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A Case Study on Using a Mini Project in Structural Material Testing to Address ABET Student Outcomes

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Abstract:

This is a case study manuscript exploring the potential of a mini-project centered around a civil engineering course to satisfy several of the student outcomes outlined by ABET. The mini-project was developed to help students meet specific objectives based on Bloom's taxonomy. Students were expected to utilize the materials learned in the Structural materials lecture and lab to come up with a plan to test the effect of a pozzolan/supplementary cementitious material (SCM) on the properties of concrete. The student groups worked on five different mixes, investigating the effect of two different pozzolans: fly ash and silica fume. The first mix was a control group consisting of concrete with typical ingredients (Test A), while the other four mixes were Test B, Test C, Test D, and Test E. Test B consisted of mix in Test A +fly ash (1/3rd the weight of cement in the mix), Test C involved replacing 1/3rd of the weight of cement in Test A with an equivalent weight of fly ash, Test D consisted of mix in Test A +silica fume (1/3rd the weight of cement in the mix), and Test E involved replacing 1/3rd of the weight of cement in Test A with an equivalent weight of silica fume.

The addition of pozzolan affects the properties of fresh and hardened concrete such as temperature, workability, density, air content, compressive strength etc. Therefore, students conducted experiments for testing these parameters and cast and cured concrete cylinders to test the compressive strength of hardened concrete at the end of 1, 7 and 28 days, and the results were presented using tables and bar charts that compared the properties of fresh and hardened concrete in the five tests.

The mini-project enabled student groups to learn about the experimental design process, explore different types of pozzolans, apply the knowledge gained from lectures and previous labs to conduct the experiments, use the collected data to develop visual representations, make informed decisions based on engineering judgment and develop a good team spirit. A survey was conducted to gather information on the effect of the mini-project on different factors related to student learning and is also included in the manuscript. The findings of the survey indicate that the mini-project was effective in addressing many of the ABET student outcomes.

Introduction

The Accreditation Board for Engineering and Technology (ABET) ensures that graduates in different fields such as applied and natural science, computing, engineering, and technology, are equipped with the right kind of education vital for their profession. This type of quality assurance helps to improve the quality of technical education and make sure that the graduates are well equipped to work in the current world of technical advancement. This is accomplished by making sure that the programs adhere to the different sets of criteria set forth by the board. There are eight different criteria applicable for the baccalaureate programs and of those eight, Criterion

3 focuses on student outcomes. The seven student outcomes put forward by ABET are as follows [1]:

1. an ability to identify, formulate, and solve complex engineering problems by applying principles of engineering, science, and mathematics.
2. an ability to apply engineering design to produce solutions that meet specified needs with consideration of public health, safety, and welfare, as well as global, cultural, social, environmental, and economic factors.
3. an ability to communicate effectively with a range of audiences.
4. an ability to recognize ethical and professional responsibilities in engineering situations and make informed judgments, which must consider the impact of engineering solutions in global, economic, environmental, and societal contexts.
5. an ability to function effectively on a team whose members together provide leadership, create a collaborative and inclusive environment, establish goals, plan tasks, and meet objectives.
6. an ability to develop and conduct appropriate experimentation, analyze and interpret data, and use engineering judgment to draw conclusions.
7. an ability to acquire and apply new knowledge as needed, using appropriate learning strategies.

The main objective of these outcomes is to enhance the student's practical skills and prepare them for real-world scenarios. This is achieved by utilizing the theories learned from diverse areas to identify, formulate, and resolve intricate engineering issues through collaborative brainstorming with fellow students. Additionally, students will apply engineering judgement to propose workable solutions. As mentioned in the ABET website [2], “the attainment of these outcomes prepares graduates to enter the professional practice of engineering”.

