Entrepreneurial Minded Learning in a Core Junior-Level Mechanical Vibrations Course

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Abstract

This paper describes the implementation of a project that incorporated prototyping and the entrepreneurial mindset into a core, junior-level Mechanical Vibrations course in the mechanical engineering curriculum. The course underwent an update that included the modification of a hands-on prototyping project integrating aspects of the entrepreneurial mindset into the project requirements starting Summer 2021. The project required that all aspects were verified using traditional theoretical relationships, were modeled using a variety of simulation tools, were physically built and experimentally verified, while also marketed and validated as profitable endeavors based on real-world data. Prototypes were demonstrated in the final presentation at the end of semester.

Students reinforced and advanced their entrepreneurial mindset through investigating sources of destructive vibration in the world around them or identifying opportunities where vibration could be used to enhance human experience. Some groups drew on prior work experience for projects: one group worked on minimizing vibration to a circuit board, whereas another group developed an idea for a latte-shaker to minimize the need for disposable spoons. Other groups' projects were inspired by daily-life experiences: one group prototyped a wristband to relieve anxiety, and another group designed a damper system to prevent bolt bounce in firearms. Throughout the process, students were tasked with generating ideas both individually and in groups, interviewing stakeholders, and reflecting on the value added for their proposed projects. To prepare for prototyping, students were assigned safety and machine shop equipment training early in the semester.

Mechanical Vibrations utilizing the new project structure was taught across three different semesters with three different faculty members, using a variety of delivery methods. Faculty collaborated closely, both during the course's developmental phase and throughout the semester, to ensure a common entrepreneurially minded experience for all students. An anonymous course survey was conducted at the end of the course, targeting both the technical and entrepreneurial mindset learning outcomes for the course showing significant improvement in student's understanding of value creation in engineering design.

Keywords

entrepreneurial mindset, mechanical engineering education, mechanical vibrations

Background and Introduction

Mechanical Vibrations is a challenging course for students, requiring them to apply knowledge of differential equations, Laplace transformation, dynamics, linear algebra, and numerical methods to real-world scenarios. To help students bridge the theoretical-to-real-world gap, a typical undergraduate vibrations course will employ some combination of lectures, lab experiments, and/or design projects. Practical course projects can motivate students' interests in vibrations and help reinforce the lessons learned in class. However, due to the complexity of vibrating systems, numerous steps are taken to simplify these projects, making them achievable in a typical 16-week semester. There are instances where instructors have created vibrations projects utilizing simulation software such as Simulink, MATLAB, Python, Ansys, etc. [1-3]. While simulations help students analyze vibrations systems, faculty in the Mechanical & Industrial Engineering (MEIE) Department at the University of Wisconsin-Platteville wanted to promote further in-depth student learning by incorporating projects that built off the simulations and resulted in finished prototypes by the end of the semester. Not only were the faculty interested in finished prototypes, but the focus was placed on prototypes that created value for others. For engineers, it is important to understand the bigger picture, recognize opportunities, evaluate the market, and learn from mistakes to create value for themselves and others. Therefore, the goal as engineering educators was to strive to bring those mindsets into the classroom and to help students think more broadly about the changing world, and better understand customer's needs.

The Mechanical Vibrations course in the MEIE Department at the University of Wisconsin Platteville is a required, three-credit course typically taken during a student's Junior year. This course was updated in Summer 2021 to include a semester-long project involving design, modeling, and prototyping of a practical vibrational system. To enhance students' learning and help them identify opportunities and create value, the idea of an entrepreneurial mindset (EM) was incorporated into the project. An entrepreneurial mindset (EM) is a mental habit geared toward action. It is a learned behavior; a way of thinking about the world and acting upon what an engineer sees. EM, as defined by the Kern Entrepreneurial Engineering Network (KEEN), consists of three key elements: Curiosity, Connections, and Creating Value [4]. It empowers people to identify opportunities and create value in any context. These characteristics are important for student success. In recent years, instructors have applied EM into different engineering courses with results showing a significant advancement in technical and EM skills [5] - [8].

