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Development and Implementation of an Assessment Model in a Sophomore Electromechanical Systems Design Laboratory for the ETAC-ABET Accreditation

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Professor Lili Ma received her Ph.D. in Electrical Engineering from Utah State University focusing on autonomous ground vehicles. After that she did three-year post-doctoral training at Virginia Tech working with autonomous aerial vehicles. Prior to joining the Computer Engineering Technology (CET) department at City Tech in fall 2016, she taught at Wentworth Institute of Technology for many years. Professor Ma's research areas include autonomous mobile robots, vision-based control, visual servoing, visual tracking, coordinated control, and sensing & perception techniques.

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Abstract

In the field of assessment in higher education, practitioners regularly mention two features as key for success at implementing a sustainable assessment model, i) it has to be faculty-driven, and ii) it has to become part of the curriculum. This paper describes an assessment model incorporating these features. The model was developed and implemented for assessing both the ETAC-ABET Program Criteria for an associate degree in Electromechanical Engineering Technology program and the new ETAC-ABET (2019-2020) student outcome (2), which regards students' ability to design systems, components, or processes for well-defined engineering technology problems appropriate to the discipline. This paper describes the implementation of our assessment model, including a description of the performance indicators used for assessment of criteria mentioned above, the structure of course selected for the assessment, the details of the laboratory experiments and final design project used as assessment tools, a summary of the collected data and a discussion of the assessment results, and the arrangements we made in response to the COVID-19 pandemic. We believe that our method of incorporating assessment as regular course activities helps achieve the ultimate objective of education, i.e., continuous and constant improvement of students' competencies and learning experiences.

Introduction

The Department of Computer Engineering Technology (CET) at New York City College of Technology offers a two-year associate degree in Electromechanical Engineering Technology (EMT). This program is ABET-accredited, and thus, it abides by the accreditation criteria established by the Engineering Technology Accreditation Commission (ETAC) [1]. Defining a sustainable assessment model is essential for accreditation as an element of an institution's process for continuous improvement. In the field of assessment in higher education, practitioners regularly mention two features as key for success at implementing a sustainable assessment model, i) it has to be faculty-driven, and ii) it has to become part of the curriculum. In this paper, we present a sustainable assessment model that incorporates the two key elements.

The ABET criteria for accreditation have two sections, the General Criteria and the Program Criteria. The former applies to all programs accredited by an ABET commission. The latter is a discipline-specific accreditation criterion; programs must show that they satisfy the specific Program Criteria implied by the program title. Initially, our model was developed and implemented for assessing the ETAC-ABET Program Criteria for the EMT program, which has been kept roughly the same for more than six years. However, the 2019-2020 ETAC-ABET General Criteria changed substantially. A new Criterion 3 (Student Outcomes) was published, changing from ten Student Outcomes to only five more manageable to assess Student Outcomes. The new Criterion 3 included a new Student Outcome (2) regarding students' ability to design systems, components,

[1] https://www.abet.org/accreditation/accreditation-criteria/criteria-for-accrediting-engineering-technology-programs-2019-2020/

or processes for well-defined engineering technology problems appropriate to the discipline. Our assessment model relies on a direct assessment method called performance appraisal using a scoring rubric, and it has been successfully used to assess both the Program Criteria and the new Student Outcome (2). We believe that our method of incorporating assessment as regular course activities helps achieve the ultimate objective of education, i.e., continuous and constant improvement of students' competencies and learning experiences.

The rest of the paper is organized as follows, in the following section, we describe our assessment model, including the course used for assessment and its structure, the selected performance indicators for the scoring rubric, details of the two laboratory assignments designed to assess the program-specific criteria and examples of the recently-added final design projects for assessment of students' design abilities. Then, the next section describes the assessment implementation, including an overview of the collaboration between the assessment coordinator and instructors. After that, the following section presents the assessment results and lists the cycles for data collection and analysis of assessment. Then, in a different section, online teaching, we discuss the arrangements we made in response to COVID-19 by transitioning from in-person to online learning. And finally, the last section, conclusions and future work, presents a discussion of the assessment results, the effectiveness of our assessment model, and directions for future improvement.

