Assessing Sophomore Cornerstone Courses in Electrical and Computer Engineering

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1. Introduction

Over the last five years, we have initiated, implemented, and refined our approach to teaching sophomore-level cornerstone courses labeled ECE 211 Introduction to Design Processes and ECE 212 Introduction to Project Development. The original impetus for the development of these courses was the realization that students did not have sufficient preparation for demanding capstone projects and that waiting for the senior year to fix the deficiencies was not effective. While there are introductory level project-based courses in the first year, students do not have enough technical background to make the projects technically challenging. While they may get some teamwork experience from such courses, they usually only get very basic, if any, training in project management. This is why we decided to introduce our cornerstone courses in the sophomore year.

We developed a two-quarter-long course sequence: one focused on design processes and another on project implementation [1-6]. We had two overarching goals:

1. Teach students design and project development well before senior Capstone projects.
2. Integrate various strands of electrical and computer engineering through experiential learning.

Given their project-based nature, these courses are a natural fit for the assessment of many of the student outcomes listed by ABET [10]. We have developed a series of assessment tools, primarily in the form of rubrics. These rubrics are generalizable and can be applied in other courses, especially project-based ones. We paid special attention to three of the so-called "professional skills": teamwork and project management, life-long learning, and communication. Rubrics for other outcomes were also developed and reported in [2] but are not discussed in this paper.

In this paper, we will describe each of the assessment tools, their deployment, examples of analysis, and how this analysis can be used in ABET assessment. These tools have changed over the years, and Covid makes historical comparisons difficult. However, with the return of in-class instruction, we are now collecting data continuously and can identify potential problems in student learning. We have also developed detailed course information describing assessment and other organizational issues arising in this and similar courses.

The rest of the paper is organized as follows: first we provide a curricular, institutional and course context, followed by an in-depth analysis of assessment of three student outcomes, and conclusions at the end.

2. Cornerstone courses

During the regular academic year, ECE 211 is taught in the fall quarter and ECE 212 is a continuation of it in the winter quarter. In ECE 211 we make a formal and detailed introduction to topics such as project management, teamwork, and design. Students put this knowledge to practice in a 2-week long practicum during ECE 211 and follow that up with full project implementation in ECE 212. Teams are formed in ECE 211 and carry forward to ECE 212. This sequence is required in both Electrical Engineering (EE) and Computer Engineering (CMPE) programs. Even though this is a sophomore course there are a lot of students who are juniors, primarily students who transfer from community colleges. Most of the transfer students take the sequence during the summer term where it is compressed to 8 weeks total instead of the usual 2x 10 weeks.

Starting with Fall 2021, we transitioned back to full face-to-face instruction and teams met mostly during class times but were allowed to have one online meeting per week. Project demonstrations were conducted with full class participation.

In ECE 211 teams select their own projects which are supposed to address a specific need. Areas of interest covered by projects vary widely. Students are instructed to be realistic in their expectations and planning but to also push themselves to reach for goals that may not seem doable at first. “Failure” or risk taking is encouraged so long as it is accompanied by hard work, ambition, and learning from such failures. Teams are trained in Scrum-like project management and we provide Scrum Leaders who are recruited from upper-division students. Scrum enables frequent iterations of product prototypes and near-daily team interactions [9]. This gives us much greater visibility into how teams operate during the project, not only at the very end. Scrum approach to project management is gaining popularity in engineering programs outside of software engineering and a recent paper even provides guidance on its implementation [7] and we have offered a workshop on this topic [13].

2.1 Development and improvements

From the very beginning these courses were meant to provide a wealth of data not only for improving the courses themselves but also to provide program level data. Given that the courses are nominally sophomore level, assessment data is largely going to be developmental, unlike the data from capstone courses that are summative in nature and more informative for ABET accreditation. Nonetheless, we paid special attention to documenting the course developments and reasons for changes. In addition, the detailed documentation is useful for sharing course teaching and for potentially implementing similar courses at other institutions. The documentation contains the course structure and syllabus, all assignments, report templates, and rubrics used for assessment. Each of the main topics is explained in some detail: product design, teamwork, project management, assessment, schedule, and tools used (Trello, CATME). This handbook is available from the authors as a pdf file.

Over the five years we have made improvements in:

- Streamlining of sprint and final project reports to make them less time consuming and more useful for assessment
- Alignment of project assignment and assessment with ABET requirements for design and ethics considerations
- Refinement of rubrics and grading
- Addition of project financials into project planning
- Better integration with prerequisite courses by using a common microcontroller

Finally, the development of various aspects of the courses is documented in a series of conference publications and workshops [1-6],[13].

