

Board 84: A Teamwork-based Electrical & Computer Engineering Introductory Lab Course

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In 2020 I left the US Navy to pursue my Bachelors of Science in Electrical and Computer Engineering. Throughout my time in the Navy I worked in collaborative team environments, filled with diverse individuals, with the goal of accomplishing specific tasks to accomplish our mission. When I left and began my education at Western Washington University, I found myself surrounded by individuals who wanted nothing more than to succeed. It was only a matter of time before my cohort realized we are stronger together than we are apart. The curriculum gave us opportunities to work together as a team, and we quickly learned that everyone brought their own strengths to the table. Working with others, asking questions and being actively involved has always made a huge impact on my ability to learn.

A Teamwork-Based Electrical & Computer Engineering Introductory Lab Course

Abstract

In this paper, we present successful efforts in teaching teamwork principles, fostering an effective teamwork culture, and training teamwork practices in an Electrical and Computer Engineering (ECE) introductory lab course. We also provide details of the measures and data collected from this course and the criteria adopted to assess the attainment of ABET Student Outcome (SO) #5. Additionally, assessment results, discussions on student survey questions, and survey responses from recent course offerings are included in this paper as well.

I Introduction

The Engineering Accreditation Commission of ABET requires engineering programs such as Electrical and Computer engineering programs to demonstrate the attainment of required student outcomes that prepare students for their professional careers after graduation. Among these, teamwork, as an important element, is highlighted in SO #5 as “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” [1]. Moreover, teamwork and leadership skills are must-have qualifications for engineering graduates entering the workspace in industries, a fact well recognized by the higher education community [2][3]. It is paramount for engineering programs to include teamwork-related content and training in the curriculum [4][5][6] and implement a process to assess the attainment of SO #5.

In our ECE program, teamwork has been introduced to students in the curriculum as early as in the first-year freshman-level ECE introductory lab course. Moreover, measures and assessment data from this introductory class, along with data from several higher-level ECE courses, have been used to gauge the attainment of SO #5. The assessment results from this introductory class serve as a useful baseline and reference for understanding the trend of SO #5 attainment across different year groups of students, ranging from freshmen to seniors.

II Overview of the Introductory ECE Lab Course

This is a 1-credit course offered to first-year ECE pre-majors. Students attend a two-hour laboratory session for 10 weeks during the winter quarter of their freshman year. Concurrently, they also take a 1-credit introduction to ECE seminar course and other required science and math classes to prepare them for applying to the ECE major. This lab class aims to engage pre-major students in our program.

The course learning outcomes are specified in Table 1.

| | |
|----|---|
| 1. | Demonstrate appropriate use of electrical and computer engineering lab tools (instruments and selected software). |
| 2. | Successfully design, construct, and program a simple microcontroller-based project. |
| 3. | Demonstrate the ability to work as a team. |

Table 1: Desired course learning outcomes for the Introductory ECE Lab Course

To promote students' engagement, we have introduced a series of hands-on lab assignments. Throughout the quarter, students work on four to five labs and a 4-week long micro-controller-based course project. The lab topics include software, circuitry, and microcontroller programming that tie to real-life applications. A sample of lab topics introduced in winter 2023 is described in Table 2.

| Lab (Schedule) | Lab topics |
|--------------------------------|---|
| #1 (week 2) | MATLAB-based digital piano keyboard |
| #2 (week 3) | Arduino-based 24-key piano keyboard |
| #3 (week 4) | Alarm circuit using breadboard, op-amps, light sensors, buzzers |
| #4 (week 5) | Arduino-based temperature monitoring system |
| #5 (week 6) | Arduino-based motor control with IR sensor boards |
| Optional (week 6-7) Project | Soldering an alarm circuit |
| Project (week 6-10) | Arduino robot car or Arduino solar tracker |

Table 2: Sample lab topics introduced in the Introductory ECE lab course

As highlighted in the course learning outcomes, this class emphasizes providing students with teamwork experience and teamwork skill training. In the next section, we will elaborate on some of our efforts and endeavors in cultivating teamwork through the completion of the course project.

