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Building a Framework of Open-Ended Project Ideas and Entrepreneurial Mindset for First-year Student Teams

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Abstract

This Complete Evidence-based paper describes a long-term effort of building a framework for guiding first-year student teams through open-ended project directions and development of entrepreneurial mindsets, aiming to enhance the students' creativity, collaboration, and problem-solving skills in early academic stages.

Open-ended projects are assignments that allow for a high degree of freedom in how students approach and solve a problem. Compared to traditional, well-defined projects with specific instructions and clear outcomes, open-ended projects present much broader real-world problems without a predetermined solution. This would encourage students' creativity, critical thinking, problem-solving, and innovation, as students must define the problem, decide on a particular approach, explore various potential solutions, and finalize an optimal solution. Studies showed that open-ended projects increase student engagement and motivation, especially in STEM fields. Students' feedback showed that they enjoyed the creative freedom and the ability to work on projects that are meaningful to their personal achievement and communities.

The framework offers a structured roadmap for picking project ideas, allowing students to explore diverse project topics including sustainability and accessibility topics, while receiving mentor support in project ideation. Key components include scaffolded milestones and instructor oversight. The ultimate goal is to balance autonomy and systemic guidance. The framework was implemented in 66 first-year student teams in Spring 2024. The assessment includes a final project presentation and showcase. Results indicate that the proposed framework could effectively encourage critical thinking and creative work. This study provides valuable insights into the design of open-ended project structures for academic institutions.

Introduction

In today's rapidly changing industry, engineering graduates need to possess both technical and professional skills in order to maximize their employability. To meet labor market expectations, accreditation organizations around the world require engineering schools to include professional skills such as systemic thinking, communication, collaboration, problem solving, and critical thinking. The Accreditation Board for Engineering and Technology (ABET) provides a framework that demands students to build broad professional abilities while considering a variety of restrictions and designing applications that go beyond technical content understanding [1].

Including framing engineering in a larger social perspective will also aid to retain students who identify as female or from other underrepresented minority groups, who have been proven to be more sensitive to the link between engineering and enhancing people's life [2,3]. According to Christensen and Ernø-Kjølhede [4], the engineering education community globally values socio-technical thinking and capabilities. According to research on the benefits of incorporating socio-technical abilities into engineering courses, engineers must be deliberate and careful while developing solutions to real-world challenges [5,6].

While most engineering graduates have a strong technical foundation, they lack the broad 21st century capabilities and professional skills required to handle complex, real-world situations. Winberg et al. [7] raised concerns about engineering graduates' work preparation and identified 'interaction skills' as one of the essential graduate abilities that are still underdeveloped. Furthermore, Sumanasiri et al. [8] expressed worry about graduate employability, indicating that despite existing procedures inside universities to promote employability, the situation remains difficult and lacks enough clarity. Several other studies have stressed the need to provide graduating students with professional skills to face real-world issues [9-11].

The utilization of team projects is based on the implicit idea that grouping students together will naturally foster collaborative behavior, cooperation, and team-building abilities, as well as discipline-specific knowledge. However, studies have revealed that assigning students to teams in a "sink or swim" approach [12] may have minimal influence on learning course content or learning about teams and team growth. Other research has highlighted issues that impede team success, such as social loafing, labor specialization and discrepancy in learning, transactional and opportunity costs, grade fairness, and the suppression of individual originality and innovation. McCorkle et al. discovered that social loafing is the primary reason students detest group tasks [13].

Labor specialization is a common cause of social loafing. When teams divide tasks among themselves, students with a poor goal accomplishment orientation may evade their responsibilities. Labor specialization also reduces group interaction and students' knowledge of the project's scope and complexity [14,15]. Specialization can lead to inconsistent learning outcomes and limit students' understanding of their peers' accomplishments [16]. According to Hall and Buzwell [17], free riding can be unintentional and caused by students' primary language not being the language of instruction, putting additional strain on students who must deal with project requirements as well as weak communication skills.