Background

There is a widespread agreement among engineering professionals that there exists a significant gap between the theoretical knowledge imparted through engineering education and its practical applications ([3], [4], [5], [6], [7]). In an attempt to gauge the effectiveness of engineering education, recent engineering graduates were interviewed, and the results showed that the majority of them felt that their education failed to impart the practical skills required for their jobs [8]. Additionally, other researchers ([9], [10], [11], [12], [13]) have also highlighted the inadequacy of engineering education in preparing students for engineering practice. Some studies have even documented the distressing impact of this gap on recent graduates, leading them to seek alternative career paths ([14], [15]). In response to this issue, several researchers in the field of engineering education have emphasized the importance of experiential learning ([16], [17], [18], [19], [20]). In fact, ([19], [20]) has suggested that universities should promote practical projects that allow students to gain hands-on experience and exposure to experiential learning.

[21] stated that “Experiential learning engages students in critical thinking, problem solving and decision making in contexts that are personally relevant and connected to academic learning objectives by incorporating active learning”.

It's widely recognized that there is a gap between engineering education and practice, and that practical exercises are essential for building a strong theoretical foundation. Although many faculty members have innovative ideas, logistical issues such as time constraints often prevent these ideas from being implemented in lecture classes.

This case study explores how the authors incorporated a mini-project into a civil engineering course to address select ABET student outcomes. The course is centered on the theory behind material properties and concrete mix design, among other topics. To supplement the curriculum with practical experience, the course included lab sessions, though it was not a standalone lab course like others in the engineering field. The idea behind assigning the mini-project was to help students meet the following objectives based on Bloom's taxonomy:

- Remember the material properties and testing standards covered in the lecture.
- Understand the material properties and their corresponding tests.
- Apply the knowledge acquired in both lecture and lab in an experiential setting.
- Analyze the data obtained from the lab experiments.
- Evaluate data, generate graphs, and arrive and informed conclusions.

The mini-project aimed to fulfill ABET student outcomes 1, 5, and 7. After completing lectures and labs on concrete properties and compressive strength testing, students worked in groups to achieve specific objectives:

1. Name at least two pozzolans.
2. Identify the appropriate tests and corresponding ASTM standards for measuring the properties of fresh and hardened concrete.
3. Describe the effect of pozzolans on the workability of concrete.
4. Describe the effect of pozzolans on the temperature of concrete.
5. Describe the effect of pozzolans on the density of concrete.
6. Describe the effect of pozzolans on the compressive strength of concrete.
7. Understand that different pozzolans have different effects on the properties of concrete.
8. Understand that the properties of concrete can vary based on the quantity of pozzolan added.

Methodology

The objective of the mini-project was to investigate how a supplementary cementitious material (SCM) affects the properties of fresh and hardened concrete. The students collaborated with their peers to generate different ideas, and based on classroom knowledge, they identified several potential SCMs. However, due to material availability in the lab, the groups were advised to use fly ash and silica fume for their mini-project. To determine the impact of SCM on the physical properties of concrete, the student groups had to measure the mix temperature, slump, density, and air content. For strength comparison, the groups decided to evaluate 1 day, 7 days, and 28 days strength, and appropriately selected ASTM standards for each test.

Five distinct sets of tests were used in the study. The tests used are given below.

Test A- Control group – Concrete with typical ingredients.

Test B- Test A + fly ash (1/3rd weight of cement)

Test C- Replaced 1/3rd weight of cement in Test A with fly ash

Test D- Test A + silica fume (1/3rd weight of cement)

Test E- Replaced 1/3rd weight of cement in Test A with silica fume

The groups were tasked with using identical mix proportions since all groups shared their data. All groups used a 1:1:2 mix with the water-cementitious material ratio fixed at 0.5 to eliminate the effect of change in water content on the properties of concrete. Also, more than one group worked on all five mixes to rule out errors during batching. Table 1 displays the mix proportions used by different groups in the mini-project.