III Teamwork-centered Curriculum adopted in the Course Project

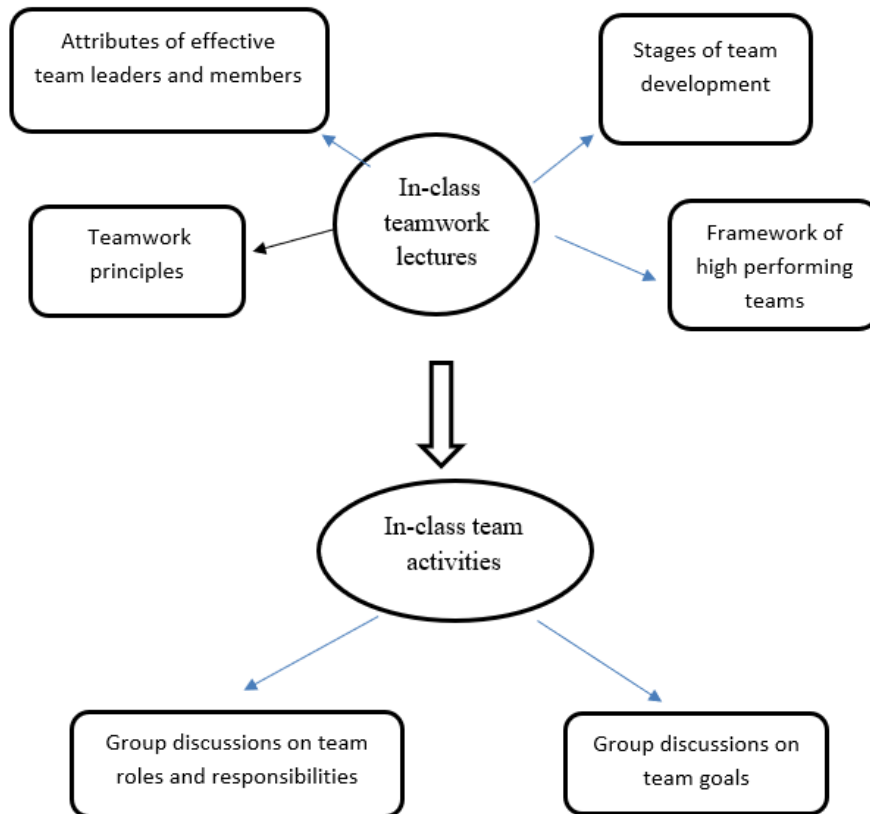
All the lab assignments in this class are team-based. However, students gain significant teamwork training and practice through the course project process. They choose a project topic from two options, form a team, and work closely together through a 4-week or 5-week project journey. The teamwork curriculum is carried out in the following aspects:

- In-class lectures and activities to introduce teamwork essentials such as

- Teamwork principles and attributes of effective team members covered in the textbook [7] and from external references [8]. A sample of topics is depicted in Figure 1 and
- Small group discussions and brainstorming on team goals, roles, and responsibilities.
- Weekly assignments to improve teamwork productivity such as
 - Weekly project team meeting
 - Weekly project deliverables: A sample of these deliverable requirements is provided in Figure 2. As student survey responses indicate, most students felt that this requirement helped ensure teams making progress.
 - Weekly team member activity log: we created a log template that students can use as a guideline for their weekly activities toward completion of the course project. Many students acknowledged that the weekly log was also beneficial for making progress over time.
- A new team member role structure that consists of four different roles with corresponding responsibilities, as described in Table 3.

| Team member role | Responsibilities |
|-----------------------------|--|
| Technician | <ul style="list-style-type: none"> ● in charge of parts needed for the project ● ensure all team members understand the functions and purpose of all components, and ● maintain the components in a safe location for the team. |
| Quality assurance personnel | <ul style="list-style-type: none"> ● understand the requirements for the project, and ● make sure that the team understands the requirements thoroughly so that the requirements can be implemented and met by the end of the project cycle. |
| Log keeper | <ul style="list-style-type: none"> ● assign tasks for each team member that shall be completed by the end of the week, and ● maintain a list of these tasks and log whether they have been completed by their deadline. |
| Drafter | <ul style="list-style-type: none"> ● develop a flow chart for the design of the project such as the coding process or a circuit design schematic |

Table 3: New team member roles and responsibilities



○ .

