 85kg. <u>Patient 2</u> Pearl E White weighs 50kg.

- A compression force of # N is being applied to the implant.
  - Using your research, find a reasonable amount for the joint force under different (three minimum) scenarios (e.g., setting, walking, jogging, etc.). Select one of these scenarios to show in your force diagram.
  - Show all the forces on the joint.
    - Make sure to include all the forces (Active and reactive).
  - Update the geometry (angles and dimensions) accordingly for your selected scenario.
- Determine the joint reaction force and the bearing stress (force divided by the projected area).
- Based on your calculations of the bearing stress, select a material for your implant.
- For the elastic region only, generate a Stress vs. Strain curve **<u>(Use only one of the above scenarios)</u>**.
  - Your curve data should be based on a range of your own calculations (stress).
  - The stress will range from zero (unloaded) to the yield point.

- Find a reasonable range for the strain and plot that vs stress (using the selected material Young's modulus).
- Your curve should only show the elastic region. Transfer the curve to a word document and state the definitions of the properties below.
    - Show all your work and make any appropriate assumptions.
- This curve must include (annotate the curve accordingly):
    1. Young's Modulus
    1. Yield Strength
    1. Axis labels with units and appropriate title

- Discuss the following:
    - The material properties of your implant and how they impacted material selection.
    - Titanium alloys are common materials used in orthopedic implants. Why? Did you select this material for your implant and why?

- **Create a scenario in which your implant fails. The failure of the implant is nothing other than a design flaw. Discuss possible reasons the implant failed. In this scenario identify what type of symptoms that the patient would endure with a failed implant. How would this impact the market for your implant and what modifications would be made to correct this mistake? What did you learn from this failure?**

This is an open-ended problem; using your research, make any reasonable assumptions for the unknown (not given) variables and cite the sources you used to make these assumptions.

BMEG 2813 Project - Non-EML

Patient Profile 1 (Groups 1-4)

- Chris P. Bacon is a 65-year-old man who has been experiencing pain in his left hip. After a visit with his orthopedist, Dr. Pepper decided that the wear and tear on his hip joint were too extensive and that he needs a complete hip replacement to properly treat.

Patient Profile 2 (Groups 5-8)

- Pearl E. White is a 35-year-old woman who is a marathon runner. She has been experiencing some pain in her right knee for a while now, and at her last race, she fell and has been experiencing server knee pain ever since. Upon meeting with her doctor, Dr. Fizz, they examined the damage and found early to the mid-stage formation of osteoarthritis, which has been causing server damage to the knee joint. Dr. Fizz decided that the best plan of action is to do a total knee replacement.

Module 1

Goal: Write a research paper outlining your plan to treat this patient. Research and discover all types of treatment options. Choose two different options and discuss why one is better than the other to treat your patient. The guidelines to follow are listed below.

Outline guidelines:

1. 12-point font, times new roman, and double spaced.
1. Structure:
    a. Introduction
        - This should include an introduction and background to your patient and the problem you are trying to solve.
    a. Treatment plan
        - This section should include your plan to properly treat this patient. In this section, you should list the different types of implants most commonly used and the reasons why you chose the ones that you did. As well as the risk factors associated with this type of surgery and materials used.
        - Google search, identify, and define "shelf-life" and discuss how it connects to your treatment plan.
    a. Connections
        - Use this section to connect what you have done during this module to what you have learned thus far in class. Make sure you include specific examples of what you have learned in this course and how it has helped you create your treatment plan.
    a. Conclusion
        - Briefly conclude your treatment plan. In this section, you should review the factors that helped you decided on this treatment and why this is the best plan.
    a. References
        - There should be correctly cited sources in APA format.

Module 2

Using the information gathered in Module 1, your team is going to create a PowerPoint presentation. To present this, your team will create a zoom meeting and record the session then upload the link to Blackboard.

Helpful links:

- https://www.youtube.com/watch?v=YA6SGQlVmcA - Zoom Screenshare Tutorial
- https://www.youtube.com/watch?v=lZHSAMd89JE - Zoom Recording Tutorial (Make sure to enable "uploading to the cloud" option). Share the link to the cloud video.