Table 1. Mix Proportions for Different Tests

Material	**Test A**	**Test B**	**Test C**	**Test D**	**Test E**
Cement (lb/yd^3)	30	30	20	30	20
Fine Aggregate (lb/yd^3)	30	30	30	30	30
Coarse Aggregate (lb/yd^3)	60	60	60	60	60
Water (lb/yd^3)	15	20	15	20	15
Fly Ash (lb/yd^3)	------	10	10	10	10

All groups adhered to the standard procedure for gathering materials and mixing concrete. Once the concrete was thoroughly mixed, various tests were performed to determine its properties with and without fly ash. These tests included temperature (following ASTM C 1064), slump (following ASTM C143), density (following ASTM C138), and air content (following C231). Following the tests, three-cylinder molds of size 4x8in. were cast for each mix, and the compressive strength of the concrete was measured at three different ages (1 day, 7 days, and 28 days), per ASTM C31.

Results

Table 2 displays the average values of temperature, slump, density, and air content for the five test groups (A, B, C, D, and E), while Figure 1 illustrates the variation in compressive strength for each group over the aforementioned periods.

Table 2. Physical Properties of Concrete With and Without Pozzolan

Properties	Test A	Test B	Test C	Test D	Test E
Temperature (^oF)	77	63	63	64	70
Slump (in)	7.75	10.5	8.75	10	9
Density (lb/ft^3)	146.05	141.95	144.60	136.38	132.70
Air content (%)	2.2	4.4	4.9	2.2	2.2

Table 2 shows that the addition of pozzolan lowered the temperature of concrete. It was also noted that the addition of $1/3^{rd}$ weight of Pozzolan (Test B and D) resulted in lower temperature compared to when $1/3^{rd}$ weight of cement was replaced with pozzolan (Test C and Test E). Similarly, it was observed that the addition of pozzolan increased the workability of concrete and reduced the density of concrete. Figure 1 shows the trend in the gain of compressive strength of the five different concrete mixes over a period of 28 days.