Figure 1: A sample of in-class lecture topics and activities on teamwork

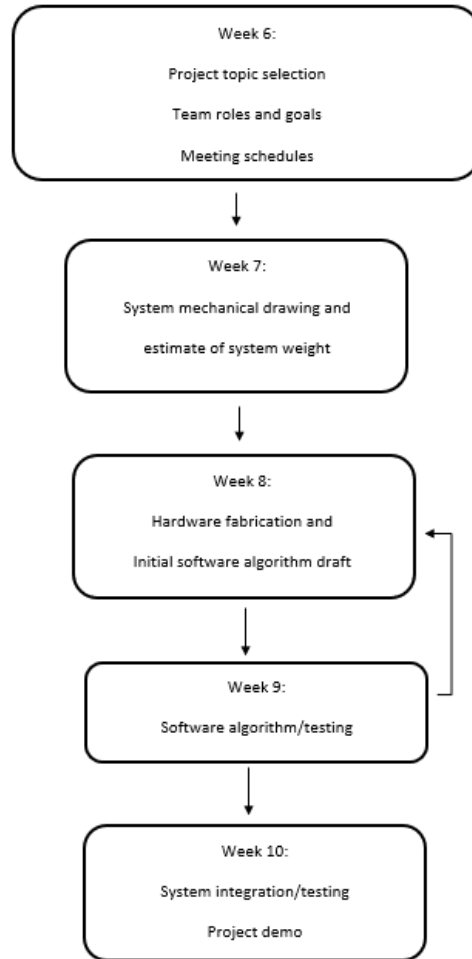


Figure 2: a sample of weekly deliverables required in the course project

IV Assessment Metrics, Criteria, and Assessment Results on ABET SO #5

IV. A Assessment metrics for ABET SO #5

For the assessment of SO #5, we have used two measures from the winter 2023 EECE109 class.

- The first measure is the course project score from each student to measure the overall success in meeting the requirements as a team. For this measure (measure #1), the student scores are converted to a 0-3 scale as described below, using percentage cutoffs for letter grades: a score less than 73% (C-) is a 0, a score less than 83% (B-) is a 1, a score less than 93% (A-) is a 2, and above 93% is a 3.
- The second measure is assessed by a teamwork survey that gauges the efficiency of teamwork, collaboration, and the overall teamwork experience. Appendix I provides the full list of twelve survey questions. We have chosen question #7 (“Do you feel that your

team has functioned effectively as a team whose members together provide leadership, create a collaborative and inclusive environment, establish goals, plan tasks, and meet objectives through the project experience”) as the specific measure. Note that although this survey question is directly taken from the ABET SO #5 language, we have purposely designed a series of questions (questions 1-6) in the survey that lead to this question. The discussion on the reliability of the survey questions are presented in Section IV. E.

For the survey measure (measure #2), responses from question #7 are mapped to 0 to 3 as described below. Specifically, “strongly agree” to 3, “agree” to 2, “No strong opinion” to blank, “disagree” to 1, and “strongly disagree” to 0.

We would like to point out that some of the survey questions are created according to research-proven findings and leading industry perceptions on key factors to form effective teams. Survey questions #4 and #5 aim to measure the teamwork psychological safety aspect, ranked as a top factor by Google researchers [8]. Psychological safety refers to an individual’s perception of the consequences of taking an interpersonal risk or a belief that a team is safe for risk-taking in the face of being seen as ignorant, incompetent, negative, or disruptive. In a team with high psychological safety, teammates feel safe to take risks around their team members. They feel confident that no one on the team will embarrass or punish anyone else for admitting a mistake, asking a question, or offering a new idea.

