Full Paper: Bringing Innovation and Open-Ended Problem Solving to the Classroom

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Introduction

Engineering graduates must be prepared to address challenges that extend beyond well-defined textbook problems. As they enter a dynamic and evolving workforce, students must develop the ability to navigate real-world, open-ended problems using both technical knowledge and creative thinking. National initiatives such as the National Academy of Engineering's Grand Challenges [1] and the ABET student outcomes [2] highlight the need for innovation, teamwork, and the application of knowledge in unfamiliar contexts. Meeting these expectations requires intentional integration of problem-based learning [3, 4] and opportunities for creative exploration, particularly in the early stages of the engineering curriculum [5].

The FIRST organization is a global robotics community that promotes STEM education by helping students build technical skills, confidence, and resilience. In the FIRST LEGO League program (FLL), students work in teams to build and program LEGO robots to complete themed game missions, while also developing innovative solutions to real-world problems aligned with that year's theme. Drawing inspiration from this model, the First-Year Engineering Program (FEP) adapted the structure into a 12-day project within an Introduction to Engineering course. The primary goal was to cultivate innovation, open-ended problem-solving, and teamwork through hands-on, collaborative activities. This paper presents the structure, implementation, and outcomes of the project, with a focus on student engagement, learning outcomes, and examples of final deliverables.

Project Structure and Learning Outcomes

For many years, the First-Year Engineering Program (FEP) has incorporated a robotics project into its Introduction to Engineering courses. While the project has offered valuable hands-on experience, as well as opportunities to practice programming and teamwork, it was constrained by rigid game rules and limited time, which restricted problem-solving. In summer 2023, the robotics project was redesigned and expanded to include the open-ended innovation component.

The expanded 12-day robotics project is designed to engage first-year engineering students in both innovative thinking and hands-on problem solving. The project is divided into two major components: an innovation component and a robotics component. In the innovation component, teams are guided to identify a real-world problem and develop a potential solution. In the robotics component, teams must program and test a LEGO robot to complete specific missions within time constraints. FLL 2022-2023 Season: SuperPowered™ [6] was chosen as a base because the energy theme is relevant to a variety of engineering majors for the innovation component.

On Day 1 of the project, students are assigned to teams of six and begin the project by completing a team contract that outlines expectations for collaboration, communication, individual responsibilities, a project timeline, and plans for conflict resolution. This step helps set the tone for shared accountability and effective teamwork throughout the project.

A key focus of Day 1 is giving students flexibility to define their energy problem and choose to work on the innovation component, robotics component, or both. Offering choice encourages students to engage with topics that are meaningful to them, draw on their unique strengths, and bring their own perspectives to the project. This approach not only supports a more equitable learning environment but also creates a deeper sense of ownership and motivation [7].

Day 2 to 12 of the project is outlined in the Innovation Component and Robotics Component sections below. Both pathways allow students to show mastery of the same learning outcomes:

1. Collaborate effectively within a team and demonstrate shared responsibility.
2. Develop and apply written and verbal communication skills.
3. Engage in thoughtful analysis and self-reflection throughout the project.
4. Identify and address open-ended problems using creative and analytical approaches.
5. Apply the steps of the engineering design process to develop and evaluate solutions.
6. Manage tasks, deadlines, and team responsibilities across a multi-component project.

Innovation Component

The innovation component of the project allows students to be creative, practice critical thinking, and connect classroom work to real-world applications. Each team selects one of four energy-related themes: Renewable Energy, Hydroelectric Energy, Energy Cost, or Energy Flow. Individually, members complete a brainstorming assignment, identifying real-world problems and proposing innovative solutions related to their theme. In the next class, each member presents their best idea, and the team selects one idea to pursue. The team then writes an opportunity statement describing the current situation, the issue to address, and why the opportunity is worth pursuing. This statement is reviewed by the instructor before the team moves forward with the project.

Next, team members focus on either the innovation or robotics component of the project. The team then creates a news article explaining the problem their project addresses, clearly presenting technical details, and highlighting the significance and potential impact of their solution. A more in-depth research phase follows, where teams investigate existing solutions, gather consumer feedback through in-person or online surveys, and conduct an interview with an energy expert (AI energy company CEO) via an interactive tool in the course's Blackboard Ultra learning platform [8]. Using the results of their research and interview, the team writes a two-page or less summary paper outlining the currently existing solutions, feedback questions and results, and their takeaways from the CEO interview.