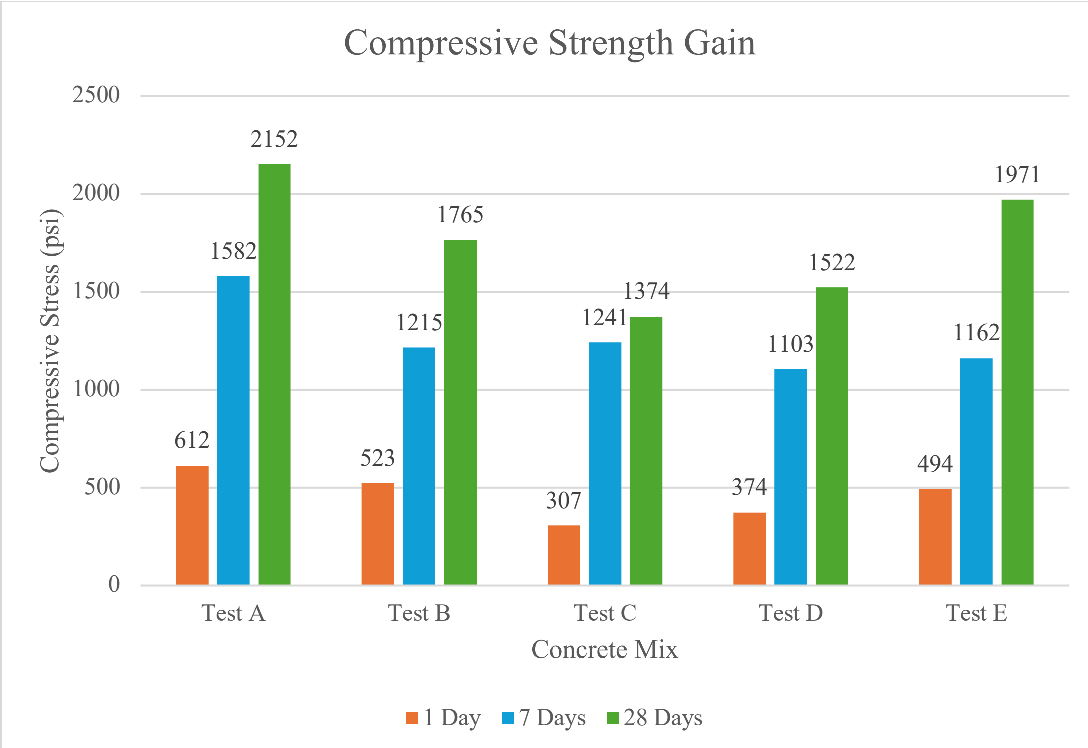


Figure 1. Compressive Strength vs. Age

Figure 1 shows that the control group (Test A) had higher compressive strength compared to the other four tests. The students found it interesting that although the initial compressive strength is low for Test E compared to Test A, the gain in strength between 7 and 28 days is close to 70 % for Test E compared to 36% for Test A during the same period.

All groups were given access to the raw data. They first summarized it into tables and then explored different methods of visually representing the data. This allowed them to gain hands-on experience with Microsoft Excel, a program with which the majority were not previously familiar. Based on their tables and graphs, each student group applied their engineering judgment to conclude the effect of SCM on concrete.

Survey

A survey was conducted to collect data from students to assess the effect of the mini-project on their understanding of the properties of concrete, the effect of the pozzolans on the properties of concrete, group work, data analyzing skills, how to use engineering judgment in the context of properties of concrete etc. The survey used in the study is given below.

Survey to assess the role of the mini-project in improving student understanding of the properties of concrete and pozzolans

This is a survey designed to assess your knowledge related to the material properties of concrete and related tests. The questions are based on the mini-project where you are determining the effect of Supplementary Cementitious materials/Pozzolans (Fly Ash and Silica fume) on the properties of fresh and hardened concrete. Additionally, there are some questions to gauge your communication, analytical and graphical skills.
Choose the appropriate Likert ratings 1 –Poor/Bad 3- Somewhat 5- Very, for each of the following questions.

1. The mini-project gave me a chance to apply the knowledge acquired in the lecture related to concrete properties in an experiential setting.

1	2	3	4	5

2. The mini-project helped me to remember the material properties related to concrete and Pozzolan discussed in the lecture.

1	2	3	4	5

3. The mini-project helped me in finding the different ASTM standards used for the testing of properties of concrete.

1	2	3	4	5

4. The mini-project helped to improve my understanding of the properties of concrete and Pozzolans

1	2	3	4	5

5. The mini-project helped to apply the different test procedures for finding the properties of concrete that were learned in the previous labs. (Slump test, temperature test, density test etc.)

1	2	3	4	5

6. The mini-project improved my confidence in designing an experiment in a small group to test the effect of a Pozzolan on the properties of concrete.

1	2	3	4	5

7. The mini-project helped to improve/practice my skills to develop graphs to represent experimental data effectively.

1	2	3	4	5

8. The mini-project helped to understand how to make an informed conclusion based on the data collected from the it.

1	2	3	4	5

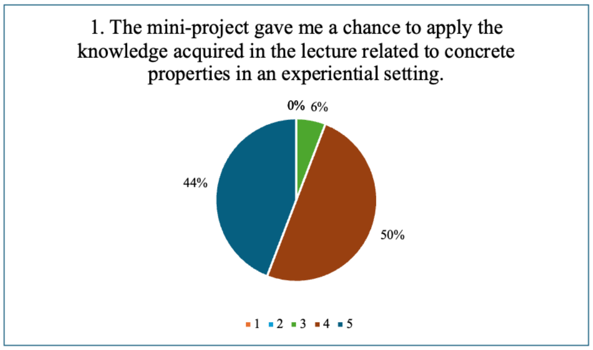
9. Working in groups for the lab mini-project helped me to bond with my team members.