3. Assessment

The main purpose of assessment in these courses is formative but we also need to apply it to grading of teams and individuals. One advantage of using a Scrum (Agile) project management framework is that it enables continuous observation of student performance and enables earlier intervention. Where possible, it is advantageous to have more than one assessment instrument to enable triangulation, i.e., to make more reliable observations and evaluations. In most of our assessments we use rubrics which were described at the program level in [2]. Current versions of those discussed in this paper are given in the Appendix. We also make use of evaluations by Scrum Leaders which are done for every sprint, i.e., every two weeks. Students also get to do self- and peer-evaluation of teamwork, based on the CATME framework [8].

Our rubrics are based on a 4-level performance scale: Beginning (1), Developing (2), Proficient (3), and Exemplary (4). In most cases, we allow intermediate levels, such as "Developing/Proficient." This often arises when, for example, one sub-criterion is assessed as "Developing" but another one is "Proficient." We believe that this gives the assessor more flexibility and will enable the easier identification of problem areas. However, having more levels can also lead to a false sense of "accuracy" which may not really be there when using rubrics. The assigned scores still rely on the assessor's judgment, and there is bound to be some variability even when all assessments are done by one person.

Most rubrics have more than one major criterion and each criterion usually has more than one performance metric. For example, the rubric for ABET outcome 5 which deals with teamwork and project management has three main criteria:

A. Project planning (2 items),
B. Project Implementation (5 items)
C. Team Functioning (6 items)

Each criterion has more detailed descriptions or sub-criteria, e.g., Project planning has two such items. Performance metrics are given for each level but in a few cases we limit the highest level

to Proficient. Evaluators can fill in the rubric for each performance metric or can give an overall score for the whole criterion based on some "average" over all performance metrics. In general, rubrics are shared with students so that we establish and communicate our expectations.

Given that these are sophomore courses, we cannot expect that everyone will perform at the Proficient or Exemplary level, and we expect to see some components that need improvement. Also, because these assessments are done at the sophomore level, they cannot be the only assessment used for ABET evaluations. However, the same assessments are easily extendable to Capstone projects. Furthermore, it is essential to do this or similar assessment early on in the program so that we can diagnose where problems originate instead of just identifying their existence in the senior Capstone project. If the same set of rubrics is used over several years it may be possible to document improvements and to determine the effectiveness of instructional changes.

Because these two courses are project based, they are well suited for evaluation of ABET outcomes 2 to 7. These tend to be the more difficult to assess, especially outcomes 3 - 7. In this paper we will focus on assessment of outcomes 3 - Communication, 5 - Teamwork and Project Management, and 7 - Life-Long Learning.

3.1 Assessment of ABET outcome 3: Communication

The assignment used in this assessment is the final project report. Students are given detailed instructions on the purpose and content of this report. Assessments are in general done the same way for all teams, but we make some allowance for teams smaller than four when giving final course grades. The rubric has three main components: Organization, Content, and Data Analysis (see Appendix A.). The latter is similar to ABET Outcome 6 on experimentation, but it does not encompass the whole of Outcome 6. The instructor reads all reports - nine of them in the case described in this paper - and uses the rubric for assessment.

3.1.1 Evaluation of data

We expect sophomore teams to be functioning somewhere between Developing and Proficient performance levels. There are two ways to examine data: a) via average scores, where numerical values are assigned to different levels, and b) via histograms of scores. We use the former to identify potential problems and the latter for a more detailed examination of possible root causes.

Each of the three major criteria: Organization, Content, and Data Analysis, is broken down further into 9 sub-criteria, and each sub-criterion has more detailed descriptions of what constitutes it. In total, there are 25 criteria in the current version of the rubric. This may seem excessive, but instructors can assign scores based on the 9 sub-criteria only and use the more detailed descriptions as reminders of what to consider when assigning a score. Overall, the rubric is organized as follows:

I. Organization
   A. Organizes report properly (4 items)
   B. Makes report aesthetically pleasing (3 items)
   C. Demonstrates proper use of English (3 items)
II. Content
   D. Presents abstract (Summary) (2 items)
   E. Presents introduction & motivation (3 items)
   F. Presents conclusions (1 item)
   G. Discusses relevant topics (varies) (1 item)
III. Data analysis
   H. Presents content in own words to demonstrate comprehension (4 items)
   I. Provides supporting data and critical analysis (4 items)

In the first step, each performance level is assigned a numerical value: Beginning = 1, Developing = 2, Proficient = 3, Exemplary = 4. Not Applicable (N/A) is assigned a zero. Intermediate values are the average of the two, e.g. "Developing/Proficient" = 2.5.

In the second step, we calculate averages for each of the 9 criteria (A. to I.) to identify any significant trends or problems. An example of this data is shown in Table 1.

Table 1. Average scores for criteria A. to I. for 2023 class.