People create reputations in both educational and professional situations when they feel a person can do tasks well while also being helpful and cooperative with others [18]. However, issues with division of labor, free riding, opportunity, and transaction costs persist. According to Neu [15], high-performing teams deal with these issues proactively as well as reactively. Students respond to labor disparity by doing extra work. They address inequality proactively by denying students assignments that could negatively affect the group's performance. To put it another way, group members designate a member as untrustworthy if they feel that person will do future injustice.

In order to prevent dealing with unfairness later, team members proactively take on more responsibilities. They assign work according to trustworthiness and divide it out according to ability. Therefore, students, who are really interested in addressing social loafing and transactional costs, are the ones who gain the most from teamwork.

In New York University, an entrepreneurial mindset mentoring course was implemented in the first-year teaching in Spring 2024. There is no requirement regarding prior knowledge or skills of engineering design before taking this course. The novelty of this study lies in the students are not just solve real-world problems using the framework of Entrepreneurial Mindset In The First Year (EMIFY), but seek for broader impact of their work by incorporating National Academy of Engineers (NAE) grand challenges into their problem statement, and provide an effective solution within a time-constrained (one semester), budget-constrained ($100), and collaborative (group project) environment.

Methods

The entrepreneurial mindset amplifies the technical skills engineers already have. By combining EM with these skills, students are equipped to: Recognize and identify opportunities; Focus their impact; Create value in any context.

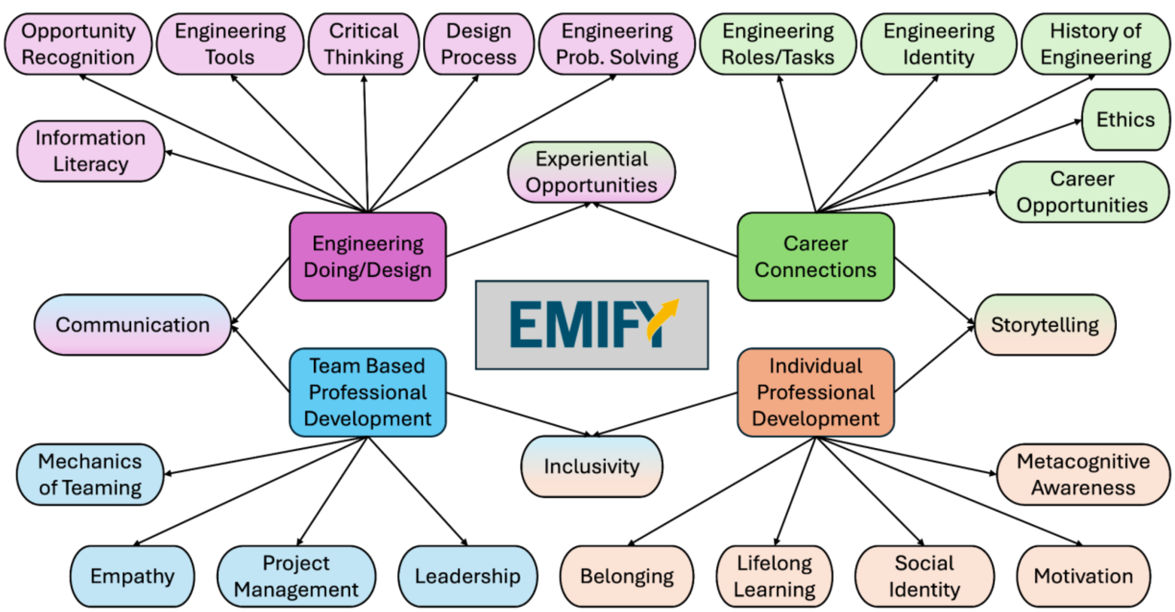


Figure 1. EMIFY infrastructure by Engineering Unleashed.com [19]

The course structure comprises three critical elements: lecture, recitation, and semester-long design project. Lectures give out introductory information on how to be an entrepreneur and the resources available for students. The semester-long design project is the main activity in which student groups work as a team to create a prototype. The recitation is the venue where the student groups report their weekly progress.