With this foundation, the team begins designing their innovative product by completing a Project Design Canvas. This outlines how the product works, its function, its impact, how it differs from existing solutions, and includes a detailed sketch. The project concludes with a poster presentation, where teams showcase their product and give a 2–3 minute talk. To encourage participation, each student completes online feedback forms for at least two other teams' posters.

Robotics Component

To ensure all students gain basic programming skills and understand the robotics component, a brief "Driving Basics" module is completed before the SuperPowered project begins. In pairs, students use a LEGO Spike Prime robot, which has a graphical programming interface [9] and complete Training Camp 1: Driving Around to learn and demonstrate basic movements like driving and turning. They also complete a quiz to confirm their understanding of the coding.

After teams of six are formed for the bigger project, teams often select two or three members to be responsible for the robot component while the remaining members focus on the innovation component. Those that are focused on robotics complete the "Advanced Driving" lesson. This consists of *Training Camp 2: Playing with Objects* and *Training Camp 3: Reacting to Lines* [9]. *Training Camp 2* shows students how they can use an ultrasonic sensor to stop the robot at a specific distance and engages a third motor to raise and lower an arm to grab an object. *Training Camp 3* utilizes a color sensor to stop at or follow a black line on the mat.

Once students have displayed their understanding of these basic operations of the robot, they are shown the SuperPowered™ mat and game rules [6]. The FLL SuperPowered™ game is played on an 80" x 45" mat which sets in the middle of an 8' x 4' table which has a wall made from 2" x 4" lumber on all four sides. The game mat consists of two quarter-circle launch areas and is covered with various mission models. Mission models represent aspects related to the energy theme and provide different ways for the robot to interact to score various points.

Teams submit a Mission Plan of which missions they intend to complete and how much they expect to score and a Robot Path Diagram where they draw out how the robot will execute that plan on the board. Teams then have four class periods (plus the ability to work specific times outside of class) to modify their robot, develop code, and test their missions. At the end of each of these class periods, teams submit a log detailing what they worked on, what issues they came across, and plans for the next class. These serve as an update to teammates focused on other areas and for instructors to track progress. During the week before the end of the semester, teams complete a practice competition run timed and scored by the instructor/course assistant to check their progress and make sure they understand the rules before the competition day. They submit a Practice Round Reflection to note any changes they may need for the competition.

During the penultimate class of the semester, the programming focused part of the project culminates in the FLL SuperPowered competition. Each team is given two attempts of 2 minute and 30 second matches. For scores to count, teams must attempt at least four missions. Each team's best score is compared against teams across all class sections. A portion of the team's grade is dictated by how they scored relative to the best overall team and the overall average. The top teams in each section and the overall highest scoring team receive bonuses. All team members are required to attend class on robot competition day (even if they mainly worked on the innovation component.) The final day of class is used to reset the robot to the original driving base while returning and sort extra parts back to their cabinets. Points are assigned for this process to make sure all team members participate.

Student Reflection and Feedback on Project

Students were offered 50-points bonus to fill out an end-of-semester survey which included 15 questions about the project.

1. The project in this class improved my engineering problem-solving skills.
2. The project in this class improved my ability to communicate solutions to engineering problems.
3. The project in this class helped me appreciate the multi-disciplinary nature of engineering.
4. The project in this class helped me appreciate the role of engineering in modern society.
5. Which part of the project did you primarily work on?
6. I had a good experience with my team and project.
7. I would have had a better experience if I had worked with different teammates.
8. Our team was able to easily overcome disagreements/challenges.
9. All members of our team contributed to the project in some way.
10. Please tell us any additional feedback you have about your teammates on this project.
11. I would have had a better experience if I had worked on a different project.
12. What do you think was the most challenging aspect of your project?
13. What are three skills that you think are improved in yourself as a result of participating in the project?
14. Please list three things you enjoyed about the project.
15. Please list three things you disliked about the project.