Organization	Av. score	**Content**	Av. score	**Data analysis**	Av. score
A. Organize	2.78	D. Presentation	3.0	H. Comprehend	2.76
B. Pleasing	2.83	E. Intro	3.0	I. Data	2.64
C. English	2.63	F. Conclusions	2.67		
		G. Topics	2.67		

It is hard to use averages for overall assessment purposes, but we can see some general trends. In 2023 there were no glaring problems with items A., B., and C. which are part of "Organization." This has been consistent throughout the years. Another factor that helps teams score well in this area is that teams also have to write a project proposal that covers similar topics. This gives teams much-needed practice and a chance to receive feedback from the instructor. A slightly lower score in C. English is due to teams not doing the final proofreading carefully so that careless mistakes are left uncorrected.

Items D. and E. have not been a problem recently because students use the provided template. However, the results for the F. Conclusions and G. Topics criteria can be improved. Students often include new topics in the Conclusion section or discuss irrelevant or tangential topics such as the history of their product development. Similarly, criteria H. Comprehend and I. Data can be

improved, but such improvements are difficult to achieve within these courses alone. While some work can be done in these courses, follow-on courses need to address these outcomes more explicitly, especially the students' ability to critically analyze the data.

More detailed information can be obtained from histograms organized by section (A-I). A sample of these is shown in Figures 1 and 2 for 2023 assessments. These are presented to illustrate the assessment procedure and what types of conclusions can be drawn from the data. There were 32 students organized in 9 teams.

For the criteria in the "Content" area shown in Figure 1, teams performed well overall, though the conclusions section and coverage of relevant topics need improvement. Around 50% of the reports were at the Proficient level. Students need more practice to make their writing more concrete, but all of them had appropriate content and the quality was appropriate for the sophomore level. Based on the comparison with prior years (not shown here) we can also see improvements in these areas.

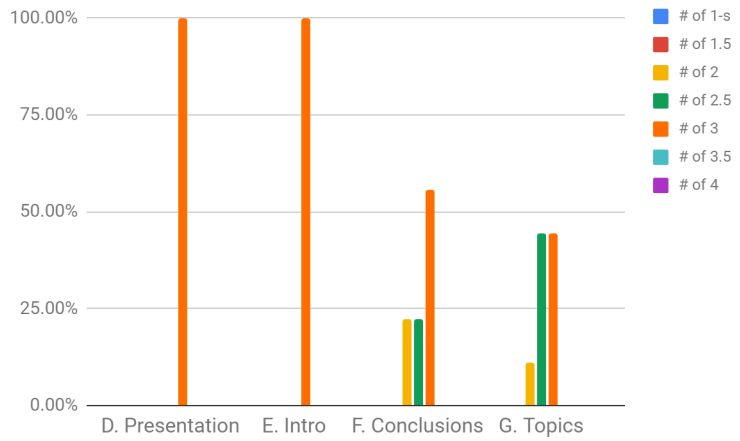

Figure 1. Winter 2023 - Histogram of scores for section "Content" consisting of criteria D, E, F, and G.

Data for criterion I. Data Analysis is shown in Figure 2 and is at the acceptable level. The results have improved over the prior years (not shown here) but are not quite at pre-Covid levels. Data is skewed by one team that did not have a functioning prototype and no final test data. Nonetheless, this is one area that we need to emphasize and provide more examples to students to make our expectations clearer.

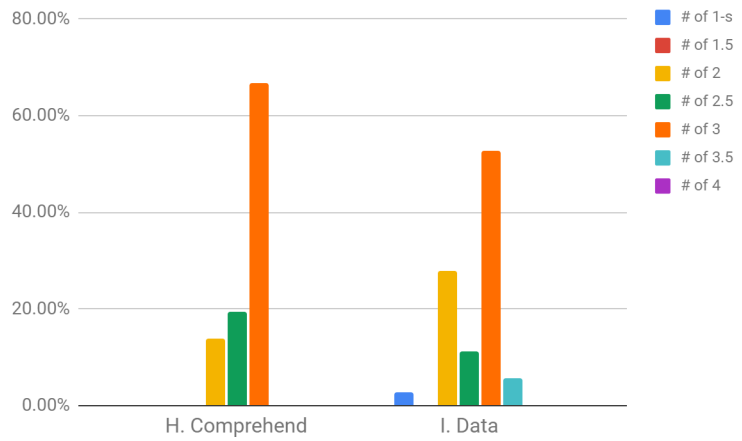

Figure 2. Winter 2023 - Histogram of scores for section "Data Analysis" consisting of criteria H and I.

The reports overall are of reasonably good quality but there is some variability, and we should work on reducing the distribution at the low end of the scale.

Overall evaluation of written reports: students are between "Developing" and "Proficient" levels in their writing (communication) skills. This meets the performance level for this criterion given that this is a sophomore class. With some additional practice, students should be well-prepared for their senior capstone projects. Areas of testing, data analysis, and writing better summaries (conclusions) still require more attention.

3.2 Assessment of ABET outcome 5: Project management and teamwork

Assessment of project management is difficult. It is usually done based on artifacts that teams produce either at the end of the project, such as a project report, or based on some intermediate artifacts, such as team or individual progress reports. These are inadequate if we want to gain insight into, for example, team dynamics. In the context of the ECE 211+212 sequence, students are asked to apply Scrum-like project management which lends itself more readily to such assessment.