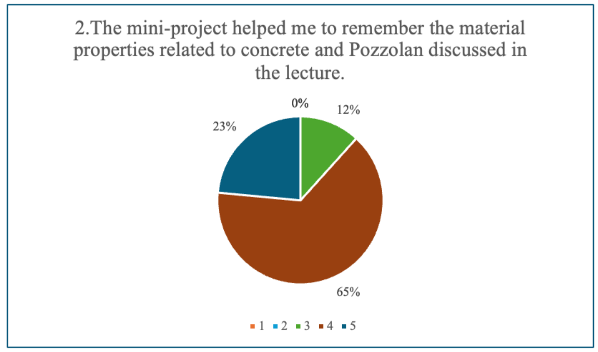
1	2	3	4	5

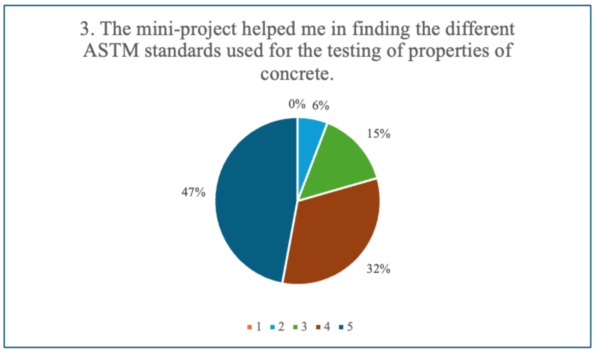
10. The mini-project report writing helped me to remember/understand the material properties, corresponding ASTM standards, test procedures, and develop good report writing skills.

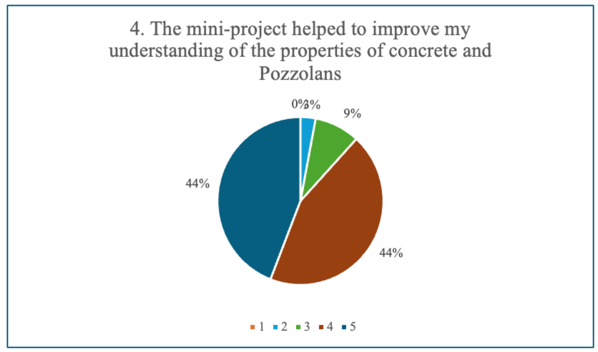
1	2	3	4	5

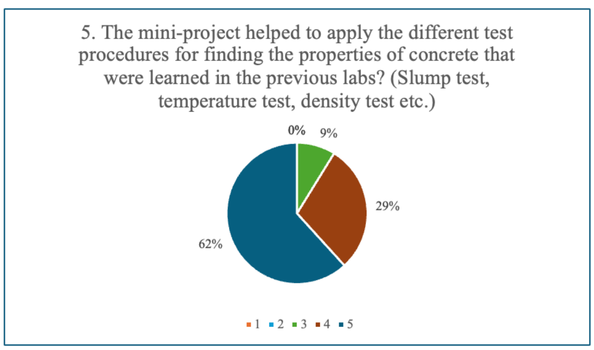
Sixty-seven percent of the students in the structural materials class took the survey and the results of the survey are summarized in the figures below.

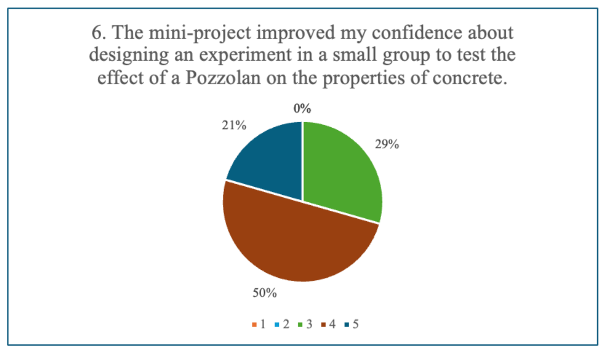

1. The mini-project gave me a chance to apply the knowledge acquired in the lecture related to concrete properties in an experiential setting.
0%
6%
50%
44%
1 2 3 4 5