In the Summer 21, Fall 21, and Spring 22 semesters, this course was consistently taught by three different faculty members via different instructional delivery methods including face-to-face, online asynchronous, and in a combination of online asynchronous lectures with in-person project activities (hybrid model). The instructors collaborated closely on the projects to ensure a common entrepreneurial mindset experience for the students. This paper describes the implementation of these projects into the course over this timeframe.

Entrepreneurial Minded Learning Based Projects

The project for this class could be described very succinctly as the fabrication of a vibratory motion device. Students were encouraged to pursue ideas that sparked their curiosity with the overall goal being the creation of a simple, profitable device that performed some practical operation(s) using vibrations. The project was developed such that there were both individual and team deliverables

throughout the course of the semester and was designed to encompass four different parts. Each group completed a team contract at the beginning of the project. The team contract is included in the Appendix section.

The first part of the project was all about idea generation. No limits were put on the device providing students the opportunity to dive into any area of curiosity (industrial, commercial, research). Students were encouraged to find inspiration from their daily life and to conduct both individual idea generation and then to move on to group idea generation and winnowing. To reinforce EM principles, for each idea generated they were required to identify at least one opportunity and relate it to potential stakeholders. By the end of part one of the project, students submitted sketches of their ideas and explained how their projects utilized or reduced vibrations for specific probable customers.

The second part of the project involved modeling their idea via both theoretical and numerical simulation tools. Each team's final idea was modeled using single or multiple degree-of-freedom systems or distributed parameter systems. This led into the third part of the project where building and then experimental verification of the physical prototype occurred, leading to quite a bit of iteration.

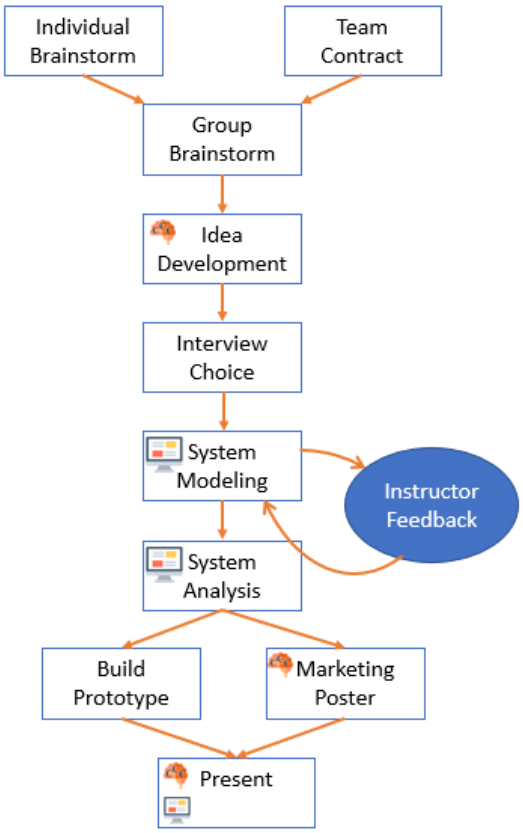


Figure 1: Scaffolded deliverables for the project, including objectives that are included.

The final part of the project was focused on the EM principle of Creating Value. Teams had to devise methods to "sell" their idea to their intended audience through either a marketing ad (poster), a commercial (simulated television ad), or a final presentation focused on the benefits the product created for their target markets. This was all in addition to the traditional engineering report explaining the results of the analysis, experimentation, and prototyping. While the project was broken into four larger parts, the overall project was scaffolded such that there were multiple deliverables for each part as shown in Figure 1. This resulted in nearly continuous engagement with the project throughout the semester.

Throughout the project, not only were the normal course outcomes assessed, but the project also contained EM mindset and skillset outcomes that were assessed at various points throughout the semester. With these mindset and skillset outcomes combined, students were able to see the link between an initial curiosity question and how it can relate to creating value for their organizations and communities in successful and rewarding engineering careers. These outcomes were identified through icons, as shown in Figure 2.