We used two assessments:

1. Assessment of project management and teamwork by the Scrum Leaders and instructor.
    a. Uses a newly developed rubric with three different criteria broken down into several sub-criteria.
    b. Completed periodically (every two weeks) by scrum leaders.
    c. The instructor does the final evaluation based on scrum leaders' reports and his/her own observations.
2. Assessment based on peer evaluation using the CATME system [8].

a. Three questions out of five are used for the assessment of project implementation and two for the assessment of teamwork.

Having two different assessments enables cross-checking on collected data. Teams are supposed to have four members but in this class we ended up with five four-person teams and four three-person teams for a total of 9 teams.

The newly developed rubric for project management and teamwork has three main criteria:

A. Planning (2 items)
B. Implementation (5 items)
C. Teamwork (6 items)

As explained above, performance levels are labeled Beginning (1), Developing (2), Proficient (3), and Exemplary (4). A rubric template can be found in the Appendix B. As in Outcome 3, we allow intermediate scoring. These rubrics were filled by Scrum Leaders for each sprint. Evaluations by Scrum Leaders of earlier sprints are used to track team performance and to intervene if any problems are detected. The instructor examined scores given by Scrum Leaders for the final sprint and gave one overall score for each of the three criteria. This data is presented below.

We also use student evaluations of their teammates' contributions and their own performance. These can be done at different times and frequency: at a minimum, there should be one after the practicum in ECE 211 and one at the end of ECE 212. If students are well trained, it is possible to require students to file these peer-evaluations after each sprint. CATME data was collected on the catme.org website and downloaded as a spreadsheet. We examined only the five most important characteristics:

1. C - Contributing to the Team's Work
2. I - Interacting with Teammates
3. K - Keeping the Team on Track
4. E - Expecting Quality
5. H - Having Related Knowledge, Skills, and Abilities

The first two items (C and I) were grouped as indicators of the Teamwork part of project management, while items K, E, and H were indicators of the Implementation part of project management. It was not possible to assess the Planning part by using CATME data.

Detailed CATME data has to be manually processed and interpreted to make it useful for this assessment. By its very nature, CATME is based on individual assessments of other individuals and this has to be converted into assessment of the overall team performance. So far, we have approached this problem qualitatively by using the data to inform the instructor's judgment of the team performance, as described below.

The data was first processed qualitatively by looking for signs of trouble. One such sign is the score in "Adj. Factor" in Figure 3. If all scores are larger than roughly 0.85 then we assume that the team in question is doing reasonably well. However, if this is not the case, we need to examine the team functioning more closely. For example, just because one team member is not performing well does not always mean that the entire team is not functioning well. Therefore, some qualitative assessment by the instructor is needed to convert CATME scores to our assessment levels. This was accomplished by looking for any low scores for the entire team across appropriate CATME dimensions (CIKEH). We used these intervals:

1. All or most scores are > 3.5 → this is converted to Proficient level
2. All or most scores are between 3 and 3.5 → Dev/Proficient
3. Many scores < 3.0 → Developing

This conversion was limited to the Proficient level in our scale, and we did not assign any Exemplary scores. This is because we find it difficult to interpret the difference between CATME scores of 4 and 5. For example, some students give 5 to everyone just to indicate that they are happy with their team. In addition, a CATME score of "4" is defined as an intermediate score for students who "Demonstrate behaviors described immediately above and below" (see Table 2) [12]. To avoid these ambiguities, we decided to lump all of the Proficient and (potentially) Exemplary scores as Proficient.

Table 2. Illustration of the rating scale used by CATME [12].

Score	Contributing to Team's Work
5	• Does more or higher-quality work than expected. • Makes important contributions that improve the team's work. • Helps teammates who are having difficulty completing their work.
4	Demonstrates behaviors described immediately above and below.
3	• Completes a fair share of the team's work with acceptable quality. • Keeps commitments and completes assignments on time. • Helps teammates who are having difficulty when it is easy or important.

It should be emphasized that we are looking at these assessments as formative or developmental, so the important part is to identify teams in trouble and devise interventions for immediate problems and to plan how to avoid these in the future. Therefore, this analysis of team performance is used only as part of the assessment but not for individual student grading. An individual student's grade can be weighed by their contribution to the team as given by CATME scores, as well as observations by Scrum Leaders and the instructor.

A sample of raw CATME results for all five criteria is given in Figure 3 which illustrates that it is relatively easy to identify teams in trouble (Team 2, middle three rows). However, it is more difficult to quantify the level of a team's performance based on these scores.