Assessment Model

The indicators used to evaluate the program criteria include 1) constructing a 3D model of a mechanical part; 2) using knowledge of statics and strength of materials to determine stresses in a component of an electromechanical system; and 3) using knowledge of engineering materials to select appropriate materials for construction of a prototype electromechanical system. And, as mentioned before, the student outcome (2) regards students' ability to design systems, components, or processes for well-defined engineering technology problems appropriate to the discipline.

To select the course where the assessment data should be collected, we rely on the curriculum map [1]. A curriculum mapping serves as a visualization mechanism to find where Student Outcomes and courses or educational strategies intersect. It basically is a table that maps each Student Outcome with each course in the program. This mapping may be used to detect potential gaps in the curriculum and initiate the conversation for possible curriculum changes. The curriculum mapping of the AAS in Electromechanical Engineering Technology (EMT) Program identifies where Student Outcomes are covered in the curriculum. We use this mapping to select the educational strategies and decide where the assessment data should be collected.

To carry out the assessment, a course titled "EMT 2480L: Electromechanical Systems Design Laboratory" was selected. The course is a sophomore-level, one-credit laboratory with three contact hours. The course introduces 2D & 3D Computer-Aided Design (CAD) and Computer-Aided Engineering (CAE). Students learn how to use industry-leading CAD software programs [2, 3, 4, 5] (SolidWorks, AutoCAD, Inventor, VFEA) to build parts and assemblies. Computer-Aided

Engineering (CAE) techniques are utilized to introduce concepts of mechanics of materials needed to analyze the component(s).

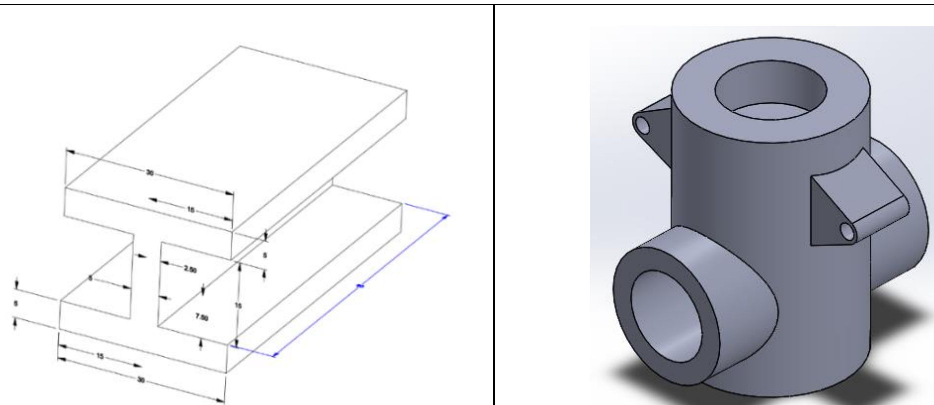
The topics covered include a) introduction of fundamental 2D/3D modeling tools and techniques for the creation of parts, assemblies, and drawings; b) simulation using CAE techniques in analyzing and virtually testing components and products; and c) application of CAD & CAE skills to develop solutions for design problems. Since the course focuses on computer-aided modeling, simulation, analysis, and design, some course activities are used to assess three Program Criteria indicators and the newly-added ETAC-ABET student outcome (2) on students' design abilities. Assessing the program criteria and the student outcome mentioned above naturally fits the course content.

Two lab assignments were developed and used to evaluate the three indicators for assessing the Program Criteria starting in Spring 2018. And, for assessing the ETAC-ABET Student Outcome (2) on students' design abilities, we use the final design project since Spring 2019.

Assessment of Program Criterion Indicators via Two Laboratory Assignments

As mentioned before, the indicators used to evaluate the Program Criteria include:

1) Constructing a 3D model of a mechanical part.
2) Using knowledge of statics and strength of materials to determine stresses in a component of an electromechanical system.
3) Using knowledge of engineering materials to select appropriate materials for the construction of a prototype electromechanical system.



(a) I-Beam | (b) Hub

Figure 1: The I-Beam and Hub labs used for assessment of Program Criteria Indicators.