Students’ responses to the other survey questions provide insightful feedback and demonstrate that some of the teamwork activities introduced in this class are effective. Their responses imply directions for future curriculum improvement and adjustments as well. We provide further discussions, including student profiles and survey responses, in Section IV. D.

IV. B Assessment criteria for ABET SO #5

For this assessment, we evaluate the percentage of students who achieved an exemplary, satisfactory, developing, or unsatisfactory score for each measure using this conversion mechanism: 3 defines an “exemplary” score, 2 is “satisfactory”, 1 is “developing”, and 0 is “unsatisfactory”. If p_3 , p_2 , p_1 , and p_0 are the proportions of students earning each of these scores, respectively, the Student Outcome is considered attained if $z \geq 0.75$ where $z = p_3 + p_2 - p_0$. This requires at least 75% of students to be at the satisfactory level or higher [9].

IV. C Assessment Data and Results for ABET SO #5 based on the Introductory Lab Course

- For measure #1 assessment results, out of the 65 students enrolled in the lab course, 38 had exemplary scores, 22 had satisfactory scores, 3 had developing scores, and 2 had unsatisfactory scores. For this measure, based on $z=89.2\%$, SO #5 was attained. Table 4 shows the assessment data.

| Meaning | Score | # of Students | Proportion of Students |
|----------------|-------|---------------|------------------------|
| Exemplary | 3 | 38 | 58.5% |
| Satisfactory | 2 | 22 | 33.8% |
| Developing | 1 | 3 | 4.6% |
| Unsatisfactory | 0 | 2 | 3.1% |

Table 4: Measure 1 assessment data from the course project score

- For measure #2 assessment results, out of the 65 students who took this class in winter 2023, 61 survey responses were collected. Among them, 26 had exemplary scores, 31 had satisfactory scores, 2 had developing scores, and 2 had unsatisfactory scores. For this measure, based on $z=90.1\%$, SO #5 was also attained. The assessment data from this measure is provided in Table 5.

| Meaning | Score | # of Students | Proportion of Students |
|----------------|-------|---------------|------------------------|
| Exemplary | 3 | 26 | 42.6% |
| Satisfactory | 2 | 31 | 50.8% |
| Developing | 1 | 2 | 3.3% |
| Unsatisfactory | 0 | 2 | 3.3% |

Table 5: Measure #2 assessment data from Teamwork survey question #7

Based on the assessment results from both measures, we concluded that overall, SO #5 has been attained. The measures demonstrate that the students were able to successfully meet the requirements for the course project and understand and practice the expected teamwork concepts.

IV. D Summary of Student Profile and Student Feedback

Student Profile:

In winter 2023, 65 students took this class and 61 survey responses were collected. Figure 3 and Figure 4 show some student profile information. Specifically, Figure 3 summarizes the year standing of these students. Although they were all declared as EECE pre-majors, their actual standing varies from Freshmen to Seniors in our institution.