Guidelines:

1. As done in Module, make any appropriate assumptions. Educated guesses (decisions) are very encouraged.
    - We know for sure that you are not experts in the field.
    - This is an open-ended problem … there is no absolute right or wrong.
    - Have fun, be creative, and think out of the box.
1. Show logical decision-making.
1. This is a continuation of Module 1 … topics researched on module 1, need to be incorporated.
1. Every group member needs to equally participate in presenting their presentation
1. Slides need to be organized.
1. The format must be consistent for all the slides.
1. Use the presentation space (Avoid too much white "unused" space).
1. Include visual aids.
1. Avoid lengthy text and complete sentences.
1. Use concise and "to the point" words.
1. You must rehearse "as a team" before you record the presentation.
1. Show enthusiasm while you present.
1. DO NOT read from the slides.
1. Prepare well … rehearse again.
1. The video must be 5-7 minutes long.

Questions to consider when creating your presentation:

- *Why does the joint need to be replaced?*
- *How does your patient's background affect your treatment plan?*
- *What are the different options for your patient? Which of these is the best option to treat the patient(Include brand, implant name, and cost)?*
- *What are the advantages and disadvantages of your option?*
- *From the material that you have learned from class, which skills did you use to complete this project?*

Module 3

Patient Profile 1 (Groups 1-4)

- Chris P. Bacon is a 65-year-old man who has been experiencing pain in his left hip. After a visit with his orthopedist, Dr. Pepper decided that the wear

and tear on his hip joint were too extensive and that he needs a complete hip replacement to properly treat.

Patient Profile 2 <u>(Groups 5-8)</u>

- Pearl E. White is a 35-year-old woman who is a marathon runner. She has been experiencing some pain in her right knee for a while now, and at her last race, she fell and has been experiencing server knee pain ever since. Upon meeting with her doctor, Dr. Fizz, they examined the damage and found early to the mid-stage formation of osteoarthritis, which has been causing server damage to the knee joint. Dr. Fizz decided that the best plan of action is to do a total knee replacement.

Using the images below create a force diagram labeling all the forces and the moment at the loads listed below.

<u>Patient 1</u> Chris P Bacon weighs 85kg.

<u>Patient 2</u> Pearl E White weighs 50kg.

- A compression force of # N is being applied to the implant.
  - Using your research, find a reasonable amount for the joint force under different (three minimum) scenarios (e.g., setting, walking, jogging, etc.). Select one of these scenarios to show in your force diagram.
  - Show all the forces on the joint.
    - Make sure to include all the forces (Active and reactive).
  - Update the geometry (angles and dimensions) accordingly for your selected scenario.
- Determine the joint reaction force and the bearing stress (force divided by the projected area).
- Based on your calculations of the bearing stress, select a material for your implant.
- For the elastic region only, generate a Stress vs. Strain curve **<u>(Use only one of the above scenarios)</u>**.
  - Your curve data should be based on a range of your own calculations (stress).
  - The stress will range from zero (unloaded) to the yield point.
  - Find a reasonable range for the strain and plot that vs stress (using the selected material Young's modulus).
  - Your curve should only show the elastic region. Transfer the curve to a word document and state the definitions of the properties below.
    - Show all your work and make any appropriate assumptions.
  - This curve must include (annotate the curve accordingly):

1. Young's Modulus
1. Yield Strength
1. Axis labels with units and appropriate title

- Discuss the following:
  - The material properties of your implant and how they impacted material selection.
  - Titanium alloys are common materials used in orthopedic implants. Why? Did you select this material for your implant and why?

<u>This is an open-ended problem; using your research, make any reasonable assumptions for the unknown (not given) variables and cite the sources you used to make these assumptions.</u>

Appendix III: Biomechanical Engineering Survey

Curiosity

Please answer the following statements below.	**Strongly Disagree**	**Disagree**	**Neutral**	**Agree**	**Strongly Agree**
The project allowed me to show more curiosity about worldly engineering problems.					
The project has fostered my ability to think in more innovative ways.					
The project has taught me the importance of learning new skills.					
How prepared do you feel in each of the following areas?	**Strongly Disagree**	**Disagree**	**Neutral**	**Agree**	**Strongly Agree**
Applied to learning in a new context.					
Furthered learning beyond the course content curriculum.					
Formulated questions and generated own inquiries.					
Please answer the following questions below on a scale of 1-5, with one being extremely unconfident and five extremely confident.	**1**	**2**	**3**	**4**	**5**
How confident are you in your ability to exercise curiosity about the surrounding world?					

