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Bridging Theory and Practice: Student Perceptions of Mini Projects in an Introductory Engineering Course

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Introduction

The First-Year Engineering Program (FEP) at the University of Arkansas was established in 2007 to support the retention and graduation goals for the College of Engineering. FEP was highly successful in contributing to the increase in retention rates; the first-year retention rate in the College of Engineering went up from 62.5% in 2007 to 76.7% in 2023. While supporting the college, students are the center of FEP's mission. We regularly reassess our program's missions, student outcomes, content, and delivery methods to meet the evolving needs of the first-year engineering students. Implementation of project-based learning in the introductory engineering courses support several of our essential student outcomes such as demonstrate critical thinking and problem solving, develop self-efficacy, work effectively with others, and decide engineering major with confidence.

Research on project-based learning in engineering courses has indicated gains in student motivation, engagement, and interest in engineering [1, 2]. These courses have been shown to improve students' self-efficacy and problem-solving skills, which are crucial for persistence in engineering majors [1, 3, 4]. Additional support for the effectiveness of active learning and project-based instruction comes from The Association of College and University Educators (ACUE) [5]. FEP instructors have recently completed high-quality and research-backed professional learning courses to earn certification in Effective Teaching Practices through ACUE. The Designing Learner-Centered Courses and Promoting Active Learning modules emphasized the benefits of these techniques on students' success and provided resources [6].

FEP's first implementation of project-based learning was in 2012. The content of the Introduction to Engineering course sequence was restructured to include a series of hands-on, team-based projects aimed at improving student engagement within the course and helping students get exposed to different engineering disciplines. The sections of the course were divided into four themes: biomechanical, computing, robotics, and structures. Students spent about half the semester working on activities and assignments associated with engineering skills, and the remainder of the semester was spent on two hands-on, theme-based projects. Students would choose one themed section in Introduction to Engineering I in the fall and a different themed section in Introduction to Engineering II in the spring, therefore experience two of the four themes. In 2020, the curriculum was updated to introduce programming in fall, which reduced the students' exposure to projects that represented different engineering majors.

After FEP faculty gained ACUE certification, during the summer of 2023, significant improvements were made to the first-year curriculum to better equip students with the skills to solve engineering problems, communicate solutions, and appreciate the interdisciplinary nature of the engineering fields, while also allowing them to make a more informed decision when declaring their major in the spring semester. Since fall 2023, the Introduction to Engineering I course features five mini projects (inspired by the original themes and expanded), which not only diversify students' experiences but also offer varied assessment methods.

Since project-based learning is highly valued in the first-year engineering education community, this paper presents five mini-projects we use in our first-year engineering classes. We describe how we set up these projects and what they cover. We also share students' experiences and perceptions of these projects. These projects can be easily used or adapted by other first-year engineering programs. By sharing these findings, we hope to offer valuable resources and insights to the broader engineering education community and support continued innovation and improvement in project-based learning methodologies.

FEP Mini Projects

Our project discussions begin with an introduction to the National Academy of Engineering's (NAE) Grand Challenges for Engineering [7]. These challenges, which address critical issues in sustainability, health, security, and quality of life, serve as a powerful source of inspiration for students. By exploring the NAE's website, students can discover challenges that align with their personal passions and interests. Each of our projects is associated with one or more of these Grand Challenges while simultaneously engaging students in various engineering disciplines. This approach not only motivates students but also demonstrates the real-world impact and interdisciplinary nature of engineering solutions.

With implementing these projects, our overall course goals for students are to apply the knowledge they learned from the engineering skills assignments, improve their problem-solving and communication skills, explore the multi-disciplinary nature of engineering, become better at teamwork and appreciate the role of engineering in modern society. Sample photos from each project can be found in the Appendix.

*Project **A**: **A**rduino Basics*

This project spans four class days and is designed to introduce students to basic circuit design and Arduino programming. Students work in teams of two.

Learning Objectives
By the end of this project, students will be able to:

1. Construct circuits from given instructions
2. Identify key components of an Arduino program
3. Modify Arduino programs to achieve specific outcomes
4. Implement effective troubleshooting strategies
5. Demonstrate effective teamwork skills

Project Structure
The project is designed as a progressive learning experience, with each task building upon the previous one. No prior programming knowledge is required. Students are guided through the process with example programs and modification instructions in class and on Blackboard.
Task Progression:

1. Basic LED Circuit: Students construct a circuit with one LED and program it to blink.
2. Traffic Light Simulation: Two additional LEDs are added to create a traffic light pattern.

3. Switch Integration: A switch is incorporated to control one of the LEDs.
4. Dimmer Functionality: A potentiometer is added to create a dimmer for another LED.
5. Light-Sensitive Circuit: A photoresistor is integrated to control LED brightness based on ambient light.
6. RGB LED Color Mixing: An RGB LED and additional potentiometer are added, allowing students to display and mix colors.

Assessment
Students' progress and understanding is evaluated based on their ability to successfully complete each task, modify programs as instructed, and troubleshoot issues that arise during the project. Once students are done with the task, they demonstrate the completed task to the instructor.

This project not only introduces students to fundamental concepts in electrical engineering and programming but also encourages creativity and problem-solving skills through practical application.

*Project **B**: **B**alsa Wood Tower Construction*

This four-day project challenges student teams to design, build, and test a balsa wood structure, while applying engineering design principles and structural analysis. The project culminates in a competition to test the strength of the structures. Students work in teams of three.

Learning Objectives
Students will:
1. Apply the engineering design process
2. Perform material property calculations
3. Utilize geometric principles in structural design
4. Develop prototyping skills
5. Analyze strength-to-weight ratios in structures

Project Structure
This project introduces students to the engineering design process. Prior to coming to class, students are directed by a Blackboard lesson to define the problem and research. For the problem definition, students are introduced to the following design specifications:
The structure must:
1. Weigh ≤ 10.0 g
2. Have at least four sides
3. Be 10" to 14" tall
4. Have a base between 4"x4" and 8"x8"
5. Include a 2" hole through its entire vertical length
6. Be constructed solely from balsa wood and glue
7. Support a minimum weight of 13 lbs (presser board)

For research, students are asked to go over the provided videos and other materials covering basics for the project (including previous Balsa Wood crush videos recorded in FEP classroom).

On Day 1, students carry out calculations and finalize their team's design on paper. They complete a design worksheet where they draw the top, side, and front views of the tower, then use geometry to calculate the total balsa wood length needed for the tower. Teams measure the length and weight of 15 balsa wood sticks and use Excel to calculate a linear density. They use these two calculated values, total length needed and linear density, to figure out the estimated weight of their tower to ensure that it is below 10 g.
On Days 2 and 3, teams build their Balsa Tower adhering to design specifications. Teams are only allowed to use super glue and balsa wood to construct the tower. They have access to cutting boards, knives, tape measures, and protractors. On Day 4, we have a fun competition day where we conduct strength tests on all towers. We put towers on a platform, lower a presser board (about 13 pounds), then we slowly add additional weights to determine maximum weight supported by each tower.