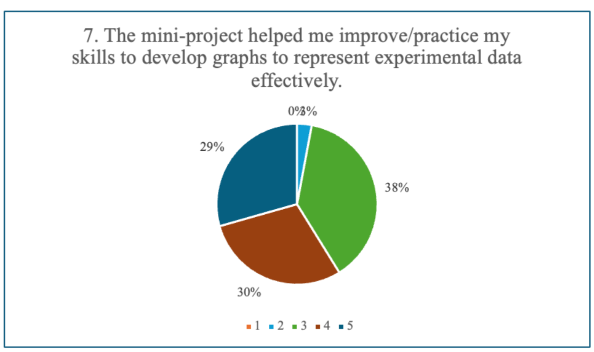

2.The mini-project helped me to remember the material properties related to concrete and Pozzolan discussed in the lecture.
0%
12%
65%
23%
1 2 3 4 5

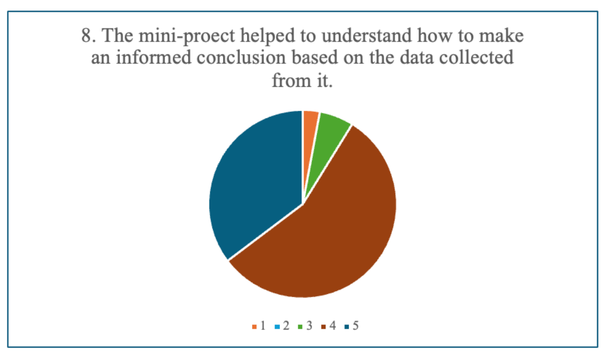

3. The mini-project helped me in finding the different ASTM standards used for the testing of properties of concrete.
0%
6%
15%
32%
47%
1 2 3 4 5


4. The mini-project helped to improve my understanding of the properties of concrete and Pozzolans
0%
3%
9%
44%
44%
1 2 3 4 5


5. The mini-project helped to apply the different test procedures for finding the properties of concrete that were learned in the previous labs? (Slump test, temperature test, density test etc.)
0%
9%
29%
62%
1 2 3 4 5


6. The mini-project improved my confidence about designing an experiment in a small group to test the effect of a Pozzolan on the properties of concrete.
0%
29%
50%
21%
1 2 3 4 5


7. The mini-project helped me improve/practice my skills to develop graphs to represent experimental data effectively.
0%
3%
38%
30%
29%
1 2 3 4 5


8. The mini-proect helped to understand how to make an informed conclusion based on the data collected from it.
1 2 3 4 5