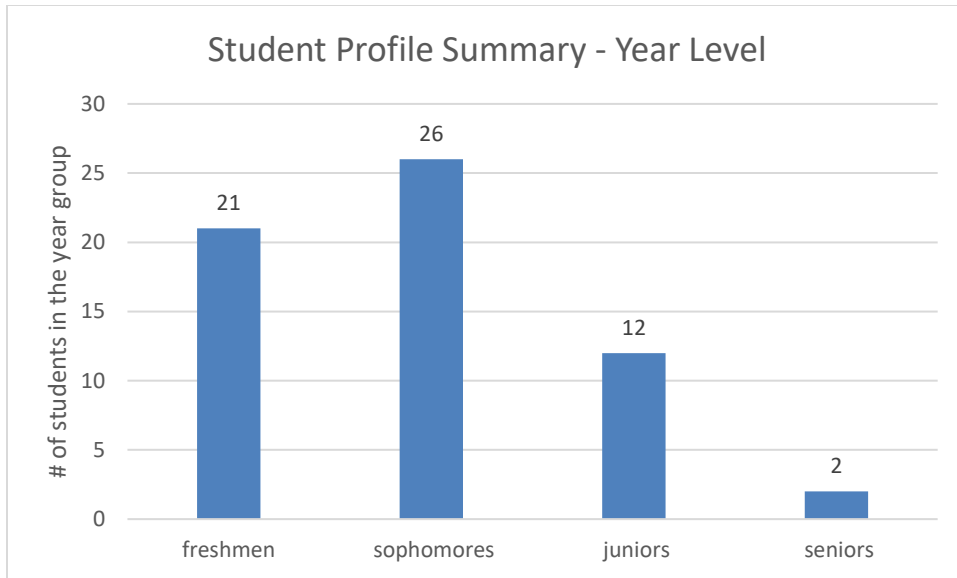


Figure 3 Student year standing data summary

In Figure 4, based on their responses to survey question #1, we provide student input about their diverse background such as age, technical expertise/experience, race, gender, etc. Note that the total number of inputs shown in Figure 4 is not equal to the total number of survey responses collected because some students indicated multiple categories (such as age and gender or other combinations). We also note that the students enrolled in this class appear quite diverse. The majority of the students recognized their differences in technical background. This often means that some students have had much experience in coding using certain software tool(s), some might have experience in circuit building or other hands-on activities, and others might have no or little experience in either software or hardware. Such differences could pose opportunities and challenges for the project teamwork setting in this class.