Assessment
Teams receive grades correlated to the weight their tower carries during the competition. To compete, the team's tower needs to meet all design specifications. The overall class winner receives a bonus. The overall winner among all sections receives an additional bonus.

This project integrates multiple engineering concepts including material science, structural design, geometry, and physics. It emphasizes the importance of precise calculations, adherence to specifications, and the balance between strength and weight in engineering design. The competitive element adds excitement and reinforces the real-world applicability of the skills developed.

*Project **C**: **C**oncentration Curve*

This two-day project engages students in creating a concentration curve for a drug in a pharmaceutical formulation using spectrophotometry. Students work in teams of two to establish the relationship between drug concentration and light absorbance, then apply this knowledge to determine unknown sample concentrations.

Learning Objectives
Upon completion, students will be able to:
1. Produce samples of selected concentrations
2. Understand the spectrophotometric measurement of absorbance
3. Develop an Excel workbook for concentration-absorbance analysis
4. Apply the derived relationship to determine unknown sample concentrations

Project Structure
The objective of day 1 is to create a concentration curve by utilizing a spectrophotometer to establish the connection between the drug's concentration and the absorbance of light. Before students start their experiment, they go through a short tutorial on how to use the spectrophotometer. For the experiment, students are given a "drug solution" (which is water with yellow food coloring). Students prepare initial drug solution dilution (1/16 concentration) and measure and record its absorbance. Students continue to create new solutions by creating a

dilution gradient, halving concentration each time. They measure absorbance for each dilution and record data in Excel spreadsheet. They continue until readings become negative or unchanging. As a final step, students use Excel to plot the concentration curve and add a linear trendline describing the relationship between concentration and absorbance.
The objective of Day 2 is to utilize the concentration curve established on day 1 to determine the concentration of three unknown samples. Students use the spectrophotometer to measure absorbance of three unknown samples. They use the concentration curve equation to calculate concentrations, compare predicted concentrations with actual values, and calculate percentage error.

Assessment
Teams are asked to reflect on the process and explain the percentage error in their calculations. To emphasize the importance of proficiency in Excel, each student is asked to submit their own Excel file.

This project integrates concepts from chemistry, physics, and data analysis, providing hands-on experience with laboratory techniques and analytical methods used in pharmaceutical research. It emphasizes the importance of precision, data interpretation, and application of derived relationships to solve real-world problems.

*Project **D**: **D**ata Analysis and Linear Optimization*

This two-day project introduces students to linear optimization techniques and Excel tools for solving complex engineering problems. While collaboration is encouraged, individual submissions are required to ensure personal understanding of the concepts and tools.

Learning Objectives
Upon completion of this project, students will be able to:
1. Identify engineering problems suitable for linear optimization
2. Apply Excel's Goal Seek tool to determine specific input values for desired outputs
3. Define key components of a linear optimization problem: Decision variables, Constraints, Objective function
4. Utilize Excel's Solver tool to find optimal solutions meeting defined criteria

Project Structure
The project is completed entirely within a single Excel file, beginning with example problems that FEP instructors use to demonstrate Goal Seek and Solver tools through detailed, step-by-step guidance. Students are also provided with pre-class video tutorials to familiarize themselves with these tools before in-class instruction. After comprehensive demonstrations, students progress through a series of problems within the same Excel file, with the instructor and course assistant available to help as needed. Students are allowed to work together while independently applying the Excel optimization techniques they have learned. The structured yet flexible learning environment enables students to develop proficiency in linear optimization tools through hands-on practice and collaborative exploration. As a post activity for this project, students were asked

to play a burrito food truck optimization game, which is a web-based app that is intended to act as an entry point for data scientists and problem solvers who could benefit from optimization [8].

Assessment

Students submit individual Excel files demonstrating their ability to correctly formulate linear optimization problems, effectively use Goal Seek for single-variable problems, and properly set up and solve multi-variable problems using Solver.

This project bridges theoretical concepts with practical applications, equipping students with valuable skills in data analysis and decision-making. Students gain experience applicable to various engineering disciplines and real-world scenarios, and also gain intermediate level skills in Excel, which is one of the most frequently specified technical skills in engineering jobs [9].

Project ***F****: Water* ***F****ilter Design*

This comprehensive six-day project engages students in addressing the global challenge of providing clean water. Working in teams of three, students design, construct, and test water filters using readily available materials. The project culminates in poster presentations summarizing their findings and discussing the global impact of clean water access.

Learning Objectives

Upon completion, students will be able to:

1. Understand the application of natural materials in water filtration systems
2. Utilize background research to inform filter design
3. Apply the engineering design process for iterative improvement
4. Develop and present a comprehensive project summary

Project Structure

This project demonstrates the full engineering design process, where students go through the design, build, test, and redesign cycle. On Day 1, teams start by developing initial filter designs using a limited set of materials including plastic cups, cotton rounds, drainage rock, pea gravel, and sand. The design phase encourages creative problem-solving and requires students to consider material properties, filtration effectiveness, and practical constraints.

On Days 2, 3 and 4, students construct two prototype filters and a final filter, systematically testing and refining their designs through a structured evaluation process. Teams conduct multiple runs, including system rinses and dirty water filtrations, measuring critical parameters such as filtration time and water transmittance. This empirical approach allows students to objectively assess their filter's performance and make data-driven design improvements.

Beyond technical design, students investigate the broader implications of water accessibility. This research component transforms the project from a purely technical exercise into a meaningful exploration of engineering's potential to address global challenges. Students use Day 5 to wrap up their research and prepare their poster.

Assessment
On Day 6, the project culminates in poster presentations, where teams demonstrate their technical work, research findings, and design process. This final stage develops communication skills, challenging students to articulate complex engineering concepts and global challenges in a clear, compelling manner.

By combining hands-on engineering and global research while addressing a real-world challenge, this project provides a holistic learning experience. Students develop technical skills in design and testing while simultaneously gaining insight into the broader implications of engineering design solutions in a global context.

Experimental Methods

In the last two fall semesters, after completing the mini-projects, students were asked to complete a survey which was distributed through Microsoft Forms via Blackboard. The purpose of the survey was to assess student satisfaction with the projects and to evaluate how well the projects helped achieve the course goals. The feedback gathered will be used to improve the projects in future semesters [10].