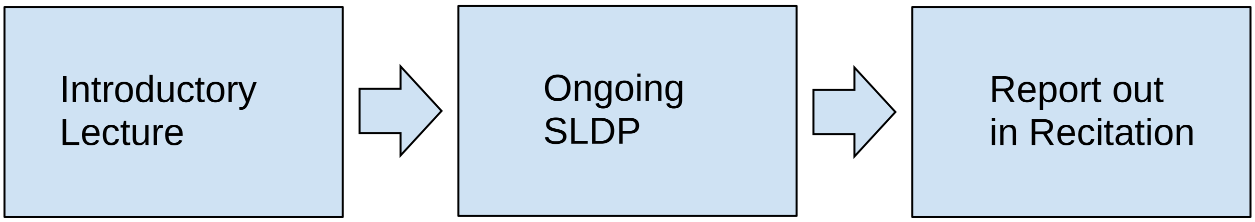


Figure 2. Instruction workflow of three elements

Scenario

The National Academy of Engineers (NAE) are looking for concepts for prototypes that solve any of the fourteen NAE Grand Challenges, which are divided into four cross-cutting themes: sustainability, health, security, and the joy of living.

Project Specifications

Those that respond to this challenge develop a tangible prototype and sales case for their product. The prototype could be new technology or an enhancement to an existing one. Each project will receive a $100.00 purchasing allowance for prototype components. A TA mentor will be appointed to help establish the project's scope, allocate duties, and manage purchasing requests. Each project must complete two benchmark assessments: A and B. Three milestone presentations will be delivered throughout the semester. They should demonstrate steady progress throughout the duration of the 10-week project, including component and later prototype testing. The project will be completed with a final submission and presentation. The prototype must finish commissioning. The project will culminate with a final submission and presentation. Professors will judge prototypes at the conclusion of the semester, with the best projects receiving a reward.

Milestones, Benchmarks, and Deliverables

As the project advances, three Milestone presentations will be given during recitation. All items assigned to Milestone are referred to as benchmark deliverables. These deliverables often consist of written submissions, presentations, and demonstrations. Furthermore, the mentor's established benchmarks must be met, and reports/deliverables that contribute to the project's development and completeness must be submitted. The 3D Printing and Logo Guide page contains information about 3D printing requirements and guidelines.

Concept mapping

Concept Maps (CMaps) are a strong research-based learning tool that allows students to reflect on, visualize, and communicate their understanding of a topic. Cmaps are extremely useful because they allow students to expand their semantic memory network and make new connections between concepts. Cmaps are particularly useful as assessment tools since they demonstrate the breadth, depth, and interconnection of students' knowledge of EM (Entrepreneurial Mindset). They can indicate changes in conceptual understanding over time and evaluate the efficacy of educational programs. Concept maps are a brief and adaptable classroom activity that can be done once to obtain a snapshot of EM or often during a course to track how students' understanding of EM changes in response to instruction.