(a) (b)

Figure 2: Icons representing (a) Entrepreneurial Mindset (b) Technical Skillset

Results and Assessments:

The projects were designed to be open-ended and poorly defined explicitly to encourage students to engage in mindset and skillset development. These projects lent themselves particularly to developing the skillsets of

- Simplifying complicated, real-world systems into ideal mathematical model representations.
- Justifying idealization and simplifying assumption choices.
- Choosing appropriate dimensions, directions of motion, and relative coordinates for these systems.
- Conducting appropriate analysis for the modeled systems.
- Numerically modeling these systems using a variety of computational tools, and
- Defending their numerical results and conclusions using appropriate conceptual information

These were challenging skillsets for students to develop. With the first iteration, few groups successfully modeled their systems appropriately. As a result, the projects required significant feedback from the instructor during the early stages of the project. This approach was then adopted for future iterations, providing opportunities for student groups to rework models based on feedback. This provided the dual benefits of 1) letting students learn through failure and 2) by

normalizing this experience, students felt positive about their learning growth, despite the initial failures.

Figure 3 illustrates a representative example of individual brainstorming conducted during the first part of the project. For this part of the EM-based projects, students generated three examples each of "good" and "bad" vibrations found in products and/or their surroundings. For each concept, the student identified as many stakeholders as possible and the associated opportunities that could arise from improvements in the design. Figure 4 shows three examples of how students used mathematical modeling to represent their ideas, while Figure 5 showcases several prototypes built by the students over the semester.

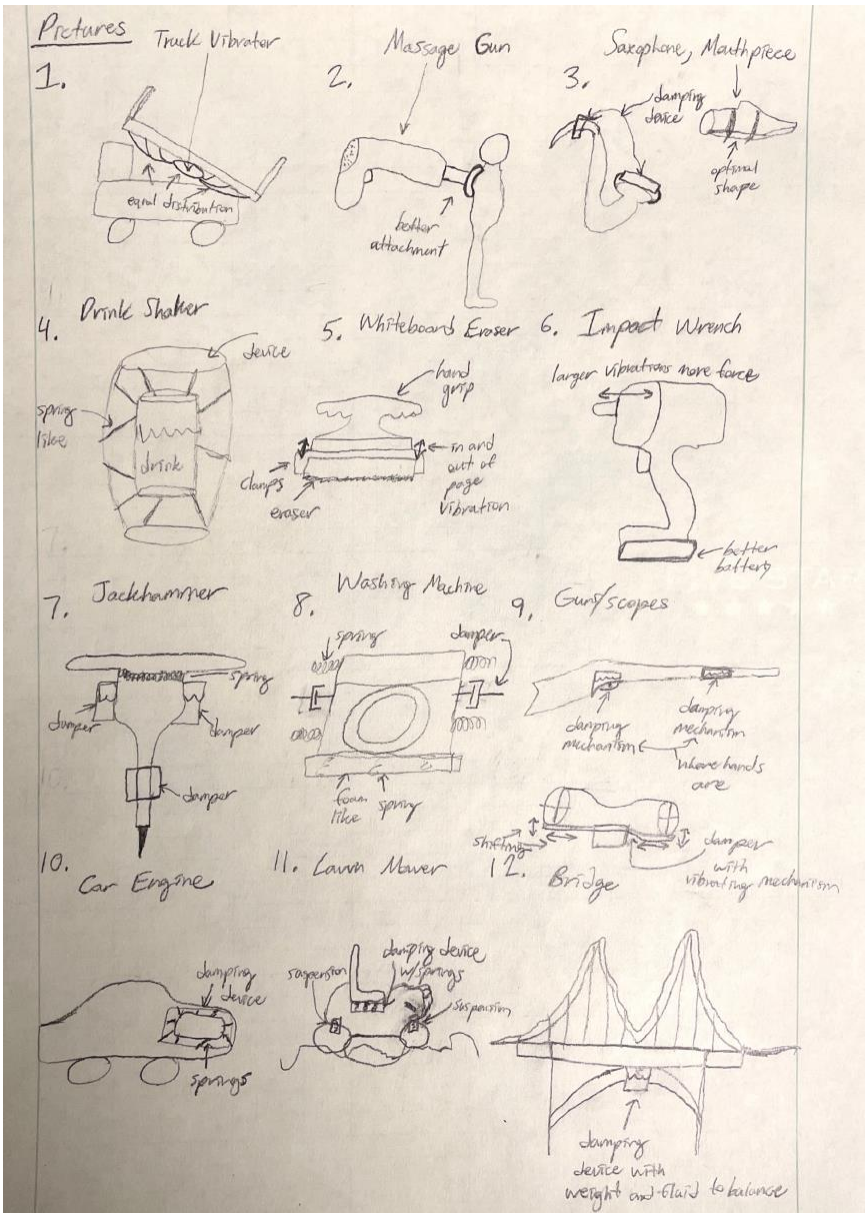
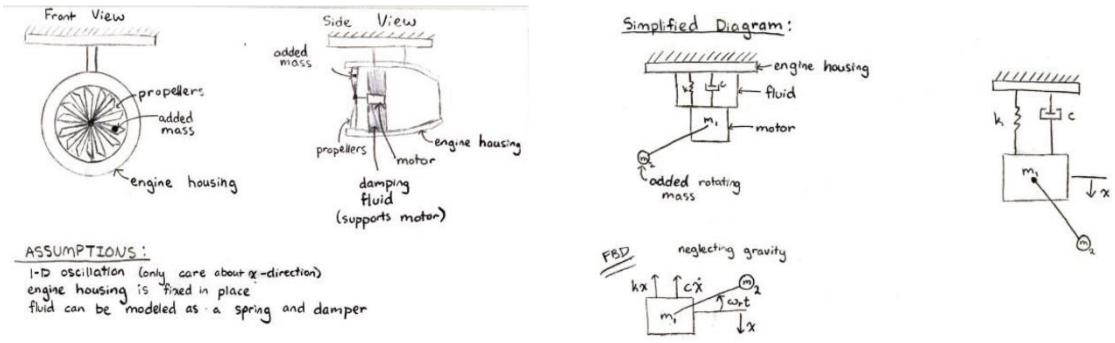