In the Fall 2023 semester, the survey was voluntary, with bonus points offered as an incentive, resulting in a 59.6% response rate (317 out of 532 students). For Fall 2024, the survey was made mandatory, with course points awarded for participation, which increased the response rate to 78.1% (459 out of 588 students). While student names were collected for grading purposes, all data analysis was conducted anonymously. The survey consisted of fourteen questions: twelve Likert scale questions and two open-response questions. Five of the Likert scale questions focused on student enjoyment of each mini project, listed below:

1. I enjoyed the project where we built circuits and programmed them using Arduinos.
2. I enjoyed the project where we designed, built, and tested balsa wood towers.
3. I enjoyed the project where we used Excel Solver to find optimal solutions to problems and explored how to make the most profit in the Burrito Truck Simulation.
4. I enjoyed the project where we built a concentration curve using the spectrophotometer and known concentrations of solutions and estimated unknown concentrations using the curve.
5. I enjoyed the project where we designed, built, and tested water filters.

The remaining seven Likert scale questions focused on how well the students felt the course goals were achieved through the projects, listed below:

6. The projects helped me apply the knowledge I learned from the engineering skills assignments (unit conversions, graphs, Excel, etc.)
7. The projects in this class improved my engineering problem-solving skills.
8. The projects in this class improved my ability to communicate solutions to engineering problems.
9. The projects helped me appreciate the multi-disciplinary nature of engineering.

10. The projects helped me improve my ability to work with others.
11. The projects helped me appreciate the role of engineering in modern society.
12. I would have enjoyed projects more if I would have chosen my own teammates.

The two open-response questions were:

13. Please list three things you enjoyed about the projects.
14. Please list three things you disliked about the projects.

The responses to the Likert scale questions were analyzed using diverging stacked bar charts created in Microsoft Excel for each fall semester [11]. A table was also created to compare the overall positive and negative responses. Neutral responses were grouped with the negative responses [12]. The open-response answers were reviewed by two reviewers, and common themes were identified.

Results and Discussion

Figure 1 shows the results from the Fall 2023 Likert scale survey on student enjoyment of each mini project.

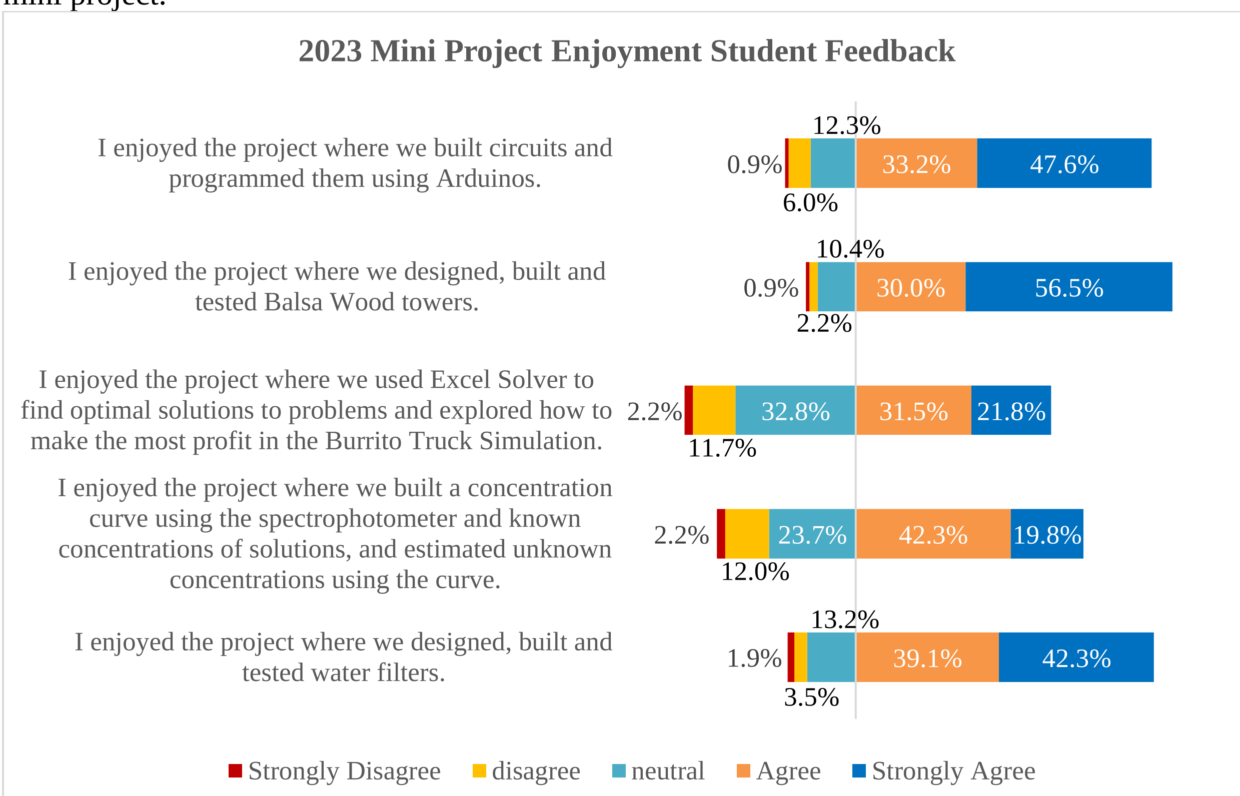

Figure 1. Results from Fall 2023 survey on student enjoyment of each mini project. n = 317

The data was grouped into negative and positive responses. This data is also summarized in Table 1 along with the data from the Fall 2024 survey for side-by-side comparison.

Table 1. Results from Fall 2023 (n = 317) and Fall 2024 (n = 459) surveys on student enjoyment of each mini project grouped into negative and positive responses.

2023/2024 Student Enjoyment of Mini Projects Statements	2023 Strongly Disagree/ Disagree/ Neutral (%)	2024 Strongly Disagree/ Disagree/ Neutral (%)	2023 Agree/ Strongly Agree (%)	2024 Agree/ Strongly Agree (%)
I enjoyed the project where we built circuits and programmed them using Arduinos.	19.2	21.2	80.8	78.8
I enjoyed the project where we designed, built and tested Balsa Wood towers.	13.5	12.8	86.5	87.2
I enjoyed the project where we used Excel Solver to find optimal solutions to problems and explored how to make the most profit in the Burrito Truck Simulation.	46.7	60.6	53.3	39.4
I enjoyed the project where we built a concentration curve using the spectrophotometer and known concentrations of solutions and estimated unknown concentrations using the curve.	37.9	44.2	62.1	55.8
I enjoyed the project where we designed, built and tested water filters.	18.6	17.2	81.4	82.8

Starting with Fall 2023, most students reported enjoying the projects, with over 50% of responses being positive for each project. Among them, the balsa wood tower project was the most favored. The survey results showed that 56.5% of respondents strongly agreed, and 30.0% agreed that they enjoyed the project, resulting in an overall 86.5% positive response rate. According to the open response feedback, students particularly enjoyed designing and building the tower, as well as the competition to see which tower could support the most weight. The main negative feedback related to not having enough time to complete the tower during class.