Search:

Contrib. to Team	Interact w/ Team	Keeping on Track	Expect Quality	Having KSAs	Adj Factor (w/ Self)	Adj Factor (w/o Self)
4.7	4.3	4.7	5.0	4.3	1.00	0.95
4.7	4.3	4.3	5.0	4.3	1.00	1.00
4.7	5.0	4.7	5.0	4.7	1.02	1.01
4.7	4.7	5.0	5.0	4.7	1.02	1.05
1.0	2.5	2.5	2.5	3.5	0.77	0.77
4.5	3.5	3.5	3.5	4.0	1.05	1.05
2.5	3.5	3.0	3.0	3.5	1.00	0.57
3.0	3.7	2.7	3.3	3.3	0.92	0.92
3.7	3.7	3.3	3.7	3.3	1.01	1.01
4.0	3.7	3.3	3.7	3.7	1.05	1.02
3.7	3.7	3.3	3.7	3.3	1.01	1.05

Figure 3. Example of CATME results for peer evaluation of five main behavioral characteristics.

Table 3 illustrates how the data for the first three teams was converted into the same scale used in our rubric.

Table 3. Example of conversion from CATME data into assessment scores.

CATME Dimensions	Team 1	Team 2	Team 3
C+I (Teamwork)	3 (Proficient)	2.5 (Developing/Proficient)	3 (Proficient)
K+E+H (Implementation)	3 (Proficient)	2.5 (Developing/Proficient)	2.5 (Developing/Proficient)

3.2.1 Evaluation of data

A summary of the data for the 2023 class is presented through two histograms:

a) Data from the assessment using the rubric, shown in Figure 4
b) Summary of CATME peer-evaluation results, shown in Figure 5

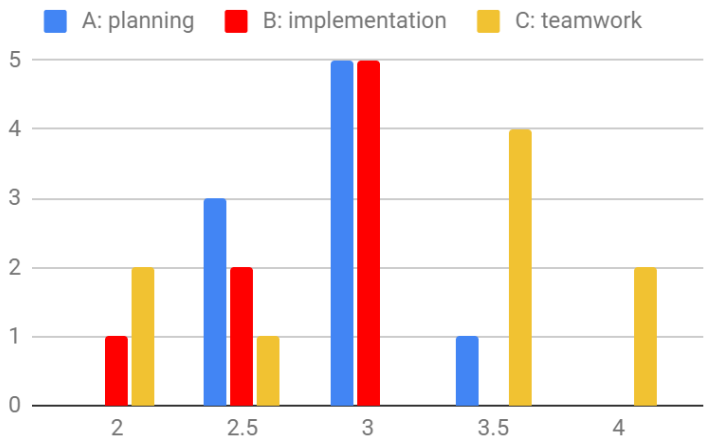

Figure 4. 2022-2023: Histogram of scores for the assessment using a rubric.

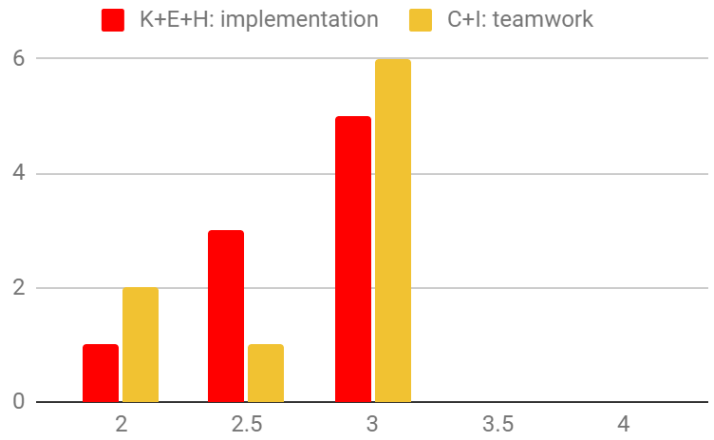

Figure 5. 2022-2023. Histogram of scores summarized from CATME.

Note that CATME results are capped at 3, so for comparison with the results using the rubric we counted scores of 3 and higher together.

Based on this data we can conclude that:

1. Criterion A. Project planning is difficult for teams, especially given that we are using the Scrum framework which requires constant changes. Note, however, that these are sophomore students or transfer juniors, and we would expect their performance to be somewhat lower than proficient.
2. Criterion B. Project implementation is also difficult for teams to do consistently. There is a tendency for teams to skip the planning and documenting of their progress, especially on Trello. Scrum Leaders give separate feedback about Trello to teams and to the instructor.
3. Criterion C. Somewhat unexpectedly, team functioning is generally at the Proficient level or above with some excellent teamwork. However, there are always one or two teams that have difficulties in this area. CATME, Scrum Leaders, and the instructor's own observations confirm these conclusions.

Overall, teams functioned reasonably well, and seven out of 9 teams were at the proficient or developing/proficient level.