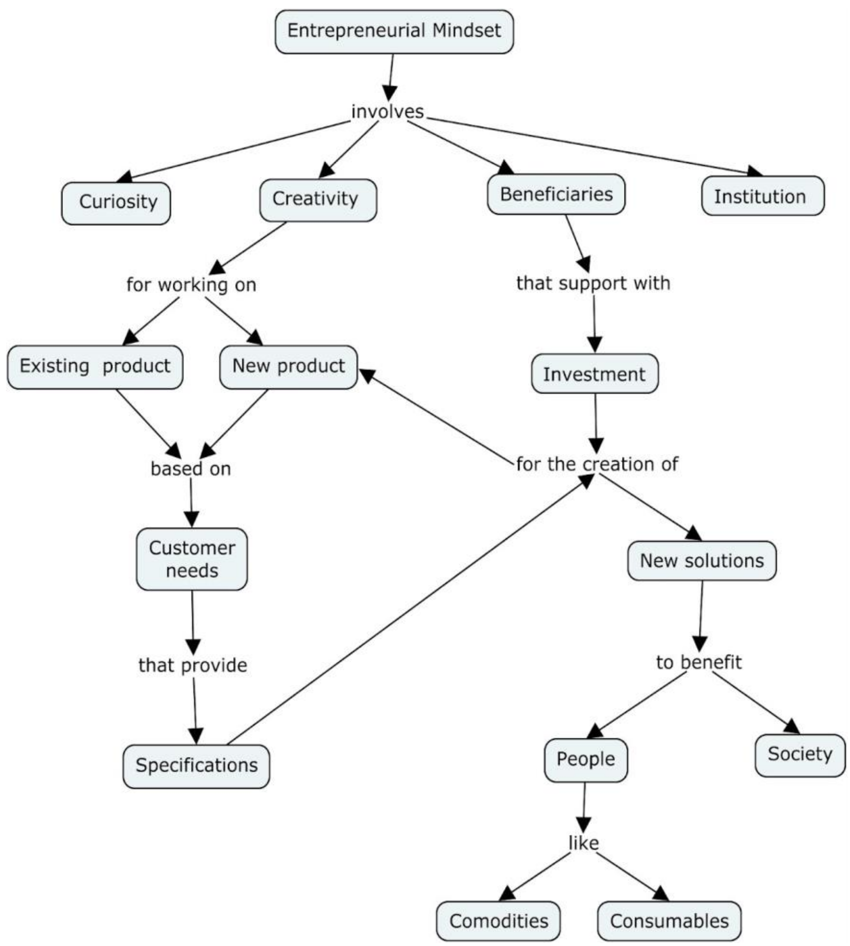


Figure 3. CMaps by Engineering Unleashed.com [19]

In this class, the instructor implements four major CMaps elements in the course:

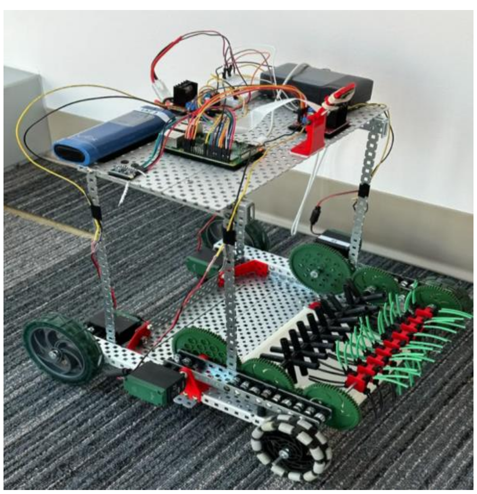
Creativity: The recitation instructors provide the presentation slides with content of entrepreneurial mindsets and creativity. Previous project examples are given in the recitation to provide idea templates (Figure 4). For example, the instructor would use Figure 4(a) to demonstrate the advantages of the robotic system to facilitate golf ball picking in the driving range. The instructor would encourage the students to explore the novelty, cost, and business model of selling such a device in the market. A thorough literature review was conducted to justify the novelty of the service robot.

Curiosity: In Week 1 of spring semester 2024, the recitation instructors would give lectures on how to select the topics of interest for their group projects. First, the instructors showed all the emerging global topics on the slides, and presented NSF ten big ideas: to understand the partnership between human and technology; develop new technologies to augment human performance; understand emerging socio-technological landscape and understand the risks and benefits of new technologies; the impact of artificial intelligence on workers and work; foster lifelong and pervasive learning [20]. Then the instructor connects those emerging technologies and topics with the students' intended majors in the engineering school and allows them to see how the technologies could impact their major selections. The students were then asked to pick the top three technology ideas they would like to work on.