The second most enjoyed project was the water filter design project, with 42.3% of respondents strongly agreeing and 39.1% agreeing that they enjoyed it, resulting in an overall 81.4% positive response rate. Positive open-ended feedback revealed that students appreciated the design aspect of the water filter and the real-world application. They also enjoyed the competition to see which group could produce the clearest water. However, negative feedback mostly focused on the project being too simple, the need for different supplies, and the boredom of watching the water filter.

The third most enjoyed project was the Arduino project, with 47.6% of students strongly agreeing and 33.2% agreeing that they enjoyed it, resulting in a total positive feedback rate of 80.8%. Positive open responses highlighted that students enjoyed using equipment they had never used before and learning about circuits. Negative feedback noted frustrations with the troubleshooting aspect and the fact that some group members dominated the coding portion.

The fourth most enjoyed project was the concentration curve project. The survey showed that 19.8% of students strongly agreed and 42.3% agreed that they enjoyed the project, for a total of 62.1% positive feedback. Positive responses indicated that students liked using the spectrophotometer and finding the unknown concentration. Negative feedback pointed to challenges with making errors when creating the concentration curve and frustration with waiting for access to the spectrophotometer.

The least enjoyed project involved using Excel Solver to optimize solutions to problems. This project received the highest percentage of neutral responses at 32.8%, and the second highest disagree responses at 11.7%. It also tied with the concentration curve project for the highest percentage of strongly disagree responses at 2.2%, resulting in a total of 46.7% negative feedback. Despite being the least enjoyed, over half of the respondents, 53.3%, still reported enjoying the project. Positive feedback indicated that most students enjoyed using Excel to quickly find solutions and learning about Excel's capabilities. Negative feedback, however, largely stemmed from some students' general dislike of Excel, not necessarily the project itself.

The same survey was conducted the following year, and the data was analyzed in the same way, enabling a comparison between the two years. Figure 2 shows the results from the Fall 2024 Likert scale survey on student enjoyment of each mini project. As in the previous year, the data was grouped into negative and positive responses, and the data is included in Table 1 above.

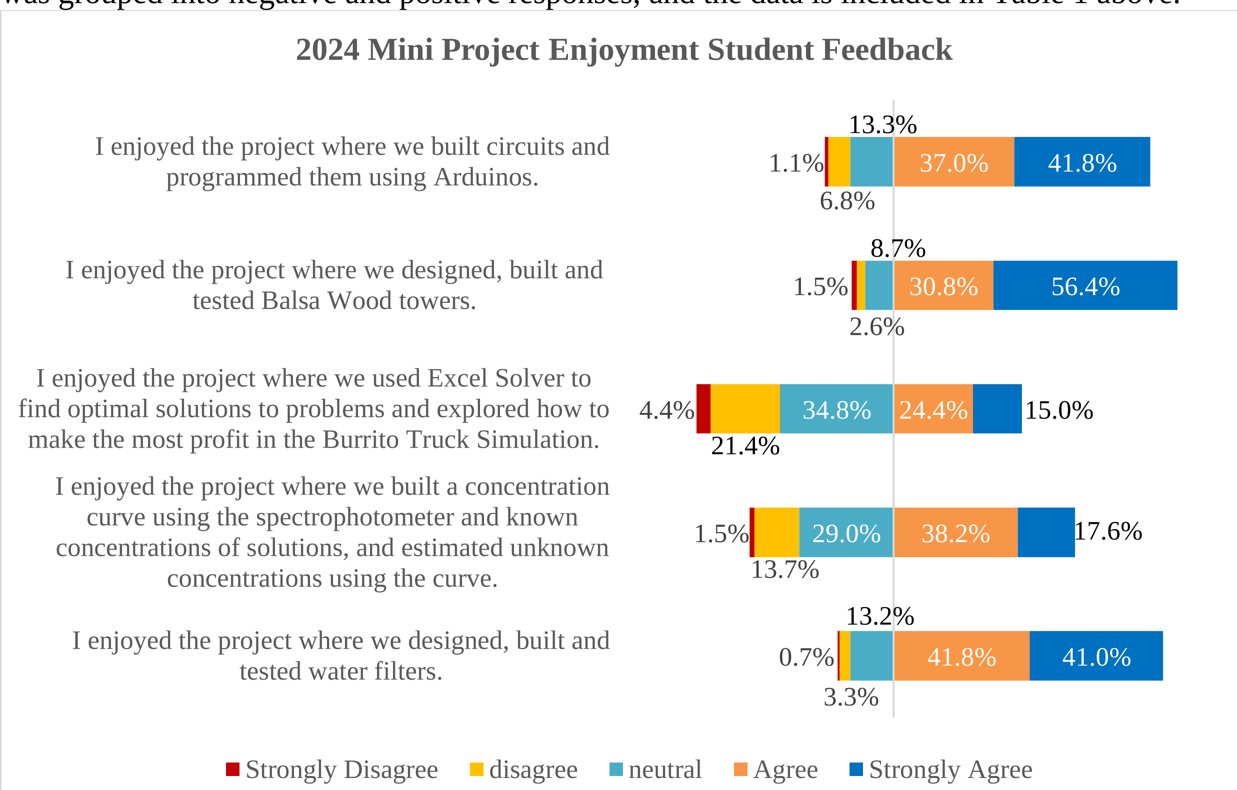

Figure 2. Results from Fall 2024 survey on student enjoyment of each mini project. n = 459

As mentioned above, the survey was voluntary in the Fall of 2023 with a 59.6% response rate and mandatory for Fall 2024 with a 78.1% response rate. The difference in response rates may explain some of the changes in project enjoyment, although further mandatory surveys would be needed to confirm this. Much of the open response feedback was similar between the two surveys. The ranking of projects in terms of student enjoyment remained the same between the two years. For the balsa wood tower project, 56.4% of students strongly agreed and 30.8% agreed that they enjoyed the project, yielding a total of 87.2% positive feedback. This is comparable to the 86.5% positive feedback in Fall 2023. Despite additional class time for the project in Fall 2024, open response feedback still indicated that some students felt they needed more time.

For the water filter design project, which was again the second most enjoyed, 41.0% of students strongly agreed and 41.8% agreed that they enjoyed it, resulting in 82.8% positive feedback. This is similar to the 81.4% positive feedback from Fall 2023. Although more emphasis was placed on the global impact of clean water in Fall 2024, this change did not appear to affect the open response feedback.

The third most enjoyed project was the Arduino project, with 41.8% of students strongly agreeing and 37.0% of students agreeing that they enjoyed the project. The total positive response rate was 78.8%, which was slightly lower than the 80.8% positive feedback from Fall 2023. There were no notable changes to this project between the two years or differences in the open response feedback.