Two lab assignments, i.e., linear static analyses of I-Beam and Hub (as shown in Fig. 1), have been used to evaluate these indicators. The assessment is carried out after teaching students basic CAD tools, multi-view drawing, dimensioning techniques, and CAE simulations. In each lab assignment, students are asked first to create the 3D mechanical part and then use different materials to compute, simulate, and evaluate stress, strain, factor of safety (FOS), and moments of inertia. These tasks allow the three Program Criteria indicators to be assessed within one lab assignment. In Spring 2018, we started using the I-Beam lab across all sessions for assessment purposes. The Hub lab has been used across all sessions since Fall 2019.

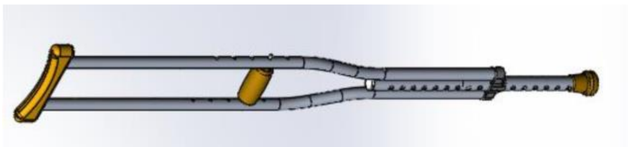
Assessment of ETAC-ABET Student Outcome (2) on Design Capabilities via Final Project

CAD skills are usually considered as design skills [6, 7]. Thus, evaluation of students' design capabilities fit naturally in this course. By asking students to design a product, explore different types of materials while analyzing their properties of stress failure and strength of materials, and practice some simple time management skills, students' design capabilities can be evaluated. We designed the following scoring rubric for performance appraisal (as shown in Table 1) for the assessment task.

Table 1: Rubrics for assessment of ETAC-ABET Student Outcome (2)

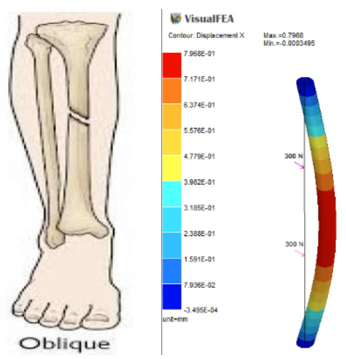
Performance Indicator	**Excellent 4**	**Good 3**	**Acceptable 2**	**Unacceptable 1**
1. Understand the Design Problem and the Requirements	Clear and complete understanding of design goal and constraints.	Overall sound understanding of the problem and constraints. Does not significantly impair solution.	Some understanding of the problem. Major deficiencies that will impact the quality of the solution.	Little or no grasp of the problem. Incapable of producing a successful solution.
2. Use Project Management Techniques for Completion	The timeline is clearly defined and developed. The details are comprehensive; it represents a plan with a high probability for project completion.	The timeline illustrates an understanding of individual task requirements, potential bottlenecks identified, reasonable potential for project success.	The timeline is loosely defined and lacks a clear understanding of time requirements for tasks, risks incomplete project.	Lacking a defined timeline.
3. Evaluate Alternative Designs and Options	Final design achieved after review of reasonable alternatives. This includes different materials and/or economic advantages.	Alternative approaches identified to some degree. For example, different materials	Serious deficiencies in exploring and identifying alternative designs.	Only one design presented or clearly infeasible alternative given.
4. Complete Implementation of Design Process	Quality and focused design process implemented, fully documented and clear qualitative and quantitative criteria for making design decisions.	Rational, documented process, measurable criteria for making design decisions.	Vague process implemented for the design, little record of the process, and poorly defined criteria.	No design process implemented.

Since Spring 2019, a final project was added into this course, allowing students to practice skills learned in the class to handle real-world examples for hands-on learning. Examples of the final project are shown in Fig. 2.

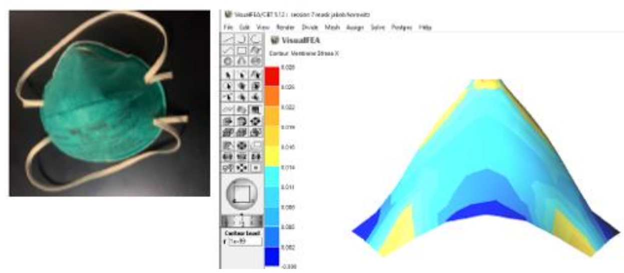


(a) Design of Crutches

(b) Creating meshes for simulation



(c) Design of bone nail to support bone break



(d) Design of surgical mask

Figure 2: The final design project used for assessment of ETAC-ABET Student Outcome (2).

Assessment Implementation

The implementation of the assessment process involves collaboration among several faculty members in specific ways. One faculty member, Chair of the department's assessment committee, provides continuous guidance about the assessment expectations and timely feedback regarding collected results. Several course instructors work together and significantly improve the course materials by adding well-designed laboratory assignments and design projects. Having attended the ABET workshop, the course coordinator worked closely with all members to ensure that the assessment is conducted every semester. Specifically, the program-specific criteria are assessed using two carefully designed laboratory assignments.