3.2.2 Conclusions and recommendations

Overall evaluation of project management and teamwork: Student teams are performing at levels close to Proficient which we consider satisfactory for sophomore students. Areas in need of improvement include:

a) Improved planning of activities for upcoming projects (this happens during sprint planning), and

b) Improved implementation, i.e. running of the project according to plan instead of "hacking."
c) Students get confused about the difference between product backlog (i.e. requirements) and sprint backlog (i.e. tasks) which makes planning more difficult than it needs to be.

Many, if not all, teams used online tools, such as Discord and Zoom, to do some of the teamwork activities. While this brings additional benefits and flexibility it also makes it difficult for the instructor to stay informed.

Improvements in planning and implementation will be brought about by more emphasis on the planning activities in ECE 211 and improved guidance from Scrum Leaders and the instructor on how to perform well during all stages of the project.

Specifically, for future classes we will make the following improvements to the assessment:

1. Spend more time on Scrum Leader training for using the assessment rubric. We should aim to improve the reliability of their assessments. Similarly, instructors should check Scrum Leaders' work as soon as possible and on a regular schedule.
2. Ask teams to reflect on how well they are fulfilling the team contract they signed.

3.3 Assessment of ABET outcome 7 – Life-long learning

This is another criterion that is hard to assess. There are ways to probe students' attitudes toward life-long learning (LLL) but those are difficult to translate into specific outcomes that can be assessed. After experimenting with two such surveys [11] we have taken a different approach. First, we define two criteria for this outcome:

A. Acquiring new knowledge
B. Applying new knowledge

Assessment of these criteria is done in two ways:

1. **Criterion A**: Quality and quantity of references (information sources) given in teams' final reports.
    a. The project report assignment asks teams to provide a list of sources used in developing and implementing their project. This is supposed to be done at the end of the report.
2. **Criterion B**: Quality of self-reported and self-directed learning of new skills.
    a. Each team writes a sprint report every two weeks. Among many other things, each team member is supposed to list new skills learned during the sprint.
    b. There are four sprints and student submissions are judged in terms of their quality using a simple rubric, as explained below.

3.3.1 Evaluation of data

Criterion A is evaluated by the instructor. The number of sources listed is trivial to evaluate. To evaluate the quality of sources, we look for:

- Can sources be traced; this is usually most problematic for online sources for which students either do not provide links or links do not work
- Are they appropriate for the project
- Level of sophistication and variety; this is variable and requires some familiarity by the instructor with the problem and/or project

Quality and quantity of references: In this case, two teams did not provide any references even though it is clear that they must have consulted some external sources. The remaining 7 teams listed between 3 and 8 sources, with an average of around 5 sources per report. This average is good, but we have to emphasize that this part is actually required. Table 4 below gives a breakdown of the quality of references listed by teams in their reports. Those in "Dev/Prof" are in between the Developing and Proficient stages and have provided traceable but basic sources. Teams at the proficient level had a good selection and quantity of sources. Those at "Pro/Exemp" had a very good selection and number of sources and the list was relatively comprehensive.

Table 4: Quality of references in student reports, 2023.

	Beginning	Developing	Dev/Prof	Proficient	Pro/Exemp	Exemplary
# of teams	2		2	3	2	

Overall, students are doing reasonably well on this criterion, even though only minimal instruction is provided in the assignment description.

Quality of self-reported learning of new skills: For each team member, we evaluated their self-reported new learning as reported in each sprint report. Note that this learning is also self-directed because it happens during team planning and project implementation. The sprint report template has this prompt:

"New Skills: (Couple of sentences for each team member: Briefly discuss what new skills you learned during this sprint. Give this information for each team member. Leave empty if nothing new learned.)"

Some typical examples of student entries and their evaluation are given in Table 5. At the proficient level, we expect to see a specific skill that is likely to be used in the planning or implementation of the project. At the developing level, entries look superficial, i.e., not much thought is given, and they are not specific enough. The main issue at the Beginning level is that nothing is submitted, or no new knowledge is described.

Table 5. Examples of student entries for their learning and how they are evaluated.

	Beginning: No entry, very basic and/or repetitive across sprints	**Developing:** Superficial and not specific enough	**Proficient:** Specific and well described
Examples	- No entry - No new skills yet - repeats the same skill in two or more reports	- Autodesk fusion 360 - Some new syntax and code for Arduino	- Counters and timing in Arduino IDE - I learned the basics of DC motor control via a motor controller using an esp32.

Figure 6 summarizes the assessment of the quality of self-reported learning by individual students. “Sp#1” refers to Sprint #1, etc. Results are reported as percentages out of 32 students in the class. For example, in Sprint #1, 23 students (72%) entered items for their new learning that were assessed to be of the “Proficient” quality. One initially surprising observation in Figure 6 is the decline in the quality of learning. However, this makes sense in the context of project development - initially, there are many new things to learn, but towards the end the focus changes to implementation and making the project work. To compensate for this effect, Figure 6 illustrates the development of the four sprints along with the overall performance and the performance when only the first two sprints are taken into account. In the latter case, roughly 70% of scores are at the Proficient level and another 15% at the Developing level. The vast majority of the Beginning scores are due to a lack of any entry. This usually correlates with poor contributions to the team and should be addressed during the project implementation.