The concentration curve project, the fourth most enjoyed, had 17.6% of students strongly agreeing and 38.2% agreeing that they enjoyed the project, yielding 55.8% positive feedback. This is lower than the 62.1% positive feedback from Fall 2023. There were no significant changes to the project between the two years or differences in the open response feedback.

Unlike in Fall 2023, not all projects in Fall 2024 received over 50% positive feedback. The Excel Solver project saw a drop in positive responses, with only 39.4% of students reporting enjoyment, compared to 53.3% in Fall 2023. Additionally, the project had the highest neutral (34.8%), disagree (21.4%), and strongly disagree (4.4%) responses across all 2024 projects. However, there were no changes to the project between the two years, and the open response feedback was largely unchanged.

The seven Likert scale questions, which assessed how well students felt the course goals were achieved through the projects, were analyzed in the same manner. Figure 3 presents a diverging stacked bar chart of the results from the Fall 2023 Likert scale survey on course goal achievement. Figure 4 shows the results from the Fall 2024 Likert scale survey on course goal achievement as a diverging stacked bar chart.

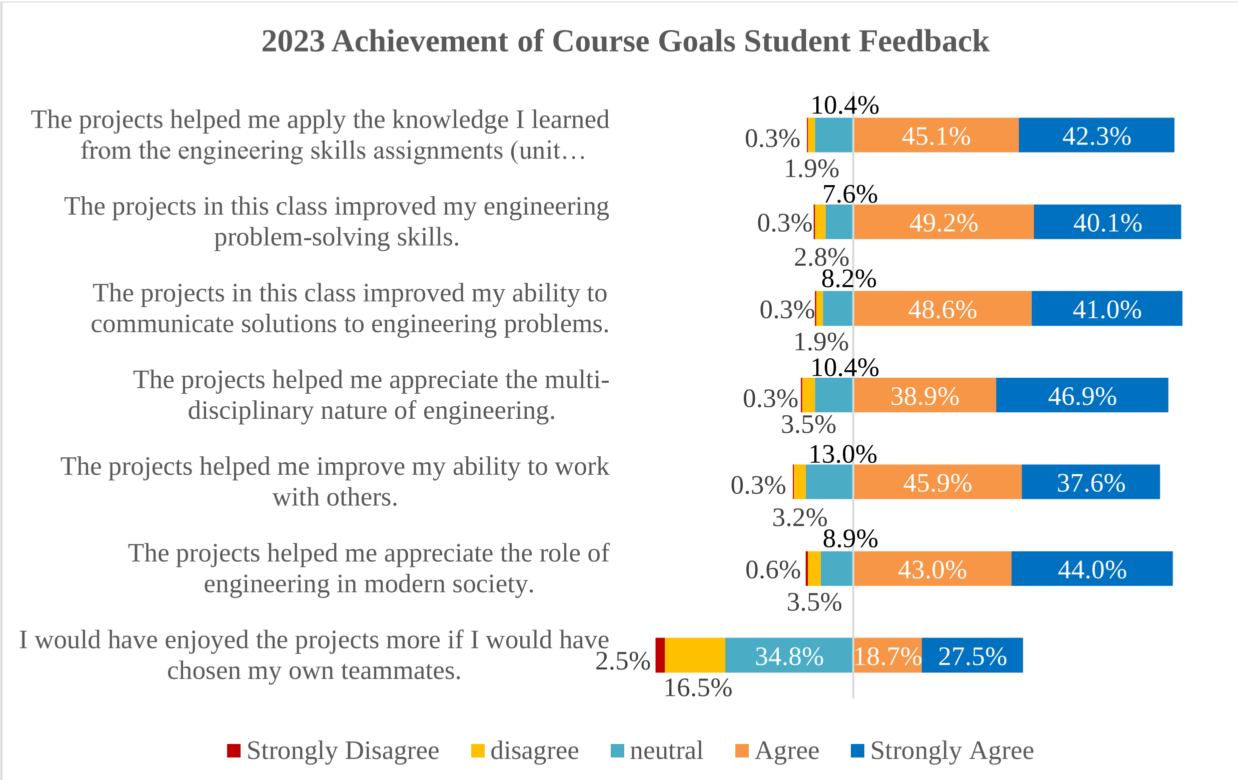

Figure 3. Results from Fall 2023 survey on the achievement of course goals. n = 317

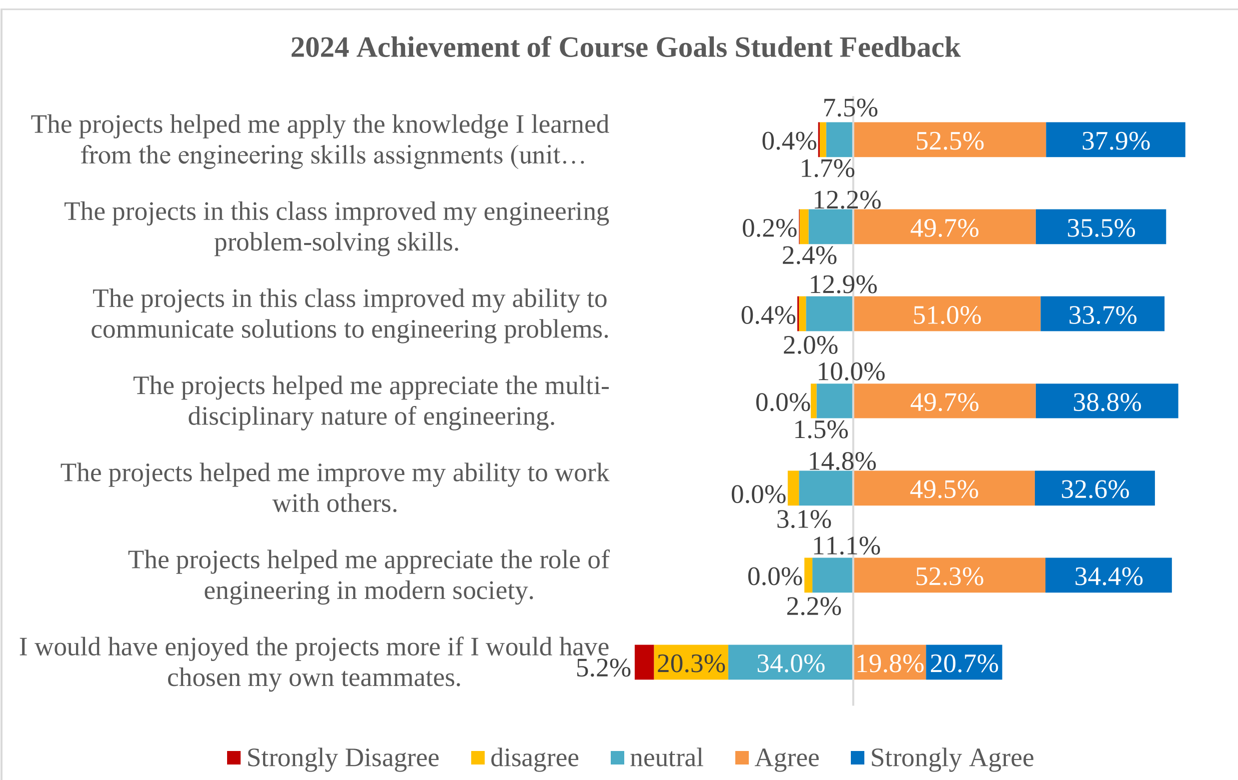

Figure 4. Results from Fall 2024 survey on the achievement of course goals. n = 459

The survey data was then grouped into negative and positive responses. This data is summarized in Table 2, which also includes the Fall 2024 survey data for side-by-side comparison.