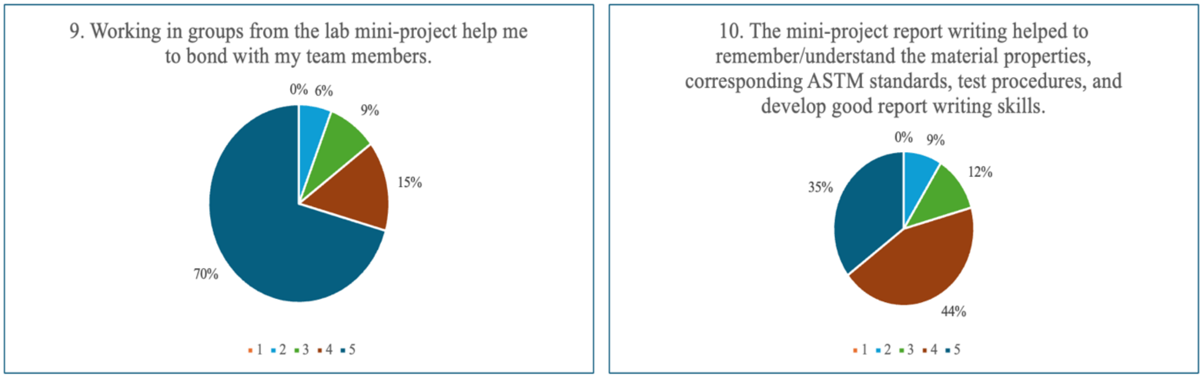


Figure 2. Survey Results on the Effect of Mini-project

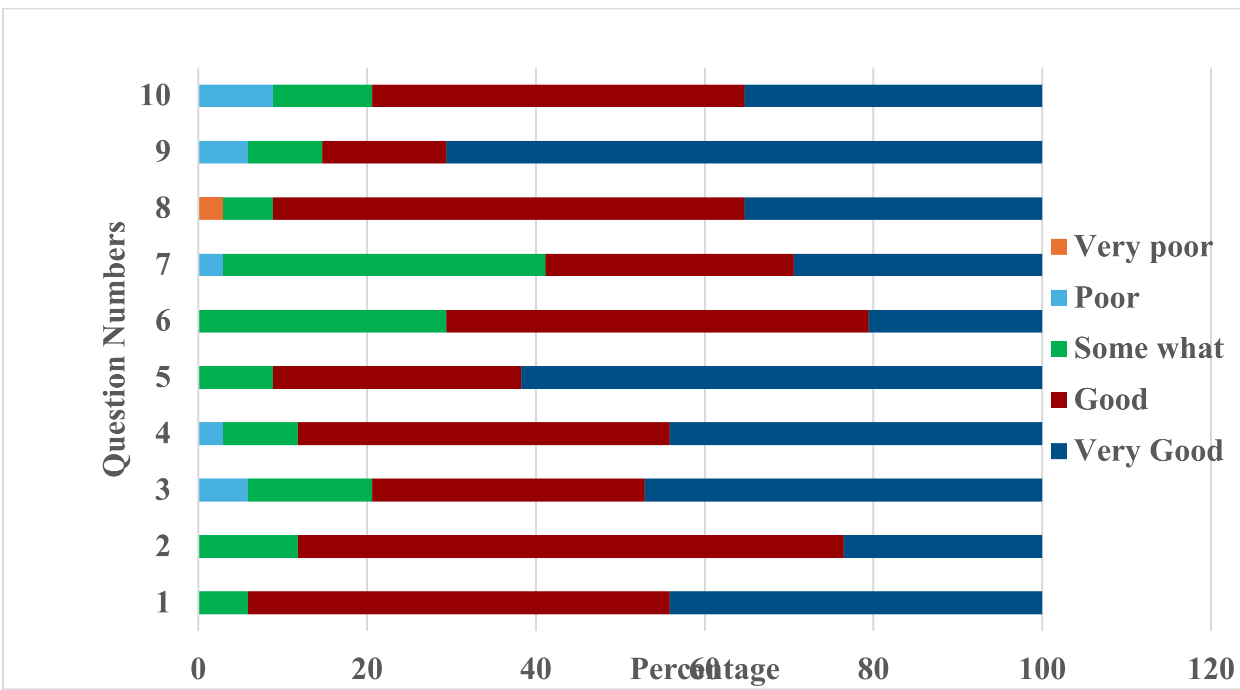


Figure 3. Summary of the Survey Results

Figure 3 summarizes the results obtained from the student survey, which included ten questions. It is evident from this figure that the majority of students agreed that the mini-project was beneficial in improving their understanding of problem identification, designing experiments to resolve them, working collaboratively to achieve a common goal, collecting and analyzing data, and drawing conclusions based on engineering judgment. Based on the student survey results, it is evident that this mini-project satisfies the ABET outcomes 1, 5, and 7.

Only two questions received a combined score of less than 75% for the categories of "good" and "very good." These questions were related to their confidence in designing experiments and graphing skills, respectively. It is important to note that most students in this class were freshmen and sophomore.

Discussion & Future Work

The present study delves into the potential of a mini-project centered around a civil engineering course to satisfy several of the student outcomes outlined by ABET. The study details how students applied the knowledge imparted in their lectures to select the appropriate SCM, identify the relevant tests and ASTM standards for their project, devise the mix, execute the test using the insights gained from previous lab sessions, organize, and analyze the data using tables, explore and learn to visually depict data via Excel, and interpret their findings.

A benefit-cost analysis will be included in future studies to consider SCM as a concrete ingredient. We also plan to conduct a pre-survey in the future to obtain a more comprehensive assessment.

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