Connections

Please answer the following statements below.	**Strongly Disagree**	**Disagree**	**Neutral**	**Agree**	**Strongly Agree**
The project allowed me to experience making connections with what I learn in class and real-world engineering problems.					
How prepared do you feel in each of the following areas?	**Strongly Disagree**	**Disagree**	**Neutral**	**Agree**	**Strongly Agree**

Explored alternatives or encourage forming contrarian views of accepted solutions.					
Collaborated in a team setting.					
Communicated engineering solutions in economic terms.					
Substantiated claims with data and facts.					
Please answer the following questions below on a scale of 1-5, with one being extremely unconfident and five extremely confident.	**1**	**2**	**3**	**4**	**5**
How confident are you in your ability to understand the motivations and perspectives of customers?					
How confident are you in your ability to make connections?					

Creating Value

Please answer the following statements below.	**Strongly Disagree**	**Disagree**	**Neutral**	**Agree**	**Strongly Agree**
The project allowed me to learn the importance of creating value while conducting engineering problem-solving.					
How prepared do you feel in each of the following areas?	**Strongly Disagree**	**Disagree**	**Neutral**	**Agree**	**Strongly Agree**
Understood the motivations and perspectives of customers.					
Please answer the following questions below on a scale of 1-5, with one being extremely unconfident and five extremely confident.	**1**	**2**	**3**	**4**	**5**
How confident are you in your ability to succeed as an engineer?					
How confident are you in your ability to create value for a customer?					

How confident are you in your ability to create value in different situations?					
How confident are you in your ability to persist through and learn from failure?					

Open Response

1.) How has this project impacted your mindset? Have you gained any new mental habits? Explain.
2.) Has this project equipped you with the tools needed to create value in any context? Give examples and explain.
3.) How has this project affected how you make connections about the surrounding world? Give examples and explain.
4.) Based on this project, in what ways are you more curious about the surrounding world?
5.) Please provide any suggestions/comments you may have about the course project.
6.) Were there specific interactions that influenced your perspective/ development of entrepreneurial skill sets.

Appendix IV: Biomolecular Engineering Project

BMEG 3824 Biomolecular Engineering (EML Version)

Project Description

Describe how a particular innovation or solution created through biomolecular engineering impacts our healthcare, economy, and society.

- The biomolecular engineering innovation could be a biopharmaceutical, a reagent used for research or it could be a particular technique, instrumentation or device used for the production of a biomolecule—something related to an application in healthcare and medicine.
- You will work in teams of 3 or 4 as assigned. **Team evaluation will be part of your grade.** Make sure that you work with your team and make a significant contribution
- Your team will write a report as well as give an oral presentation.

General Instructions:

1. Thoroughly define the innovation
2. Describe how biomolecular engineering was used to accomplish the innovation (technical detail)
3. Describe any positive and negative impacts on healthcare both in the U.S. and globally
4. Describe any positive and negative impacts on the economy and society
5. Offer future perspectives/directions/improvements for the innovation
6. Include data (figures, numbers, statistics, etc.) as much as possible, number and reference figures and add appropriate legends
7. Include a paragraph of insights gained from interviews.
8. Properly reference all cited materials
9. Do not plagiarize—referenced materials should still be paraphrased.
10. Do not use vague, no-specific words (e.g. “a lot”, “very little”, “amazing”, “little”)

Topic Submission:

As a group, pick a topic to work on and submit through Blackboard. This statement can simply be a sentence or a title, or a few sentences. The instructor will provide feedback about your topic before you proceed. Your group may have to refine your topic or select a different topic, if it is irrelevant for this project, or if it overlaps with others in the class.

Interviews:

Each team member will interview two people who have experience/connections in the field of your topic. A team consisting of four people should have eight interviews total. Interviews should be around 10-15 minutes long. You can interview in person, over the phone, or virtually. Teams should generate questions that will help thoroughly define your topic and its impacts on society. Include a paragraph of the insights gained from the interview. All interviews should be recorded and transcribed. Include interview questions and responses in an Appendix section at the end your report.

Market Analysis:

When addressing the positive and negative impacts of this innovation on the economy include a

brief market analysis section. This section should include potential customer segments, competition, supply chain distribution, market size, and market growth. This should be included during your presentation.