Customer needs: The recitation materials include the topics of entrepreneurship in Week 8, four weeks before the final presentation. The concepts of business canvas, stakeholders, customer segments and product propositions were introduced to the students [21].

New Solutions: In Week 2, The instructor suggested the students conduct a comprehensive literature review to understand the current market landscape. The search tools are Google, Google Scholar, and Amazon. The students need to present at least 10 commercialized products.

(a) Robotic project



(b) Physical Prototype

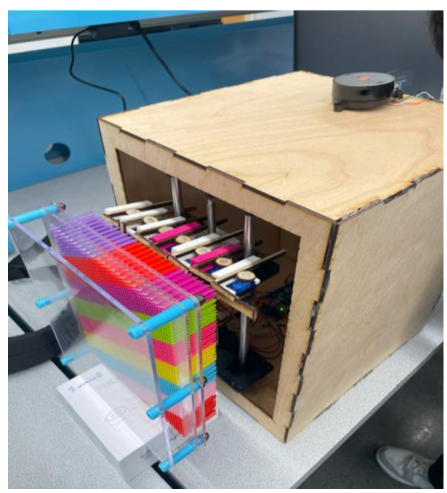


Figure 4. Previous design example, (a) Service Robot to pick up golf balls, (b) a terrain scanning device for people with blindness.

Results

The student project showcase happened at the end of the semester. Figure 1(a) shows an example teaching slides, and Figure 1(b) shows the project team competition in the auditorium. The competition rubrics are shown in **Table 1**.

(a) Example of teaching slides

(b) Showcase competition

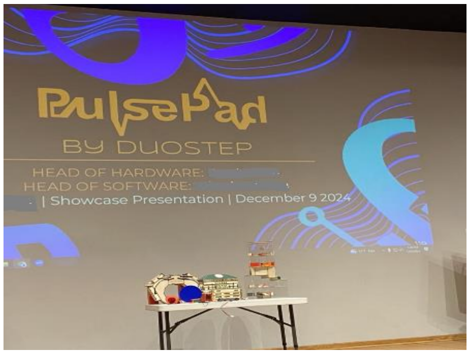


Figure 5. (a) Discussion slides on product marketing, (b) "Company" presentation in the auditorium

Table 1. Detailed Rubrics for Semester-long Design Project

Elements	Grading Rubrics
I. Introduction	• What are you trying to do? Articulate objectives using absolutely no jargon. The presentation should open with a clear and concise description of the project that provides the audience with a foundation from which to understand the remaining presentation content.
II. Innovation	• How is it done today, and what are the limits of current practice? • What is new in your approach and why do you think it will be successful? Innovation will be measured by how the presentation explores the many different aspects of the problem. Teams will show that they considered the problem from multiple perspectives (technological, social, economic, political, computational, design, etc.) and have made efforts to incorporate ideas from different fields.

III. Broader Impact	• Who cares? If you are successful, what difference will it make? Broader impact will be measured by how well the project is contextualized and motivated by its connection to stakeholders who would benefit from the new approach (social, economic, political, computational, design, etc.).
IV. Viability	• What are the risks? • How much will it cost? • How long will it take? Viability will be measured by how well the concept is demonstrated and how much consideration and effort has been taken to transform the proof of concept into an implementable solution.
V. Evaluation	• What is the midterm and final "exams" to check for success? Evaluation will be measured by how the project and approach are stated to be evaluated during the development and at the completion of the project or approach.
VI. Communication	The team's presentation was organized, clear, enthusiastic, provided useful visuals, and kept the audience engaged.