Three to four sessions of the assessed course are regularly offered in both fall and spring semesters, with a cap of twenty-two students in each session. Over the years, we have formed a team of instructors, consisting of both full-time faculty and adjunct professors, who become familiar with the assessment process and become experienced in performing the assessment task. After some pilot practices, assessing students across all sessions for both the Program Criteria Indicators and the ETAC-ABET Student Outcome (2) has been achieved starting/since Fall 2019. Furthermore, these assessment activities have been incorporated into the course as regular components to be performed every semester since then. The assessment results analysis is disseminated and discussed with the department faculty at just before the beginning of the following semester when the data collection occurred. Suggested corrective actions are implemented immediately, if needed. As a result, an effective and sustainable assessment routine was formed, which is the key for continuous improvement and to maintain or obtain accreditation [8].

Assessment Results

Assessment using the I-Beam lab started in Spring 2018 and continued every semester since then for all sessions; assessment using the Hub lab began in Spring 2019 with one session (out of three sessions) and then continued every semester for all sessions; and assessment using the final project started in Spring 2019 with two (out of three) sessions and continued every semester for all sessions. Table 2 shows the assessment timeline, where S1, S2, S3, and S4 denote session numbers. It can be seen that after some pilot practices, assessment using the three assignments were performed regularly across all sessions for every offering, starting Fall 2019.

Table 2: Assessment timeline

	Spring 2018			Spring 2019			Fall 2019				Spring 2020			
Session #	S1	S2	S3	S1	S2	S3	S1	S2	S3	S4	S1	S2	S3	S4
I-Beam	x	x	x	x	x	x	x	x	x	x	x	x	x	x
HUB				x			x	x	x	x	x	x	x	x
Project				x		x	x	x	x	x	x	x	x	x

The three Program Criteria Indicators' assessment results using the I-Beam and the Hub labs are shown in Figs. 3 and 4, respectively.