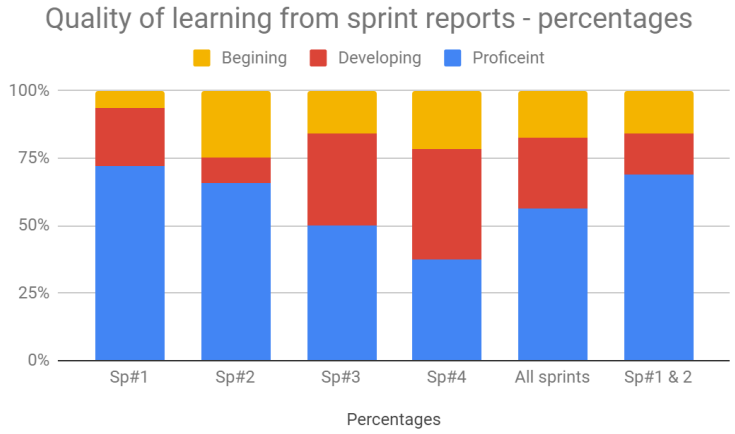

Figure 6. 2022-23 Percentages of scores for the quality of student self-directed and self-reported learning. All four sprints were evaluated as well as the overall performance and performance on only the first two sprints.

3.3.2 Conclusions and recommendations

Overall evaluation of LLL: This evaluation is done both at the team level (project reports) and on an individual student level (self-reported learning of new skills). Teams have reported a good

number of sources they used but two out of nine teams did not report any. The quality of sources was satisfactory. Therefore, the overall performance on Criterion A. Acquiring new knowledge is close to Proficient but there is room for improvement.

The quality of student learning is good and 70% of new skills reported by students were judged to be at the Proficient level. Furthermore, these new skills are immediately useful in implementing student projects. Therefore, the overall performance on Criterion B. Applying new knowledge is approaching the Proficient level. Remembering that this is a sophomore-level class, the performance is satisfactory but there is room for improvement with simple interventions such as showing good and bad examples.

4. Conclusions

Our sophomore-level sequence of cornerstone courses in the Electrical and Computer Engineering department at Portland State University has been under development and refinement for five years. We have described some of the improvements implemented over the years. We have paid special attention to developing assessment processes that can be useful for both course development and for program (curricular) evaluation. We believe that, even though such assessment is not directly applicable to ABET requirements because it happens before students are close to graduation, it is essential to do assessment across years so that problems can be identified and addressed. Given the project-based nature of the courses and the assessments used, the same assessments can be used for Capstone projects with minimal adjustments.

In this paper we have focused on describing the assessment process for three ABET-related outcomes: 3 - Communication, 5 - Project management and teamwork, and 7 - Life-long learning. Illustrative data was provided and analyzed, demonstrating what types of conclusions can be drawn from such assessments. If such data is collected continuously, then improvements over time can be demonstrated and documented. This will be a topic of a future publication. In addition, some surprising observations can be encountered such as the one regarding the diminishing quality of student learning as the project progresses.

We are still refining many aspects of the course and its assessment, but we believe that we have demonstrated the usefulness of our approach. It requires additional effort on the part of instructors, but we are working on streamlining it further. By providing detailed instructions, templates, examples, etc. we hope to reduce this burden on future instructors.

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Appendix A. Rubric for ABET outcome 3.

3. an ability to communicate effectively with a range of audiences					
Organization	**Beginning**	**Developing**	**Proficient**	**Exemplary**	**score**
A. **Organizes** report properly	Missing more than one required section	Missing one required section	All required sections included	Excellent organization that enhances readability	
	Inappropriate content in several sections	Some content placed incorrectly	Appropriate content in all sections		
	Disorganized sections, subsections and paragraphs	Sections, subsections, and paragraphs follow some logic	Sections, subsections, and paragraphs organized logically and consistently		
	Missing list of References	Weak list of references	Adequate list of references	Thorough list of references	
B. **Makes** report aesthetically pleasing	Unacceptable text appearance; fonts difficult to read;	Some text has sloppy appearance and is difficulty to read	Text well formatted and easy to read	Text, tables, figures, captions so clear and understandable as to enhance report impact	
	Table & figures cannot be read or understood	Few table or figures difficult to read or understand	Tables & figures readable and understandable		
	Missing captions	Captions are present but not informative enough	Adequate captions		
C. **Demonstrates** proper use of English	Many spelling, grammar and punctuation errors make report ineffective	Few significant spelling, grammar & punctuation errors;	No spelling errors & minor grammar or punctuation errors;	No grammar or punctuation errors	
	Many sentences have an awkward construction	Several sentences have an awkward construction	Sentences are mostly well-crafted	Varied and creative sentence structure	
	No proofreading apparent	Hastily proofread	Proof-read, but further revision could improve text	Thoroughly proof-read and revised	
Content	**Beginning**	**Developing**	**Proficient**	**Exemplary**	