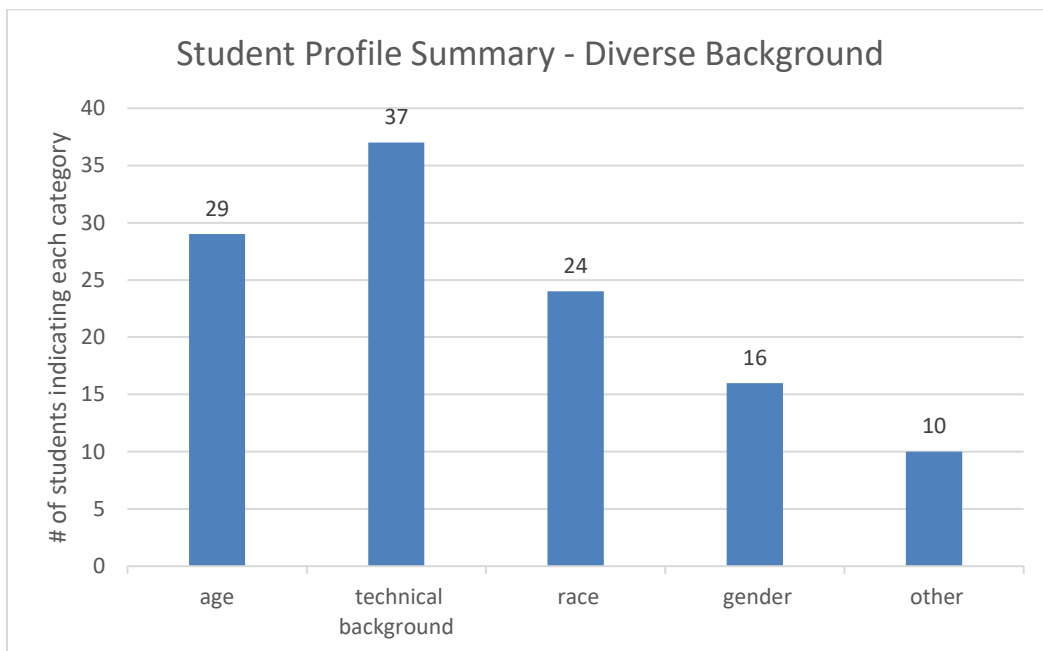


Figure 4 Student diverse background data summary

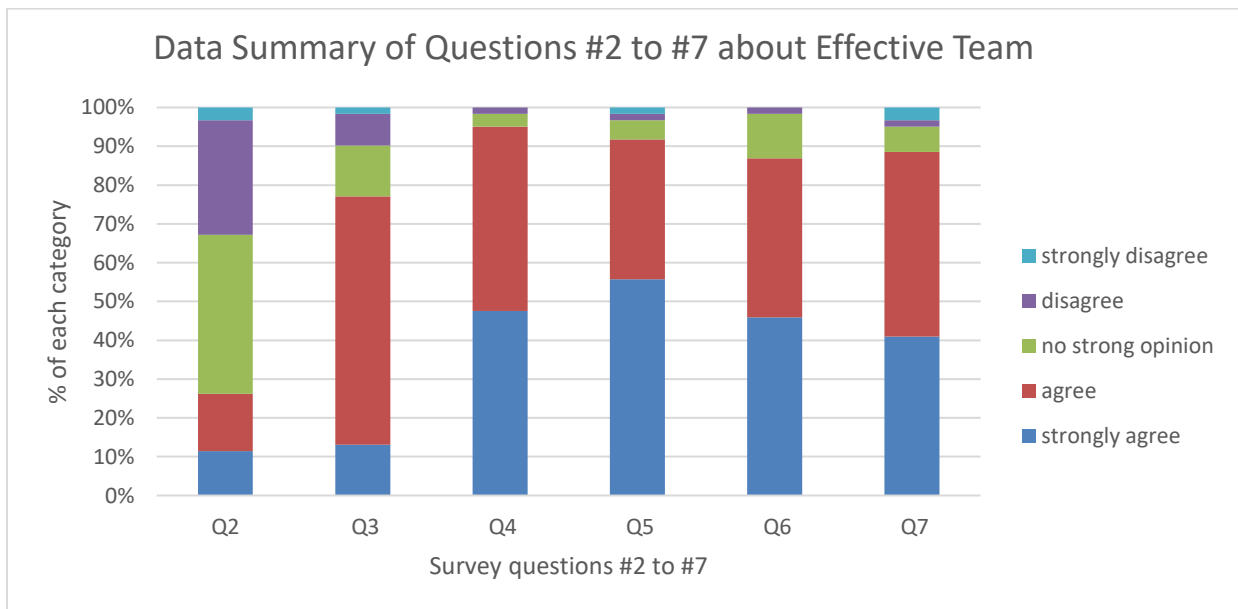
Student Survey Responses:

The survey responses for questions #2 to #7 from 61 students in the winter 2023 class are summarized in Table 6 and graphically depicted in Figure 5. For ease of data presentation, we adopted a five-point Likert scale ranging from 1 (Strongly Disagree) to 5 (Strongly Agree) and obtained the mean and variance of the responses for each question, listed in Table 6.

| Question | Strongly agree (“5”) | Agree (“4”) | No strong opinion (“3”) | Disagree (“2”) | Strongly disagree (“1”) | Mean | Variance |
|----------|----------------------|-------------|-------------------------|----------------|-------------------------|------|----------|
| #2 | 11.5% (7) | 14.8% (9) | 41% (25) | 29.4% (18) | 3.3% (2) | 2.87 | 1.36 |
| #3 | 13.1% (8) | 63.9% (39) | 13.1% (8) | 8.2% (5) | 1.7% (1) | 3.75 | 0.81 |
| #4 | 47.5% (29) | 47.5% (29) | 3.3% (2) | 1.7% (1) | 0% (0) | 4.37 | 0.5 |
| #5 | 55.7% (34) | 36.1% (22) | 4.8% (3) | 1.7% (1) | 1.7% (1) | 4.43 | 0.64 |
| #6 | 45.9% (28) | 40.9% (25) | 11.5% (7) | 1.7% (1) | 0% (0) | 4.27 | 0.63 |
| #7 | 42.6% (26) | 47.5% (29) | 3.3% (2) | 3.3% (2) | 3.3% (2) | 4.23 | 0.87 |

Table 6: Survey responses summary of questions 2 to 7

Note that a smaller numerical value for question#2 (“Only one person was seen as the leader of the group”) implies a better leadership structure in a team. For questions #3 to 7, a larger numerical value for each question would indicate a more effective teamwork experience.