Learning From Failure:
Students must submit preliminary draft of paper. Groups in the EML version of the project will have papers returned that only says "Needs major improvements". Although students won't like this, instructors don't tell them what specifics they need to improve on. They must get creative and figure out how to improve their paper. Later on, during the presentation they must discuss what they learned from failure.
**TA's/Instructor cannot give specific instructions to improve on the paper. They should turn their questions back on them- "What do you think they are missing".
**Students are not graded on this. Just for research purposes

Report Requirements:

1. Your written report should be in the format of a review paper.
1. You are required to have 1-inch margins and 12 pt Times New Roman font, double spaced throughout.
1. A review paper is NOT merely a report or summary of some references you found. It should be a document that summarizes the current state of the topic using various references and integrates them into a coherent central argument about the topic. You are a reviewer providing an overview of the topic with an objective, not someone who simply puts pieces of information together into one document.
1. You will be evaluated for grammar as well as the flow of your text. Please work as a group to generate a single paper with a good flow. I suggest finishing your draft at least a week before it's due so that all group members can get a chance to read the whole paper and make edits.
1. The main body of your text should be divided into sections as it is fit, but your paper should include at least: a title page, abstract, main text, conclusions, and references.
1. Note that the report is due after your presentations are done. Address any issues raised by the instructor within your written report to improve its quality.

Presentation Requirements:
Presentations will occur in the last three weeks of the semester. The exact order of the presentations will be provided later in the semester.

1. Your group will prepare PowerPoint slides to be used as a visual aid to your presentation.
1. You will have 12 minutes to present your project, and 3 minutes for questions at the end. Please be on time—I will stop you when your time is up.
1. You will be evaluated for presentation content, presentation skills, as well as your ability to address questions.
1. Your team will be assigned a single team grade for the presentation, so an individual member's performance will affect the entire team. Be sure to practice together as a group and be responsible for the entire presentation, not just your section.

Grading:

• Team score:
  - 70% based on the written report
  - 30% based on oral presentation

TEAM SCORING RUBRIC		
BMEG 3824- Describe how a particular innovation or solution created through Biomolecular Engineering impacts out healthcare, economy, or and/or society	**Points**	
Written Report	Available	Awarded
Definition		
1. Effective definition of innovation	2.5	
1. Description of the use of biomolecular engineering	2.5	
Impact		
1. Description of impact on healthcare	7.5	
1. Description of impact on economy/society	7.5	
1. Description of future impacts	7.5	
1. Description of interview insights	7.5	
Interviews		
1. Completion of interviews	2.5	
1. Transcription of interviews in appendix	2.5	
Market Analysis		
1. Description of market size and projected growth	7.5	
1. Description of customer segments	7.5	
1. Description of competition	7.5	
Organization and Writing		
1. Logical and systematic discussion	2.5	
1. Use of referenced data (figures, stats, etc.)	2.5	
1. Quality and clarity of writing	2.5	
Written Report Total	**70**	
Oral Presentation:		
Technical Content		
1. Effective description of innovation and technique	5	
2. Effective description of the impact on society and future perspectives	5	
3.Effective description of interview insights	5	
4.Effective description of market analysis	5	
Oral Presentation Skills		
1. Presentation skills	5	
1. Organization	2.5	
Visual Aid		
1. Effective use of PowerPoint slides	2.5	

Oral Presentation Total	**30**	
TOTAL TEAM SCORE	**100**	

BMEG 3824 Biomolecular Engineering (Non-EML Version)
Project Description

Describe how a particular innovation or solution created through biomolecular engineering impacts our healthcare, economy, and society.

- The biomolecular engineering innovation could be a biopharmaceutical, a reagent used for research or it could be a particular technique, instrumentation or device used for the production of a biomolecule—something related to an application in healthcare and medicine.
- You will work in teams of 3 or 4 as assigned. **Team evaluation will be part of your grade.** Make sure that you work with your team and make a significant contribution
- Your team will write a report as well as give an oral presentation.