The student survey was conducted at the end of the semester. The survey includes the following five questions:

1. The course improved my ability to plan and execute an engineering project.

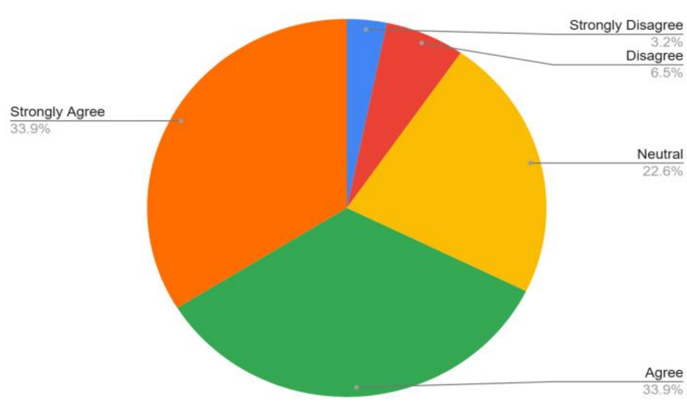


Figure 6. Students' feedback on the course

2. Please rate the level of difficulty you experienced in completing technical tasks for Benchmark A, Benchmark B, and Commissioning.

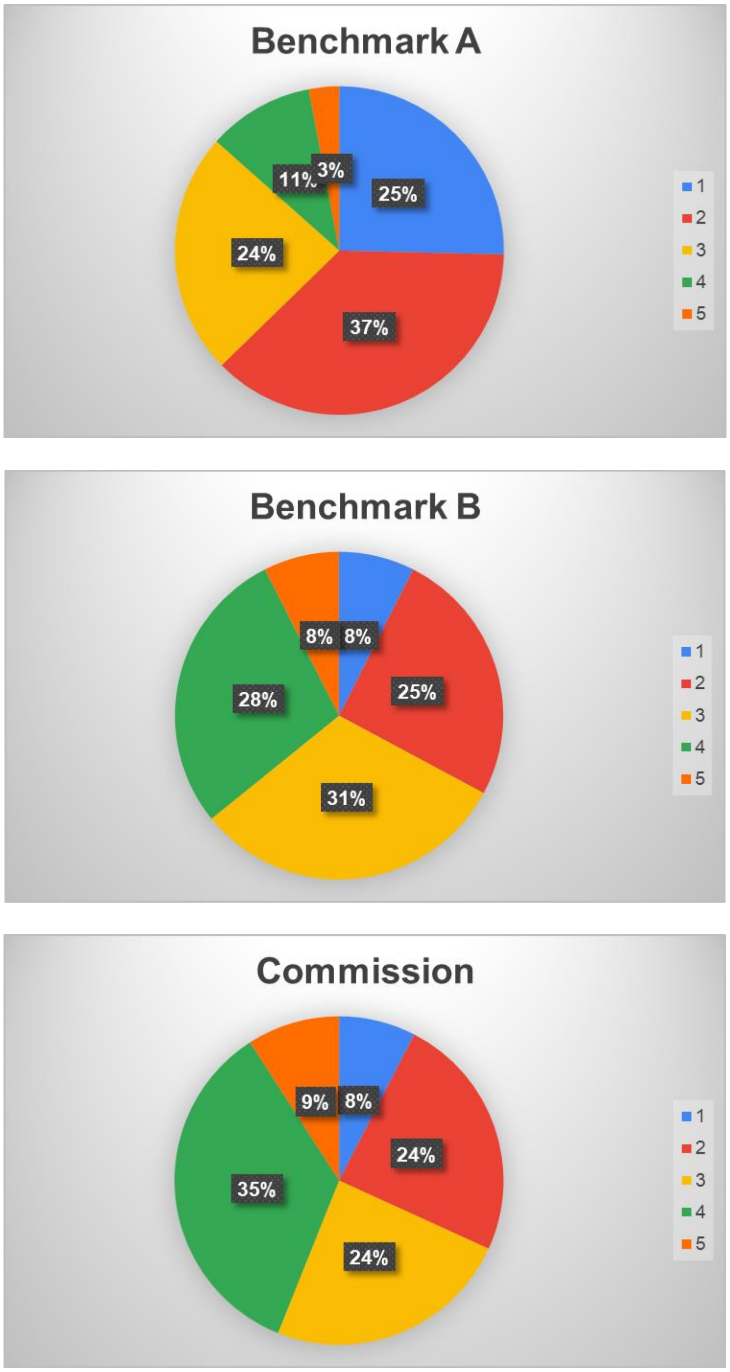


Figure 7. The student's perception about technical difficulties on Benchmark A, B, and Commission.