Figure 3: An example of individual brainstorming from a Mechanical Vibrations course



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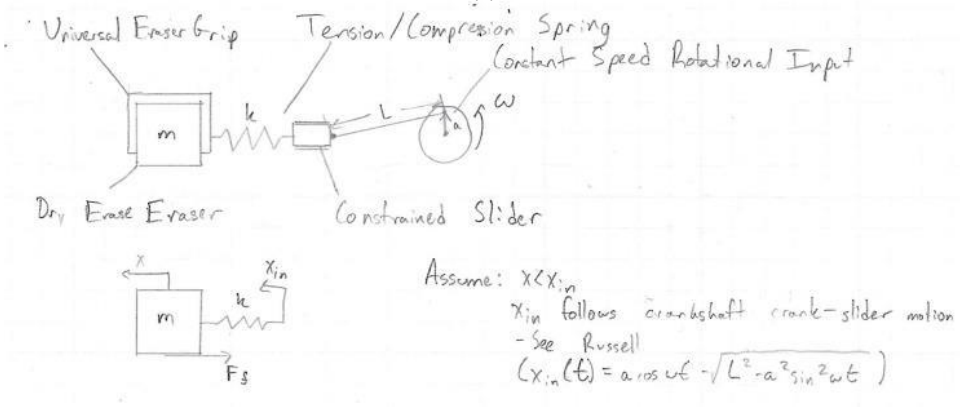

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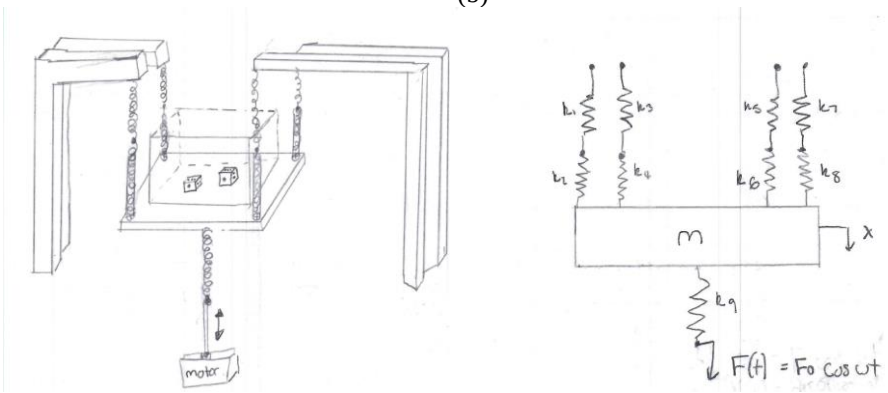
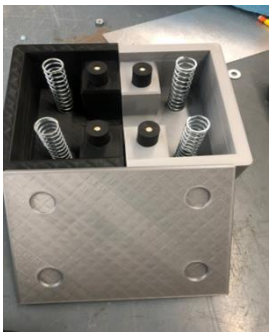