In the Spring 2025 semester, 428 students took the survey. While most students answered all questions, there were some “unanswered” responses in each question since Blackboard survey assignment does not mandate students to complete each question before submission. As discussed earlier, students were given the choice to pick their responsibilities for the project. The results of the students’ choices are collected with question 5: 201 students reported that they worked on Innovation component, 166 on the Robotics component, and 27 worked on both parts of the project.

The responses to questions 1 – 4, 6 – 9, and 11 were reported in Likert scale and are summarized in Figure 1. Questions 1 – 4 focus on long term benefits of the project on student’s gain of basic skills associated with engineering and student’s appreciation of engineering. Looking at the figure, there is clear support that the students agreed or strongly agreed that the project improved their problem-solving skills (79%), their ability to communicate (82%), their appreciation of multi-disciplinary nature (77%) and the role of engineering in modern society (78%). Questions 6 – 9 and 11 focus student’s experience with their team. The overwhelming majority (86%) of students agreed or strongly agreed that they had good experience with their team and project. When asked more about teammates and contributions to the project, the responses were mostly supportive of team environment. Only 22% of the students agreed or strongly agreed that they would have had a better experience with different teammates, 89% agreed or strongly agreed that their team was able to easily overcome disagreements, and 17% agreed or strongly agreed that they would have had a better experience if they worked on a different project.

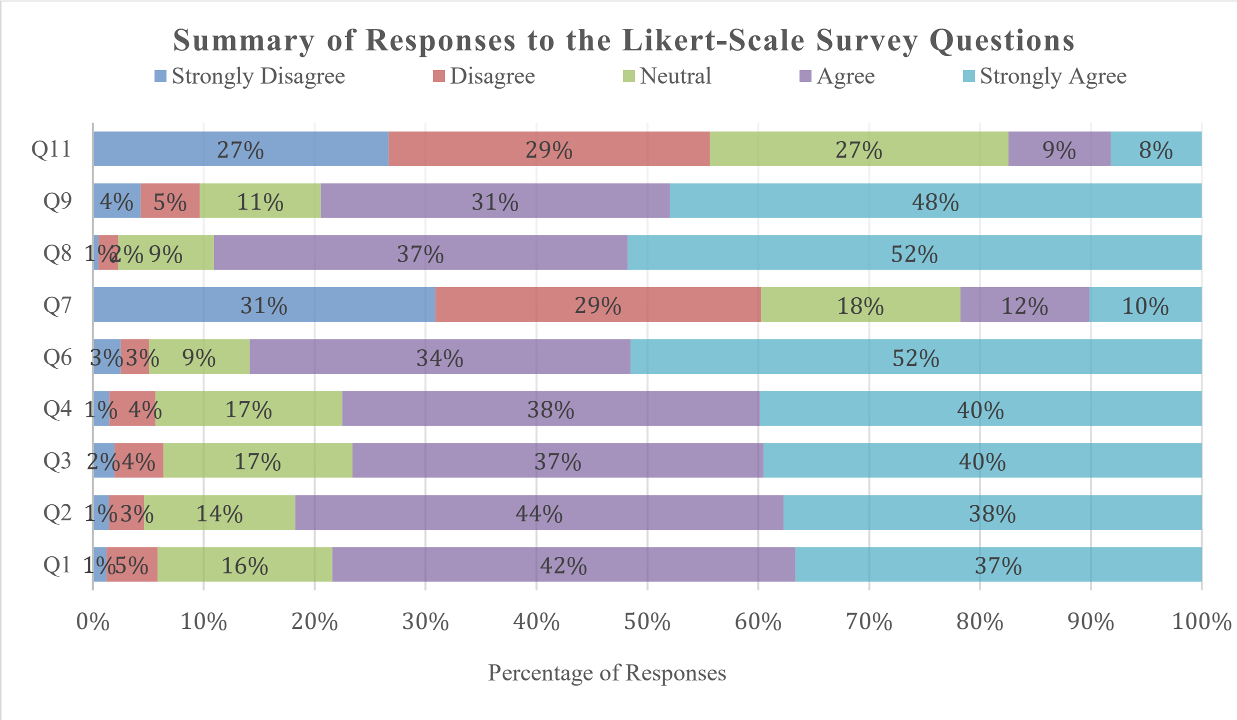

Figure 1. Students' responses to the Likert-scale questions 1 – 4, 6 – 9, and 11.