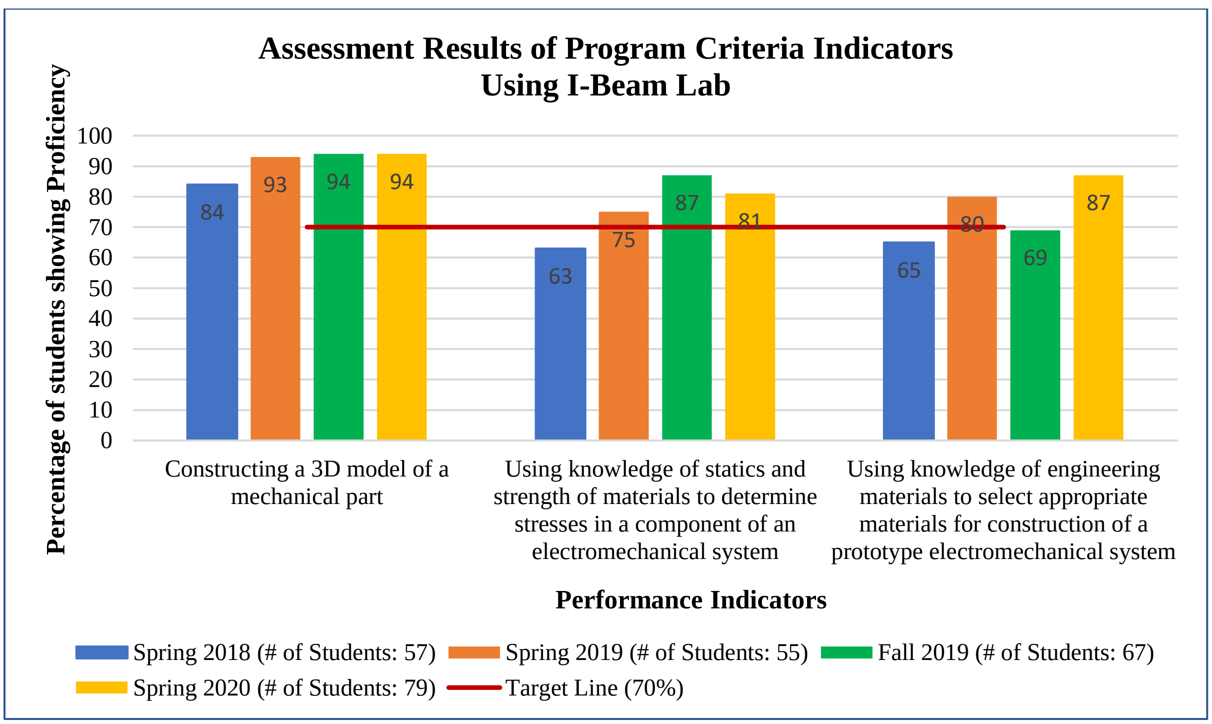


Figure 3: Assessment of Program Criteria Indicators using the I-Beam lab.

The department has set a target that at least 70% of students should meet or exceed the criteria for competence in the defined Performance Indicators. Results in Fig. 3 are for all sessions (three sessions in Spring 2018 and Spring 2019; four sessions in Fall 2019 and Spring 2020). The first assessment cycle's assessment results, Spring 2018, show that two performance indicators were below the target. However, starting the second cycle, Spring 2019, the results have been above the target showing a satisfactory performance in all three indicators. With an exception, in Fall 2019, the third performance indicator, "Using knowledge of engineering materials…," was slightly below the target. However, in Spring 2020, the percentage of students showing proficiency was well above the target.

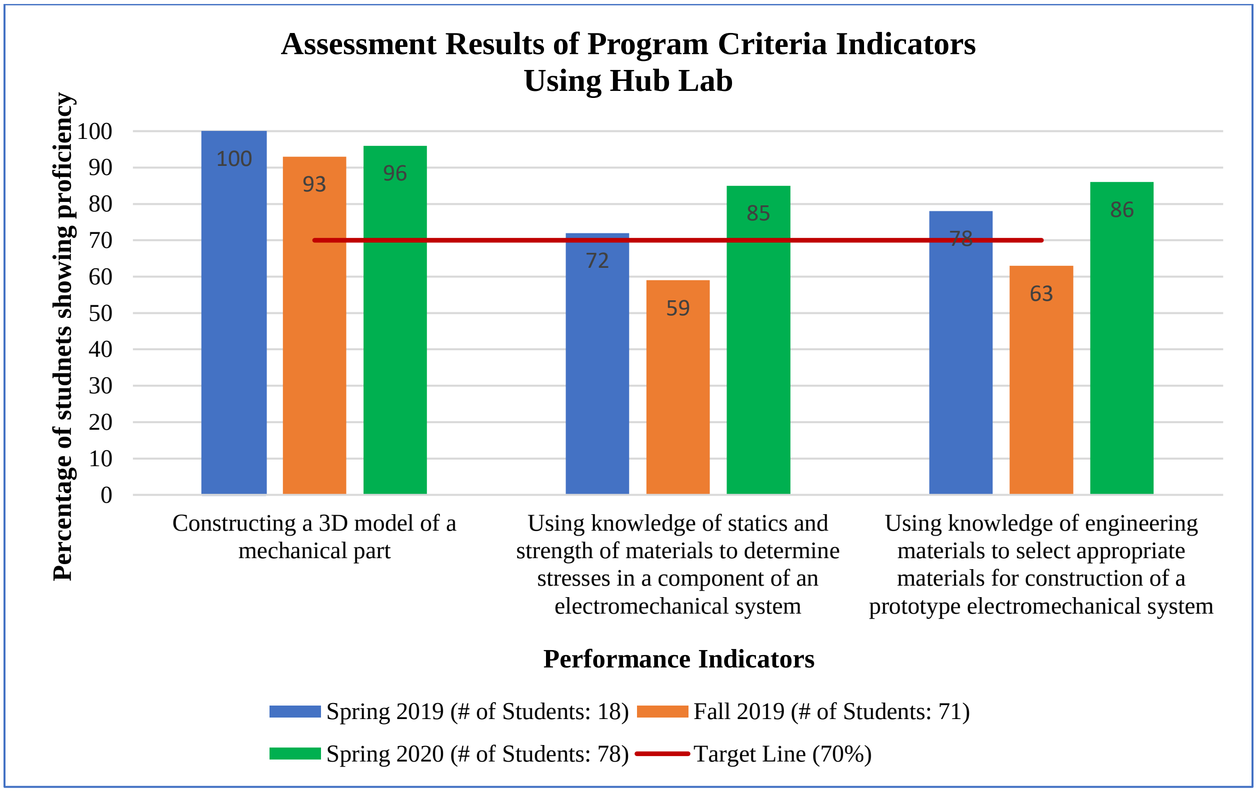


Figure 4: Assessment of Program Criteria Indicators using the Hub lab.