D. **Presents** Abstract (Summary)	Not given	Given, but no significant results stated	Clear; key results stated	So clear and complete as to enhance impact of report	
	Not written for appropriate audience	Some material not appropriate for intended audience	Easily understood by intended audience		
E. **Presents** Introduction & motivation	Missing problem statement	Inaccurate/unclear problem statement	Clear problem statement	So clear and complete as to enhance impact of report	
	No motivation or introduction provided	Motivation / introduction poorly explained	Clear motivation / introduction		
	Missing constraints and assumptions	No discussion of constraints & assumptions	Constraints and assumptions listed & discussed		
F. **Presents** Conclusions	Conclusions not given or include several ideas that are not discussed in report	Conclusions include few ideas not already discussed, missing some important parts or are not concise	Clear, concise & complete conclusions, following report discussion	Proficient + contains meaningful recommendations	
G. **Discusses** relevant topics (varies)	Many important topics not covered or poorly explained	Most of the important topics covered and explained	All of the important topics covered, explained clearly and concisely	Exceptional quality and coverage with some new insights	
Data Analysis	**Beginning**	**Developing**	**Proficient**	**Exemplary**	
H. **Presents** content in own words to demonstrate comprehension	Lacking or inaccurate or irrelevant information	Basic information, but some is inaccurate or irrelevant	Adequate information with a few minor errors or omissions	Exceptional information (accurate and relevant)	
	No evidence of research	Some research done	Adequate research	Careful and thorough research	
	Significant amount of text is copied verbatim without citation (plagiarized)	Some text has been plagiarized	Text is mostly in author's own words; only small amount copied but is properly cited in text		
	Little understanding of the topic	Basic or partial understanding of the topic	General understanding of the topic	In-depth understanding & insight	

I. **Provides** supporting data and critical analysis	Ideas not expressed clearly nor supported by details	Ideas not expressed clearly or details are weak	Ideas are expressed clearly and details are adequate	Ideas are well-developed, expressed clearly with many appropriate details	
	No interpretation of data	Data analysis is weak	Data analysis is adequate	Data analysis is thorough and clever	
	No illustrations, or they do not support core message(s)	Illustrations are unrelated, confusing, or mislabeled	Illustrations support ideas, but have some mislabeling or do not present data in best way	Illustrations clearly support core message(s) and are properly labeled and captioned	
	No attempt to critically examine the data	Some critical examination of data given, but largely wrong or misdirected	All obvious problem areas are critically examined and plausible explanations provided	Proficient + some subtle problems with data are noticed and analyzed.	

Appendix B. Rubric for ABET outcome 5.

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				
Performance Indicator	**Beginning**	**Developing**	**Proficient**	**Exemplary**
A. Project planning (documentation, timeline, decomposition, requirements, specifications)	Superficial planning document	More thoughtful planning documentation	Project proposal provides full graphical and textual documentation for timeline, functional decomposition, requirements, specifications	Proficient + anticipates problems and potential solutions (plans B and C)
	Missing or incomplete timeline, decomposition, requirements and specifications	One or two components of plan are missing, not well documented or explained	All components of a plan are given, well documented and explained	

B. Project implementation (planning, tasks, deadlines)	Team meets irregularly	Team meets regularly	Team meets regularly	
	Plans are not updated as conditions change	Overall plan updated irregularly	Plans are updated regularly	Additional project planning and management features are used, e.g., burn-down charts for Scrum.
	Intermediate tasks are too broad, lack responsible person, deadline, and definition of "done"	One of the key components of intermediate tasks (who, when, what) is not specified	Tasks are specific, detailed, have responsibilities assigned with deadlines, and define when a task is done (who, when, what)	Adjusts effectively to unexpected events
	Activities driven by external deadlines - most activity just prior to some event	Activities follow a plan	Activities follow a plan	
	No systematic updating of tasks and project progress is very difficult to gauge	Tasks updated intermittently & project progress is difficult to gauge	Tasks are updated regularly and progress checked	
	No attention paid to deadlines	Team rarely misses deadlines	Team meets deadlines	
C. Team functioning (structure, communication, spirit)	Member roles and responsibilities are not clear	Member roles are clear but execution is problematic	Member roles and responsibilities are clear and effectively executed	
	Team does not produce a team contract	Team contract is superficial	Team contract is well written and team members stick to it	Team is cohesive
	Communication is poorly set up with frequent lapses	There are occasional lapses in communication among team members	Team communicates well and regularly	There is spirit of respect
	Several team members are not contributing enough	There is an imbalance in assigned tasks and responsibilities resulting in friction among members	Team members help each other	All points of view are considered
	Team is falling apart due to personality conflicts	Some evidence of friction but team manages to work through it	No evidence of friction	