(c)

Figure 4. (a) modeling an unbalanced turbine (b) modeling of a assisted dry-eraser (c) modeling of a dice roller, all taken from a Mechanical Vibrations course.



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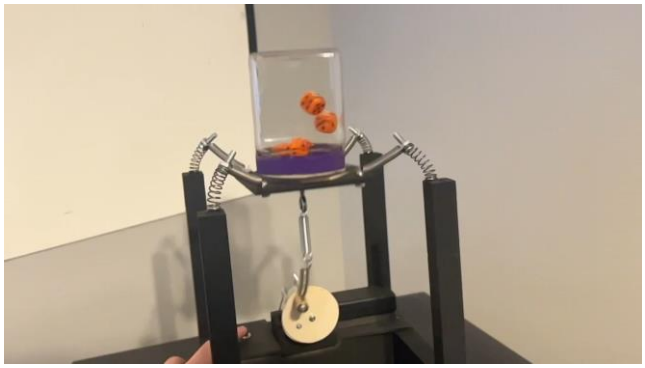


(c) (d)

Figure 5. Examples of student prototypes built for the Mechanical Vibrations course: (a) Blender Vibration Reducer (b) Baby Crib (c) Anxiety Relief Vibrotactile Bracelet (d) Automatic Dice Roller

To enhance their mindset-learning skills, the students were required to engage in reflection at various stages throughout the project including upon completion of the project. The goal was to reinforce the real-world aspects of design, non-technical characteristics that could have outsize impacts on a final product. These reflections also helped students reinforce some of the non-technical skills required to create a successful design. They were encouraged to consider the following questions, among others.

1. Who was the intended target market for your product?

2 How did your product offer additional value for this market?

3. What type of marketing and product placement would most benefit your proposed product?

4. What effect does your target market, and proposed timeframe for prototype delivery have on your design decisions, from an engineering, manufacturing, distribution, and marketing standpoint?

5. What impact does marketing have on engineering design throughout the development process?

6.What further opportunities would you have addressed if you had additional time?

The reflections were informative in a surprising way; after having described and used “creating value” with students throughout the semester, the term showed up in a surprising number of reflections, despite not being specifically prompted to discuss this element. It indicated that students internalized discussions about mindsets to at least a moderate degree.

Survey Questions and Results

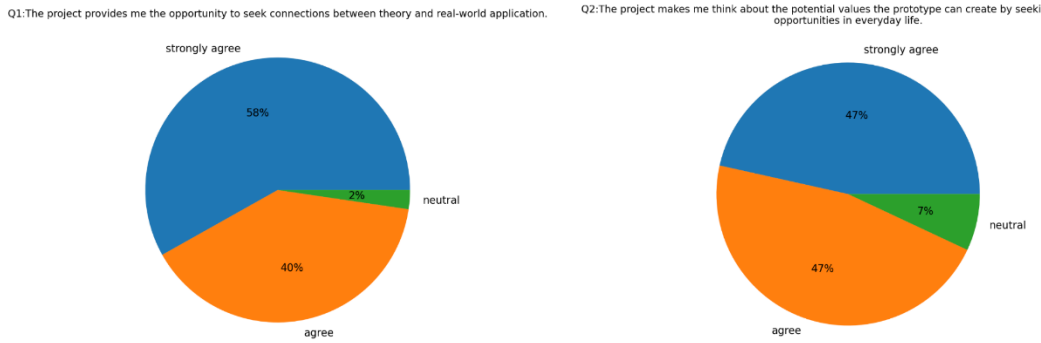
A survey was created and conducted at the end of the Spring 2022 semester to gain a better understanding of the students’ experience from the EM based project. A total of 43 students enrolled in the mechanical vibrations class completed the survey. The questions in the survey are listed in Table 1.