We also aim to gauge students’ perceptions of the effectiveness of the weekly teamwork assignments mentioned in Section III and the newly adopted team role structure. Responses from question #11 indicate such perceptions, as summarized in Table 7.

| Question | Weekly due deliverables | Weekly team log | Team roles |
|----------|-------------------------|-----------------|------------|
| #11 | 77% (47) | 44.3% (27) | 26.2% (16) |

Table 7: Survey responses to question #11

The survey results indicate the following:

- Most students felt that the weekly deliverables helped them make progress toward completion of the course project.
- Many students agreed that the weekly team log was helpful too.
- The new team role structure introduced in the winter 2023 class did not seem to work well, per students' feedback. We will refine it and re-assess its effectiveness in future offerings of this class.

In addition, we collected student input about the teamwork principles that need to be improved. Per students' responses to question #8, 38% felt nothing needed to improve, 23% noted an improvement in establishing goals and planning tasks, 18% hoped to have better coordination among team members, and 13% felt their teams should improve in meeting objectives.

IV. E Reliability of Survey Questions #2 to #7

To check the reliability of survey questions #2 to #7, we computed the Cronbach's alpha coefficient based on these six survey questions. We also provided the Cronbach's alpha values with each question removed (question #2 to question #6) as shown in Table 8. Cronbach's alpha coefficients have been widely used to measure the internal consistency of survey questions [10] to verify the reliability of survey questions. A rule of thumb is that Cronbach's alpha value close to 0.7 is acceptable [11], and the larger the better. As shown in Table 8, the Cronbach's alpha coefficient resulting from our survey questions (#2 to #7) is around 0.6636. It indicates that questions #2 to #6 are relatively correlated to question #7 ("effective teamwork"). Interestingly, Cronbach's alpha value increases to 0.7709 with question #2 being removed. It implies that question #2 might not be well aligned with the rest of the effective teamwork measures (questions #3 to #7) or the data from this question is not closely correlated with other data. We will consider revising question #2 for future offerings of this course to better measure the effective leadership aspect in a team.

| | Cronbach's alpha coefficient |
|-----------------------------------|------------------------------|
| All questions included (#2 to #7) | 0.6636 |
| Question #2 removed | 0.7709 |
| Question #3 removed | 0.65 |
| Question #4 removed | 0.5638 |
| Question #5 removed | 0.5548 |
| Question #6 removed | 0.5617 |

Table 8: Cronbach's alpha coefficients based on survey questions #2 to #7

IV. F Future Improvement on Survey Questions

We consider revising and expanding the survey used in this class to include questions that can measure other key teamwork factors such as dependability, structure, and clarity [8]. On dependable teams, members reliably complete quality work on time (vs the opposite - shirking responsibilities). Structure and clarity relate to an individual's understanding of job expectations, the process for fulfilling these expectations, and the consequences of one's performance are important for team effectiveness. This often requires setting specific, challenging, and attainable goals.

A sample of future survey questions is provided in Appendix II. We plan to conduct the revised survey in future offerings of this lab course.

V. Conclusions

In this paper, we have presented our effort in cultivating teamwork skills and providing teamwork experience through an introductory ECE lab course. We have described in detail the teamwork curriculum in this class, such as teamwork activities and weekly assignments introduced toward students' completion of a course project. Assessment metrics, criteria, and assessment data and results for ABET SO #5 based on this lab course are also provided. Student survey results from a recent course offering have shown that some of our teaching practices in teamwork are effective.