General Instructions:

1. Thoroughly define the innovation
2. Describe how biomolecular engineering was used to accomplish the innovation (technical detail)
3. Describe any positive and negative impacts on healthcare both in the U.S. and globally
4. Describe any positive and negative impacts on the economy and society
5. Include data (figures, numbers, statistics, etc.) as much as possible, number and reference figures and add appropriate legends
6. Properly reference all cited materials
7. Do not plagiarize—referenced materials should still be paraphrased.
8. Do not use vague, no-specific words (e.g. “a lot”, “very little”, “amazing”, “little”)

Topic Submission:

As a group, pick a topic to work on and submit through Blackboard. This statement can simply be a sentence or a title, or a few sentences. The instructor will provide feedback about your topic before you proceed. Your group may have to refine your topic or select a different topic, if it is irrelevant for this project, or if it overlaps with others in the class.

Report Requirements:

1. Your written report should be in the format of a review paper.
2. You are required to have 1-inch margins and 12 pt Times New Roman font, double spaced throughout.
3. A review paper is NOT merely a report or summary of some references you found. It should be a document that summarizes the current state of the topic using various references and integrates them into a coherent central argument about the topic. You are a reviewer providing an overview of the topic with an objective, not someone who simply puts pieces of information together into one document.

4. You will be evaluated for grammar as well as the flow of your text. Please work as a group to generate a single paper with a good flow. I suggest finishing your draft at least a week before it's due so that all group members can get a chance to read the whole paper and make edits.
5. The main body of your text should be divided into sections as it is fit, but your paper should include at least: a title page, abstract, main text, conclusions, and references.
6. Note that the report is due after your presentations are done. Address any issues raised by the instructor within your written report to improve its quality.

Presentation Requirements:

Presentations will occur in the last three weeks of the semester. The exact order of the presentations will be provided later in the semester.

1. Your group will prepare PowerPoint slides to be used as a visual aid to your presentation.
2. You will have 12 minutes to present your project, and 3 minutes for questions at the end. Please be on time—I will stop you when your time is up.
3. You will be evaluated for presentation content, presentation skills, as well as your ability to address questions.
4. Your team will be assigned a single team grade for the presentation, so an individual member's performance will affect the entire team. Be sure to practice together as a group and be responsible for the entire presentation, not just your section.

Grading:

• Team score:

- 65% based on the written report
- 35% based on oral presentation

TEAM SCORING RUBRIC		
BMEG 3824- Describe how a particular innovation or solution created through Biomolecular Engineering impacts out healthcare, economy, or and/or society	**Points**	
Written Report	Available	Awarded
Definition		
1. Effective definition of innovation	10	
1. Description of the use of biomolecular engineering	10	
Impact		
1. Description of impact on healthcare	15	
1. Description of impact on economy/society	15	
Organization and Writing		
1. Logical and systematic discussion	5	
1. Use of referenced data (figures, stats, etc.)	5	
1. Quality and clarity of writing	5	
Written Report Total	**65**	
Oral Presentation:		

Technical Content		
1. Effective description of innovation and technique	7.5	
2. Effective description of the impact on society and future perspectives	7.5	
Oral Presentation Skills		
1. Presentation skills	5	
1. Organization	5	
Visual Aid		
1. Effective use of PowerPoint slides	10	
Oral Presentation Total	**35**	
TOTAL TEAM SCORE	**100**	

Appendix V: Biomolecular Surveys

Introduction Survey (Pre-Survey)

Curiosity

Please answer the following statements below.	**Strongly Disagree**	**Disagree**	**Neutral**	**Agree**	**Strongly Agree**
I am curios about worldly engineering problems.					
I think in innovative ways.					
I believe that learing new skills is important.					
How prepared do you feel in each of the following areas?	**Strongly Disagree**	**Disagree**	**Neutral**	**Agree**	**Strongly Agree**
Apply learning in a new context.					
Learn beyond the course content curriculum.					
Formulate questions and generat inquiries.					
Please answer the following questions below on a scale of 1-5, with one being extremely unconfident and five extremely confident.	**1**	**2**	**3**	**4**	**5**
How confident are you in your ability to exercise curiosity about the surrounding world?					

Connections

Please answer the following statements below.	**Strongly Disagree**	**Disagree**	**Neutral**	**Agree**	**Strongly Agree**
I am able to make connections with what I learn in school and real-world engineering problems.					
How prepared do you feel in each of the following areas?	**Strongly Disagree**	**Disagree**	**Neutral**	**Agree**	**Strongly Agree**
Exploring alternatives or forming contrarian views of accepted solutions.					