Responses to the survey questions were on a 5-point Likert scale (5 – strongly agree, 4 – agree, 3 – neutral, 2 – disagree, and 1 – strongly disagree). Figures 6 (a), 6 (b), and 6 (c) represent the results of Q1 to Q3 respectively.

As shown in Figure 6 (a), approximately 98% of students surveyed either strongly agreed or agreed that the project provided them with the opportunity to seek connections between theory and real-world applications. The responses of Q2, shown in Figure 6 (b), illustrated that 94% of students surveyed either strongly agreed or agreed that the project made them think about the potential values their prototypes could create by seeking opportunities in everyday life. The responses to Q3, shown in Figure 6 (c), demonstrated that 81% of students strongly agreed or agreed that the projects in the class made them more curious about everyday vibrations and how they were modeled. Overall, the results verified that the inclusion of an entrepreneurial mindset project into a traditional core mechanical engineering course can stimulate students to achieve both technical and EM mindset goals. Through the project, students went beyond the typical technical learning outcomes and developed skills that will benefit them throughout their careers.

Table 1: Post-Course Likert Survey Questions

Q1: The project provides me the opportunity to seek connections between theory and real-world application.
Q2: The project makes me think about the potential values the prototype can create by seeking unexpected opportunities in everyday life.
Q3: The project makes me curious about vibrations examples in everyday life and how to possibly model them.



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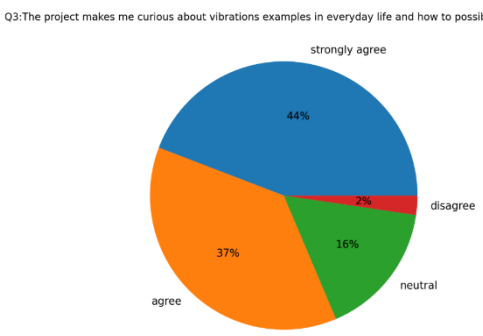

(c)

Figure 6. Survey responses distributions (a) Q1 responses distributions (b) Q2 responses distributions (c) Q3 responses distributions.

Conclusion

A core, junior-level Mechanical Vibrations course in the mechanical engineering curriculum was redesigned to include a hands-on project that incorporated prototyping and the entrepreneurial mindset. The projects required that all aspects were verified using traditional theoretical relationships, were modeled using a variety of simulation tools, were physically built and experimentally verified, while also marketed and validated as profitable endeavors based on real-world data. The projects were implemented by three different instructors using three different course delivery modalities. Based on the results, students were found to have made meaningful technical and mindset gains through these projects. Project will be expanded to additional classes to further evaluate the effects of implementing entrepreneurial mindset-based learning on student performance and engagement.

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Appendix: Team Contract

Team Name: _____

Teams can be an effective aid to learning, but to work best they require that all team members clearly understand their responsibilities to one another. These team ground rules describe the general responsibilities of every member to the team. Your team is required to add two additional ground rules that your team believes are needed. Your signature on this contract form signifies your commitment to adhere to these rules and expectations.

Team Member Communication

We agree the ways we will communicate with each other are: _____

Team Member Responsibilities

All team members agree to:

1. Come to team meetings on time.
2. Come to team meetings with assignments and other necessary preparations done.
3. _____
   _____
4. _____
   _____

Team Consequences

If a member of the project team repeatedly fails to meet these ground rules, other members of the team are expected to take the following actions:

Strike 1: If there is a persistent problem:

_____

_____

Strike 2: If not resolved:

_____

_____

Strike 3: Bring the issue to the attention of your instructor.

I reserve the right to make the final decisions to resolve difficulties that arise within the teams. However, an inability to work in groups under reasonable circumstances will also color how I view everyone's ability to work on a team. Therefore, it is in your best interest to work in good faith to try to resolve any group dynamics issues; involving the professor should be regarded as the absolute last resort, or "nuclear option".

The undersigned team members agree to the terms of this team contract.

Member's Names:	Member's Signatures:
1. _____	1. _____
2. _____	2. _____
3. _____	3. _____
4. _____	4. _____