Reference:

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Appendix I: Survey Questions

1. Your project team is diverse in these aspects (Provide all applicable answers)
 - (a) Age (b) Technical background/expertise (c) Race (d) Gender (e) Other (f) None (g) N/A
2. Only one person was seen as the leader of the group.
 - (a) Strongly agree (b) Agree (c) No strong opinion (d) Disagree (e) Strongly disagree (f) N/A
3. The amount of work required to complete the project allowed all group members the opportunity to lead the team.
 - (a) Strongly agree (b) Agree (c) No strong opinion (d) Disagree (e) Strongly disagree (f) N/A
4. Your opinions regarding the implementation and revision of the project were heard, discussed, and taken into consideration by your group.
 - (a) Strongly agree (b) Agree (c) No strong opinion (d) Disagree (e) Strongly disagree (f) N/A
5. You felt confident and comfortable asking questions or proposing changes to the project without the fear of being ridiculed by your group members.
 - (a) Strongly agree (b) Agree (c) No strong opinion (d) Disagree (e) Strongly disagree (f) N/A
6. Weekly tasks and goals were set and achievable by the end of the week.
 - (a) Strongly agree (b) Agree (c) No strong opinion (d) Disagree (e) Strongly disagree (f) N/A
7. Do you feel that your team has functioned effectively as a team whose members together provide leadership, create a collaborative and inclusive environment, establish goals, plan tasks, and meet objectives through the project experience?
 - (a) Strongly agree (b) Agree (c) No strong opinion (d) Disagree (e) Strongly disagree (f) N/A
8. Which aspect(s) do you feel that your team needs improvement?
 - (a) Leadership (b) Collaboration (c) Inclusive environment (d) Establish goals (e) Plan tasks (f) Meet objectives (g) None (h) N/A

9. Do you feel that the newly introduced team member roles (Technician, Quality assurance, Log keeper, & Drafter) are effective and useful?

(a) Strongly agree (b) Agree (c) No strong opinion (d) Disagree (e) Strongly disagree

10. The team activity provided with the team member roles helped identify team strengths, weaknesses, and sparked ideas in overcoming challenges that would be presented during the team project.

(a) Strongly agree (b) Agree (c) No strong opinion (d) Disagree (e) Strongly disagree

11. Which project requirements are helpful to ensure the team making progress (Select all applicable answers)

(a) Weekly due deliverables (b) Weekly team activity log (c) Team Roles

12. Which teamwork principles that you feel your team is strong, weak, or neutral? Fill in Tables S1 & S2.

| | Purpose | Synergy | Cooperation | Roles | Difficulty | Motivation | Weakest link | Attitude |
|---------|---------|---------|-------------|-------|------------|------------|--------------|----------|
| Strong | | | | | | | | |
| Weak | | | | | | | | |
| Neutral | | | | | | | | |

Table S1: Teamwork principles

| | Trust | Discipline | Focus | Values | Leadership | Morale | Planning and Resource | Decision Making |
|---------|-------|------------|-------|--------|------------|--------|-----------------------|-----------------|
| Strong | | | | | | | | |
| Weak | | | | | | | | |
| Neutral | | | | | | | | |

Table S2: Teamwork principles continued

Appendix II: Possible Survey Questions to be added to the Original Survey

Questions related to “Dependability”

1. When my teammates say they’ll do something, they follow through with it.

(a) Strongly agree (b) Agree (c) No strong opinion (d) Disagree (e) Strongly disagree

2. If my teammates confront a problem they cannot solve or will delay the work, they inform the team.

(a) Strongly agree (b) Agree (c) No strong opinion (d) Disagree (e) Strongly disagree

3. Teammates often do not show up on time during planned meetings.

(a) Strongly agree (b) Agree (c) No strong opinion (d) Disagree (e) Strongly disagree

Questions related to “Structure and Clarify”

1. Goals set by the group were specific, challenging, and attainable.

(a) Strongly agree (b) Agree (c) No strong opinion (d) Disagree (e) Strongly disagree

Questions related to “Meaning and purpose”

1. The work I do for our team is meaningful to me.

(a) Strongly agree (b) Agree (c) No strong opinion (d) Disagree (e) Strongly disagree

2. Regular meetings with my team helped me feel more accomplished in my work

(a) Strongly agree (b) Agree (c) No strong opinion (d) Disagree (e) Strongly disagree