Open-ended questions 12, 13, 14 and 15 received a large variety of answers. We got help from AI to summarize the results. When asked about the most challenging aspect of the project, several themes emerged. These themes and some common responses are summarized in Table 1.

Table 1. Main themes emerged within the responses to "the most challenging aspects of the project" question.

Theme	Description of Challenging Aspect within the Theme
Ideation/Innovation	Difficulty generating unique, feasible ideas; avoiding duplication of existing solutions
Teamwork/Communication	Coordinating schedules, dividing work, ensuring participation, and effective communication
Technical (Robotics/Coding)	Coding challenges, robot inconsistencies, troubleshooting, lack of experience
Time Management	Limited time for project phases, balancing workload, meeting deadlines
Research/Understanding	Finding relevant information, grasping technical concepts, applying knowledge
Design/Presentation	Creating product designs, models, posters, and presentations under time pressure

As response to question 13, the project experience improved students' communication, teamwork, and problem-solving abilities, followed by time management, leadership, technical skills, research, creativity, and perseverance. These skills align closely with those identified in educational research as key outcomes of project-based and group learning.

Students most enjoyed the collaborative, hands-on, and creative nature of the project, especially when it involved teamwork, building and coding, solving real-world problems, and engaging in friendly competition. The opportunity to learn new skills and exercise autonomy in a well-structured environment was also highly valued. And, the most common dislikes centered around group-related challenges, the disconnect between project components, time and workload issues, technical frustrations with robotics, lack of clarity or guidance, repetitive assignments, and a desire for more meaningful or engaging work. These themes suggest opportunities for improving project integration, communication, time management, and student autonomy in future iterations.

Conclusion

The project effectively fostered key skills essential to engineering education, including teamwork, communication, critical thinking, and reflection. By challenging students to identify and address an open-ended problem, the experience emphasized the importance of the engineering design process while encouraging the development of analytical and organizational skills. Survey results support the project's impact: a strong majority of students agreed or strongly agreed that the project improved their problem-solving skills, communication abilities, understanding of the multidisciplinary nature of engineering, and appreciation for engineering's role in modern society. Furthermore, questions focusing on teamwork revealed that most students had positive team experience and highlighted a strong sense of collaboration and shared responsibility among teammates. These results affirm the project's success in promoting both technical and professional competencies in a first-year engineering curriculum. The authors are happy to share any of the project templates referenced in this paper with the FYEE community upon request.

References

[1] National Academy of Engineering. 2016. Grand Challenges for Engineering: Imperatives, Prospects and Priorities. Washington, DC: The National Academies Press. https://www.nae.edu/187212/NAE-Grand-Challenges-for-Engineering. Accessed 6 May 2025.

[2] ABET Engineering Accreditation Commission. 2024. Criteria for Accrediting Engineering Programs. abet.org. Accessed 6 May 2025.

[3] Greenwood, L., & Indelicato, M., & Bazdresch, M., & Eastman, M. (2019, April), *Problem-Based Learning: A Tale of Three Courses* Paper presented at 2019 ASEE Zone I Conference & Workshop, Niagara Falls, NY. 10.18260/1-2-1153-33766

[4] Wood, J. (2002, June), *Using Problem Based Learning To Modify Curriculum* Paper presented at 2002 Annual Conference, Montreal, Canada. 10.18260/1-2--11355

[5] Savilonis, B., & Rissmiller, K. (2012, April), *Great Problem Seminars: Engaging First Year Students in Project-Based Learning* Paper presented at 2012 Northeast Section Meeting, University of Massachusetts Lowell. 10.18260/1-2-1153-53238

[6] FIRST LEGO League Past Challenges. https://www.firstlegoleague.org/past-challenges

[7] ACUE learning: https://learn.acue.org/wp-content/uploads/2025/02/DC2_Choice_IG-1.pdf

[8] https://help.blackboard.com/Learn/Instructor/Ultra/Interact/AI_Conversation

[9] LEGO Spike™ Prime. https://spike.legoeducation.com/prime/lobby/