Our motivation for using the Hub lab is to evaluate students' performance under a more challenging task. Despite the increased complexity, the results in Fig.4 show that in Spring 2020, a satisfactory performance was still observed across all sessions, meeting the target of 70%.

The ETAC-ABET Student Outcome (2) assessment results, spanning over three semesters, are shown in Fig. 5. As mentioned before, this student outcome focuses on students' design capabilities. This assessment work started in Spring 2019 as a pilot, including only two out of the three sessions running that semester. After the pilot, all sessions have been included in the assessment process. In Fall 2019, a satisfactory performance was achieved for all indicators. However, some degradation was observed in Spring 2020 regarding the "Time Management Skills". We believe this could primarily be due to the global COVID-19 pandemic, which occurred in the middle of the Spring 2020 semester. In addition to the emotional suffering and anxieties, the university needed time and arrangements to move all their classes into the virtual/remote mode. Several modifications of the Spring 2020 calendar reduced the instruction time from a regular semester of fifteen weeks to thirteen weeks. Since the final project is always the last assignment, it was affected the most. Introduction of certain time-management software may help to solve this issue.

Generally speaking, the results in Fig. 5 indicate that an acceptable percentage (around 70%) of the students continued to demonstrate competency on all the performance indicators. Therefore, no action was necessary until the next semester.