Table 2. Results from Fall 2023 (n = 317) and Fall 2024 (n = 459) surveys on the achievement of course goals grouped into negative and positive responses.

2023/2024 Achievement of Course Goals Statements	2023 Strongly Disagree/ Disagree/ Neutral (%)	2024 Strongly Disagree/ Disagree/ Neutral (%)	2023 Agree/ Strongly Agree (%)	2024 Agree/ Strongly Agree (%)
The projects helped me apply the knowledge I learned from the engineering skills assignments (unit conversions, graphs, Excel, etc).	12.6	9.6	87.4	90.4
The projects in this class improved my engineering problem-solving skills.	10.7	14.8	89.3	85.2
The projects in this class improved my ability to communicate solutions to engineering problems.	10.4	15.3	89.6	84.7
The projects helped me appreciate the multi-disciplinary nature of engineering.	14.2	11.5	85.8	88.5
The projects helped me improve my ability to work with others.	16.5	17.9	83.5	82.1
The projects helped me appreciate the role of engineering in modern society.	13.0	13.3	87.0	86.7
I would have enjoyed the projects more if I would have chosen my own teammates.	53.8	59.5	46.2	40.5

The most surprising finding from the survey was the response to the statement, “I would have enjoyed projects more if I had chosen my own teammates.” In Fall 2023, only 27.5% of students strongly agreed and 18.7% agreed with the statement, with a total of 46.2% positive responses. The responses in Fall 2024 had an even lower positive response rate with 20.7% of students strongly agreeing and 19.8% agreeing with the statement, resulting in an overall positive response rate of 40.5%. According to the open response feedback, students enjoyed the opportunity to meet new people while working in groups. Since it is a first-year course, many of the students have not established friend groups, especially in the engineering program. The most common negative feedback was that group members did not contribute equally.

For the other six statements, the positive response rate was consistently high, with all responses above 82.1%. The lowest positive response rate of 82.1% was from the 2024 survey for the statement “The projects helped me improve my ability to work with others”. Once again going back to the open response feedback, many students felt group members did not contribute equally, and others expressed a general dislike for teamwork. The highest positive response rate of 90.4% came from the 2024 survey for the statement “The projects helped me apply the knowledge I learned from the engineering skills assignments (unit conversions, graphs, Excel, etc.)". Many students noted in their open response feedback that they enjoyed the problem-solving aspect and the opportunity to apply skills in the projects.

Much of the open response feedback focused on the achievement of course goals, with the main themes remaining consistent across both the 2023 and 2024 surveys. However, some feedback was contradictory, reflecting the diverse perspectives and experiences of the students. Table 3 outlines some of the key positive and negative feedback themes.

Table 3. Summary of open response feedback from Fall 2023 (n = 317) and Fall 2024 (n = 459) surveys on the achievement of course goals.

2023/2024 Summary of Open Response Feedback for Course Goal Achievement	
Positive	**Negative**
Different teammates for each project	Could not pick group
Clear instructions	Confusing instructions
Plenty of time to complete	Too much out of class work
Hands on	Unequal effort from group mates
Teamwork	More projects needed
Variety of projects	Too many time constraints
Problem solving	Dislike of groupwork
Different types of engineering represented	Repetitive projects
Diversity of projects	Too simple
Freedom of creativity	Dislike of Excel
Application of skills	Should be more creative

Conclusions

The surveys had a few limitations. First, the Fall 2023 survey was optional with bonus points awarded, while the Fall 2024 survey was mandatory with course points given. To improve comparability, future surveys will be mandatory. A second limitation is that we did not track the impact of mini projects on major selection. While we do not intend to match student responses to names, future surveys will include a question about whether projects influenced students' choice of major. Lastly, the lack of in-person questioning was a limitation, meaning we had to rely on Likert scale responses and short open-ended answers. Despite these limitations, the survey results for Fall 2023 and Fall 2024 were largely consistent.

In both semesters, the projects were ranked in the same order based on enjoyment, with the balsa wood tower project ranked highest, followed by the water filter project, the Arduino project, the concentration curve project, and lastly, the Excel Solver project. In Fall 2023, all projects received a positive response rate above 50%, but in Fall 2024, the Excel Solver project dropped from 53.3% to 39.4%. While the open responses did not provide specific reasons for the decline, many students expressed a dislike for Excel overall.

The results were also consistent in terms of achievement of course goals, with all except one of the question statements receiving a positive response rate above 80%. An unexpected finding was that only 46.2% of students in Fall 2023 and 40.5% in Fall 2024 agreed with the statement, "I would have enjoyed projects more if I had chosen my own teammates." Open response feedback indicated that many students appreciated the opportunity to meet new people when working in groups.

While most feedback was positive, there are areas for improvement. First, the Excel Solver project has been identified as the mini project requiring the most significant enhancement. Our proposed improvements are twofold. We plan to initiate the project by presenting real-life examples of optimization in engineering problem-solving, thereby contextualizing the project's relevance. To increase engagement, we will incorporate a gamification component that necessitates teamwork, as the current procedure lacks a mandatory collaborative element. These modifications aim to make the project more practical, interactive, and conducive to developing teamwork skills, thus addressing the current limitations in the project's structure and implementation. Second, there are discussions about allowing students to choose their teammates for one of the projects, providing them with more autonomy in the course. Surveys will continue to be conducted in future Fall semesters to monitor any changes in trends.