Collaborating in a team setting.					
Communicating engineering solutions in economic terms.					
Substantiate claims with data and facts.					
Please answer the following questions below on a scale of 1-5, with one being extremely unconfident and five extremely confident.	**1**	**2**	**3**	**4**	**5**
How confident are you in your ability to understand the motivations and perspectives of customers?					
How confident are you in your ability to make connections?					

Creating Value

Please answer the following statements below.	**Strongly Disagree**	**Disagree**	**Neutral**	**Agree**	**Strongly Agree**
I know the importance of creating value while conducting engineering problem-solving.					
How prepared do you feel in each of the following areas?	**Strongly Disagree**	**Disagree**	**Neutral**	**Agree**	**Strongly Agree**
Understanding the motivations and perspectives of customers.					
Please answer the following questions below on a scale of 1-5, with one being extremely unconfident and five extremely confident.	**1**	**2**	**3**	**4**	**5**
How confident are you in your ability to succeed as an engineer?					
How confident are you in your ability to create value for a customer?					
How confident are you in your ability to create value in different situations?					

How confident are you in your ability to persist through and learn from failure?					

Open Response

1.) What does exhibiting curiosity, creating value, and making connections mean to you? Explain.
2.) In what ways do you exhibit curiosity about the surrounding world?
3.) In what ways do you exhibit making connections about the surrounding world?
4.) In what ways do you create value in the surrounding world?
4.) In your own words please describe an entrepreneurial mindset. Do you believe you have these qualities?
6.) What can this course offer in order to stimulate curiosity, connections, and creating value?

End of Semester Survey

Curiosity

Please answer the following statements below.	**Strongly Disagree**	**Disagree**	**Neutral**	**Agree**	**Strongly Agree**
The project allowed me to show more curiosity about worldly engineering problems.					
The project has fostered my ability to think in more innovative ways.					
The project has taught me the importance of learning new skills.					
How prepared do you feel in each of the following areas?	**Strongly Disagree**	**Disagree**	**Neutral**	**Agree**	**Strongly Agree**
Applied to learning in a new context.					
Furthered learning beyond the course content curriculum.					
Formulated questions and generated own inquiries.					
Please answer the following questions below on a scale of 1-5, with one being extremely unconfident and five extremely confident.	**1**	**2**	**3**	**4**	**5**

How confident are you in your ability to exercise curiosity about the surrounding world?					

Connections

Please answer the following statements below.	**Strongly Disagree**	**Disagree**	**Neutral**	**Agree**	**Strongly Agree**
The project allowed me to experience making connections with what I learn in class and real-world engineering problems.					
How prepared do you feel in each of the following areas?	**Strongly Disagree**	**Disagree**	**Neutral**	**Agree**	**Strongly Agree**
Explored alternatives or encourage forming contrarian views of accepted solutions.					
Collaborated in a team setting.					
Communicated engineering solutions in economic terms.					
Substantiated claims with data and facts.					
Please answer the following questions below on a scale of 1-5, with one being extremely unconfident and five extremely confident.	**1**	**2**	**3**	**4**	**5**
How confident are you in your ability to understand the motivations and perspectives of customers?					
How confident are you in your ability to make connections?					

Creating Value

Please answer the following statements below.	**Strongly Disagree**	**Disagree**	**Neutral**	**Agree**	**Strongly Agree**
The project allowed me to learn the importance of creating value while conducting engineering problem-solving.					

How prepared do you feel in each of the following areas?	**Strongly Disagree**	**Disagree**	**Neutral**	**Agree**	**Strongly Agree**
Understood the motivations and perspectives of customers.					
Please answer the following questions below on a scale of 1-5, with one being extremely unconfident and five extremely confident.	**1**	**2**	**3**	**4**	**5**
How confident are you in your ability to succeed as an engineer?					
How confident are you in your ability to create value for a customer?					
How confident are you in your ability to create value in different situations?					
How confident are you in your ability to persist through and learn from failure?					

Open Response

1.) How has this project impacted your mindset? Have you gained any new mental habits? Explain.
2.) Has this project equipped you with the tools needed to create value in any context? Give examples and explain.
3.) How has this project affected how you make connections about the surrounding world? Give examples and explain.
4.) Based on this project, in what ways are you more curious about the surrounding world?
5.) Please provide any suggestions/comments you may have about the course project.
6.) Were there specific interactions that influenced your perspective/ development of entrepreneurial skill sets.