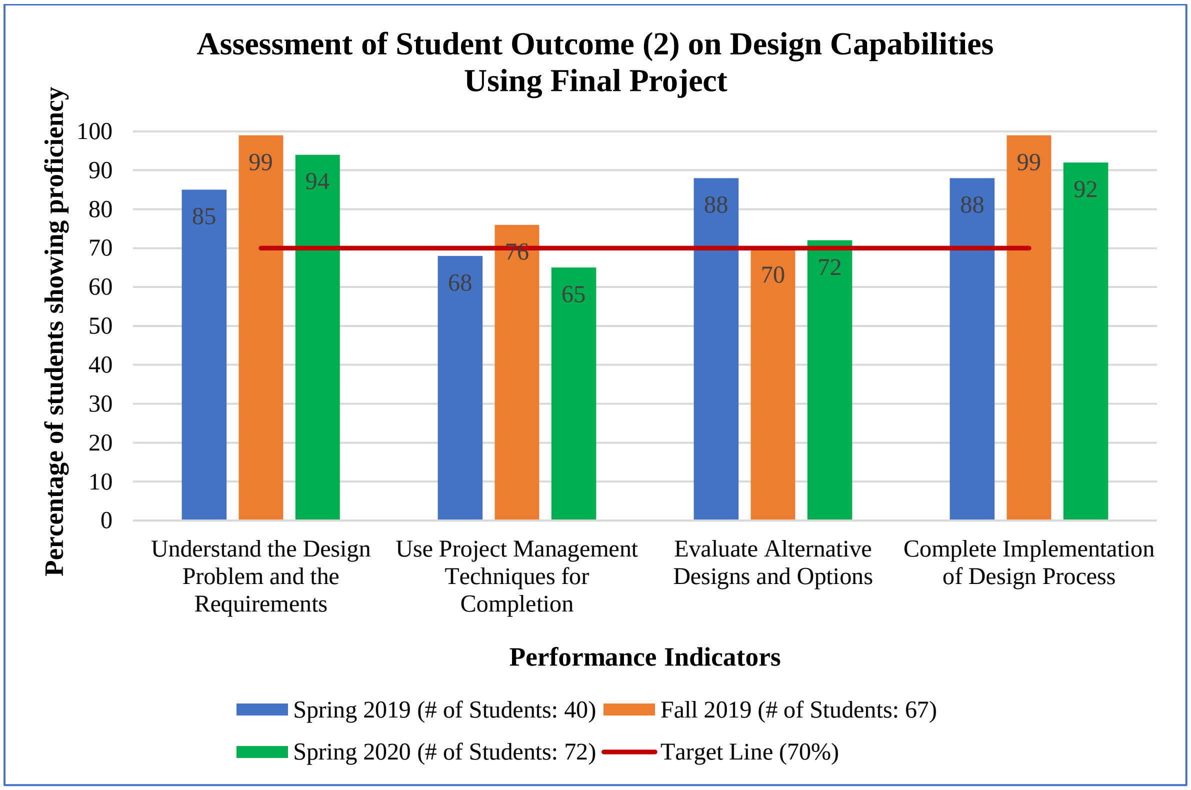


Figure 5: Assessment of ETAC-ABET Student Outcome (2) on students' design capabilities using the final project.

Online Teaching

This course was offered in-person before Spring 2020. In Spring 2020, the global COVID-19 pandemic caused our institution to shift its courses from in-person to online (remote, virtual, e-learning). To cope with this transition, synchronous virtual meetings, Blackboard, and virtual office hours were used to establish teaching presence and maintain synchronous and asynchronous interactions between the instructor and the students [9]. SolidWorks licenses were purchased by the department, allowing all instructors and students to download and install SolidWorks on their own computers. Students literarily got more access to the software than the in-person teaching mode since the software was installed only in some lab/classroom/computer-center.

Under e-learning, some instructors chose to make videos demonstrating the steps and procedures of labs/projects, and made them available to the students before each meeting. Furthermore, most instructors chose to grade classwork more frequently to ensure connection and communication with the students, providing students with timely comments and feedback, leading to improvements and revision. As a result, degradation (should there be any) in students' performance was not significant in this course.

While higher education is planning to bring more in-person instructions to their college students (or even planning a full return to campus), we have reasons to believe that teaching some session(s) of this course online can be a reasonable teaching mode without compromising student's learning experience.

Conclusions and Future Work

The assessment work described in this paper has been adopted as standard course components in the sophomore-level Electromechanical Design Laboratory since Fall 2019. The course is offered in both spring and fall semesters, and the assessment is carried out in all the course sessions. In terms of Program Criteria Indicators, the target of having 70% or more of students demonstrating proficiency in all three assessed areas was successfully obtained in Spring 2020. For the ETAC-ABET Student Outcome (2), all criteria were successfully met/achieved in Fall 2019. This demonstrated our quick response to the ABET change and our actions' effectiveness to improve areas that deserve attention. Small variations were observed in Spring 2020 due primarily to the semester's cut-short length (from the regular 15 weeks to 13 weeks). Overall speaking, progress and improvement were made both at the course level, adjusting and adding new and better-designed lab exercises, and at the program level, aligning the sequence of courses related to Program Criteria and Student Outcome (2) to better prepare the students on designing electromechanical artifacts or projects.

This collaborative work would not have been possible without the dedication from all participating instructors. Over the years, we have formed a team of instructors, consisting of both full-time faculty and adjunct professors, who become familiar with the assessment process, become experienced performing the assessment task, and always look for pedagogical strategies that lead to improvement. From the administration point of view, the CET department always tries to assign instructors who are experienced in teaching this course. These elements help maintain the course standard and strengthen students' knowledge and skills in 3D modeling and design.

The assessment work also helps us to identify areas that deserve attention and future improvement. Specifically, among the three Program Criteria Indicators, "using knowledge of statics and strength of materials…", which is usually assessed by students' abilities to perform analyses (hand computations) of strain and stress, is found to be relatively weaker than the other two indicators. For future improvement, we will try to reinforce students' analysis and computation skills.

Regarding students' design capabilities, the indicator of "use project management techniques…" was slightly weaker than the rest. As a corrective action for future improvement, we may suggest all instructors to include "Time Management" as a grading component explicitly listed in their grading policies, or to use some free time management software, such as Project Schedule for Android, documenting students' progress and schedule.

Other directions for future improvement include looking into ways to grade students' 3D models using, for example, some computer software [10] and using a combination of instructor-assessment and self-assessment [11]. We are also considering adding another direct assessment method, a locally developed exam [12], in addition to the performance appraisal with a rubric that we have been in carrying out.

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