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Appendix: Sample Project Photos

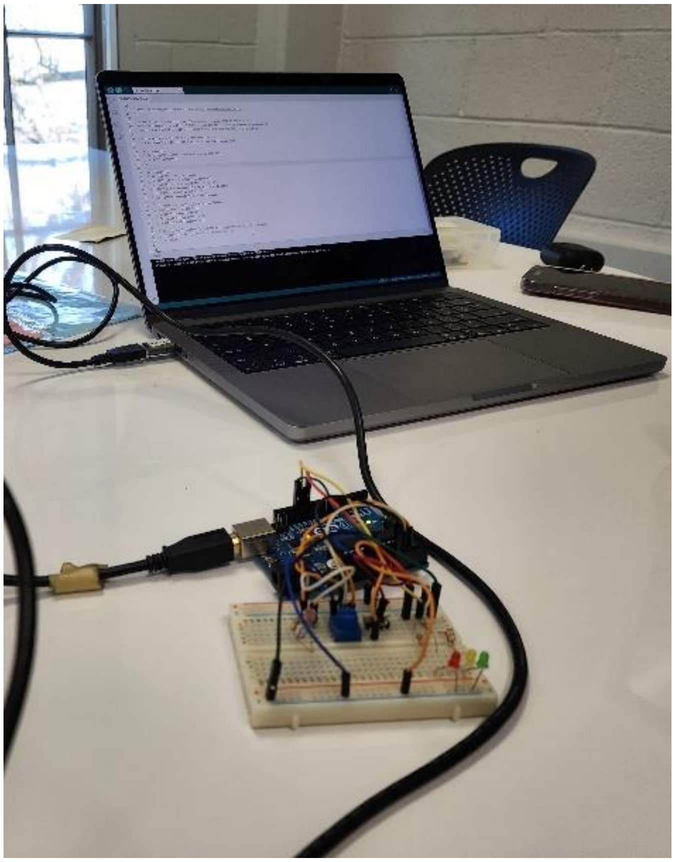

Figure A1. Project A: Arduino Basics - Step 5 with Arduino code on laptop screen.

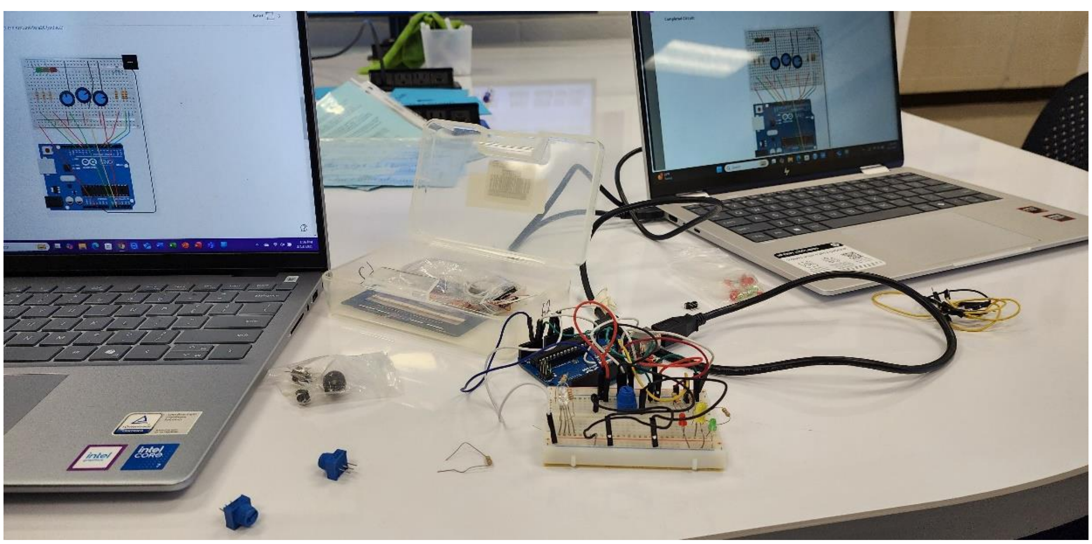

Figure A2. Project A: Arduino Basics - Last step with RGB LED with Blackboard instructions on laptop screen.

Figure A3. Project B: Balsa Wood Tower Construction – Team towers in progress.

Figure A4. Project B: Balsa Wood Tower Construction – Crush Day.

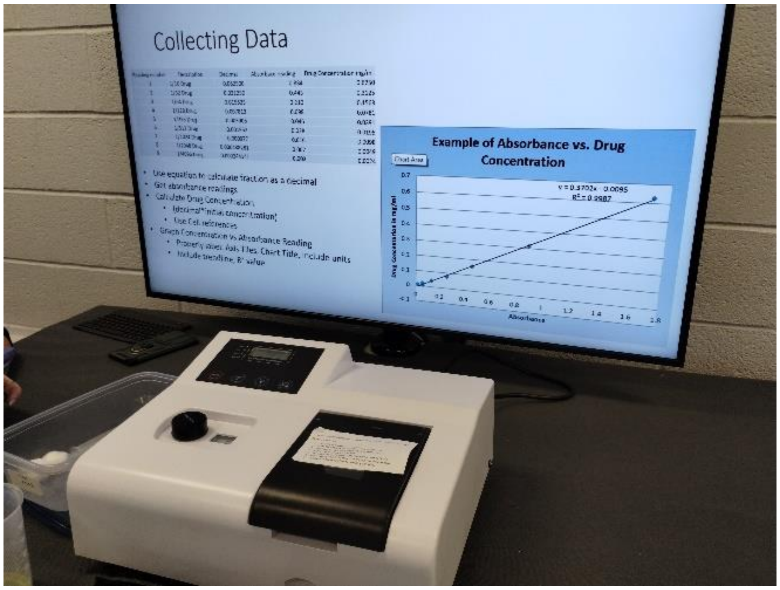

Figure A5. Project C: Concentration Curve – Spectrophotometer and the sample data analysis for students to follow on screen.

Figure A6. Project C: Concentration Curve – Supplies for students to prepare the sample for analysis.