3. Please elaborate on your experience working on your SLDP this semester. How did you and your teammates manage your time and tasks? What did you take away from the experience, and what were your major challenges?

Table 2. Student Responses from the Course Survey

I **enjoyed working on my SLDP**, as I learned a lot about teamwork and project design. My teammates and I manage our time by consistently communicating with each other in an online group chat. I took away the idea that engineering is more about knowing concepts; rather, it's also about communicating with others. Some major challenges we experienced included commissioning, which took a while to complete.
Communication **helped manage the team's tasks and deadlines**. Executing an innovative idea was new and interesting.
My SLDP performance this semester **was overall pretty fun**. Everyone in our group accomplished their required tasks and we all did what we needed to. We created a group chat and also all got along with each other which made communication easier. I think I took more away from working with people for a very long time because this is the longest I've worked with people on a project, so it gives a bit of insight into working with a team in a job. **Our major challenges were all related to getting the main function of our project to actually work** and fix coding errors and wires not working.
I managed my teammates and tasks. My major takeaway is to plan your time well and my major challenges were making sure my teammates knew what they had to get done and by when or else we would likely not have been able to fulfill benchmarking a couple times

Discussion and Conclusion

To summarize, the group projects allow students to have immersive experience in starting a new company with product pitch. The lecture component gives students introductory information on the concept of entrepreneurship. The semester-long design component allows students to work collaboratively and continuously on an innovative team idea. Bi-weekly recitations act as benchmarks for instructors to check in group progress.

The first-year students need comprehensive guidelines on three topics: prototyping building, teamwork, as well as project presentations. Some students may not have prior knowledge on mechanical design or electrical circuits. Therefore, it would take two weeks on average for them to learn and apply the skill sets onto their projects. Many students felt the engineering projects were overwhelming and fast-paced. The future plan is to implement a structured technical workshop to assist students' learning.

In terms of teamwork, some students are having issues in team communications. First-year students frequently lack significant experience with group projects, so they may struggle with essential collaborative skills like communication, task delegation, conflict resolution, and time management when working in teams, potentially leading to uneven contributions and frustration within their groups. The project progress could be significantly delayed because of some miscommunications between team members. If miscommunication cannot be resolved in a timely manner, it could adversely affect mutual trust between team members. It is possible to use AI agents to monitor the team dynamics and provide constructive feedback as well as suggest intervention strategies to the instructors.

The third topic is project management. First-year students generally lack considerable project management expertise because they are new to higher education and have not had the opportunity to work on sophisticated projects that involve organized planning, task delegation, and deadline management, all of which are essential components of project management. Most high school projects are lower in scale and may not require the same amount of organization and accountability as larger, multifaceted ones in college. Students may not be familiar with project management software or tools such as Trello, Asana, or Gantt charts, which are commonly used to track project progress. While first-year students may have fundamental organizational abilities, they still need to learn risk assessment, stakeholder communication, and dispute resolution. All those advanced skills could be introduced by the instructors in the recitation.

To sum up, a streamline engineering design course with entrepreneurial focus was developed to help students understand engineering applications and develop essential skills in preparation for their future careers. During this course, the students were able to participate in different formats of learning: lectures, recitation, as well as group projects. All the course elements were structured organically to facilitate the students' project-based learning. Lectures provide students with an overview of how to become entrepreneurs as well as the tools available to them. The semester-long design project is the primary activity in which student groups collaborate to develop a prototype. The recitation is when student groups present their weekly progress. At the end of the semester, the students were able to deliver presentations in a simulated company setting and showcase their physical prototypes. There are three major directions for improving this workshop: technical skills development workshop, more support on team building and communication, as well as better project management.

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