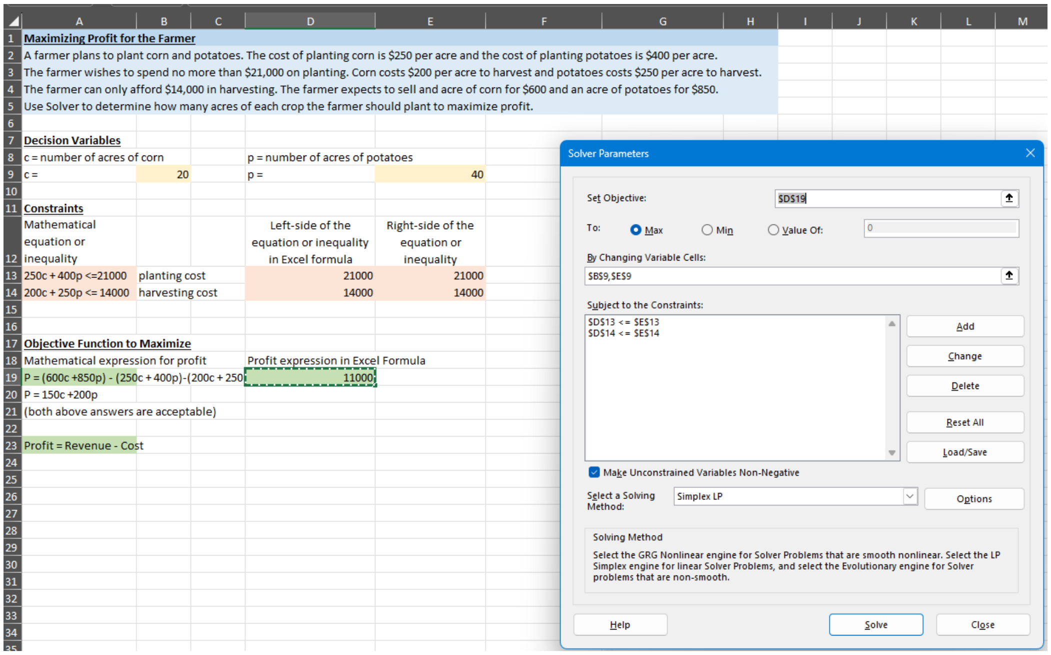

Figure A7. Project D: Data Analysis and Linear Optimization – Optimization problem instructions with Excel set-up (students fill out the highlighted cells) and Excel Solver screen.

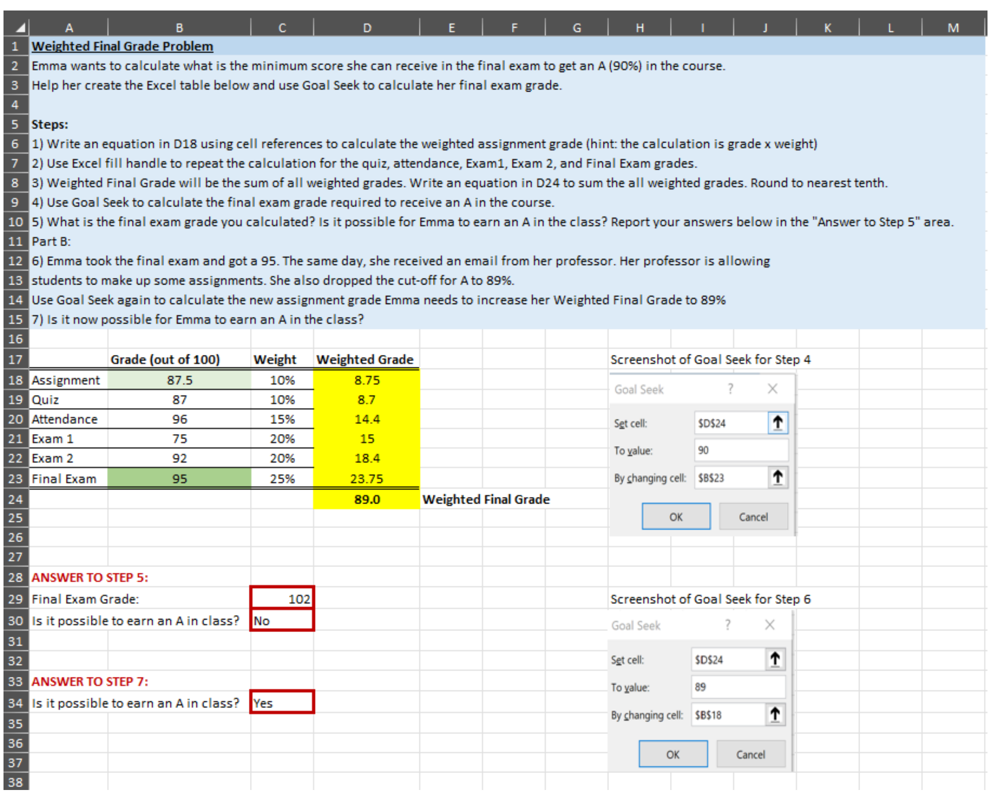

Figure A8. Project D: Data Analysis and Linear Optimization – Goal-Seek problem instructions with Excel set-up screenshots of Goal Seek screen.

Figure A9. Project F: Water Filter Design – Materials.

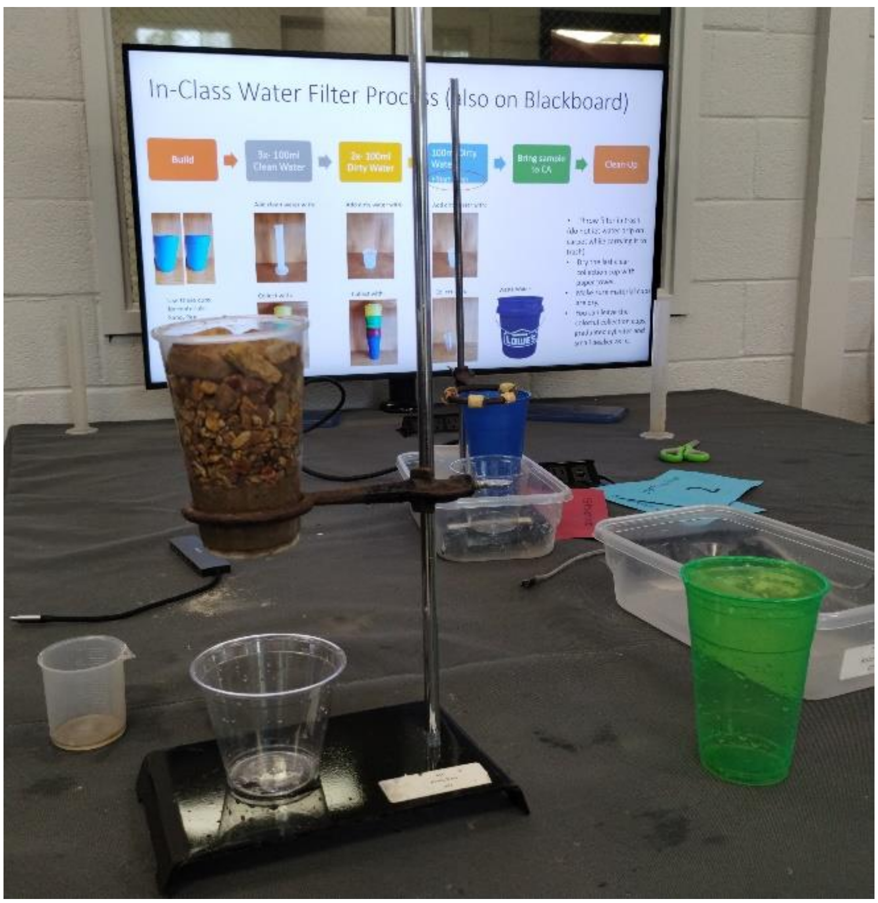

Figure A10. Project F: Water Filter Design – Water filter set up with a constructed water filter and in-class filtering procedure on the screen.