ASEE AMERICAN SOCIETY FOR ENGINEERING EDUCATION

Paper ID #35144

Broad faculty participation in course-level evaluation of student outcomes supporting continuous improvement of an undergraduate engineering program

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Session 35144

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Abstract

As part of the ABET accreditation process, an engineering program must have a continuous improvement process to guide program changes. One part of the process is course-level assessment of student outcomes (SO). Some programs place a heavy reliance on senior-level engineering design courses to assess the student outcomes and little reliance on many other engineering courses. A potential shortcoming of this is that faculty teaching courses know little about the continuous improvement process and miss the opportunity to document contributions to the attainment of student outcomes. A different approach is that each required undergraduate engineering course provide some input into the continuous improvement process. The goal is to not overly burden a few classes but to spread the collection and analysis of SO to many classes. Other than capstone senior design classes, each required class collects and analyzes data for only two SO although many courses address more than two. In the past cycle, the curriculum committee has worked to distribute the SO throughout the program so that there isn't an imbalance with many courses providing data for a SO while few courses contributing to another SO. This mapping of SO throughout the curriculum is evaluated and adjusted at the beginning of an assessment cycle. Overall, each course has a reduced documentation load and more faculty become involved in the continuous improvement process. This broader participation has encouraged faculty to document topics in their courses which have normally gone undocumented. A continual challenge is to help faculty plan their course so the collection of data is manageable and not left to the end of the semester. Examples of how to assess each SO have been generated by the curriculum committee and shared with faculty to inspire them to think beyond the use of final exam questions to assess SO in their courses.

Introduction

In 2017 the Engineering Accreditation Commission (EAC) of ABET modified criterion for student outcomes (SO) reducing the number from 11 to 7, and changing the designation for letters (a-k) to numbers (1-7)[1]. The SO are described in the ABET self-study report for Criterion 3, 4 and 5. The new changes began during the 2019-2020 ABET evaluation cycle and many programs updated each course to include the new SO. In many engineering programs, the SO are heavily evaluated in Senior Design course, which in many programs is a back-to-back course sequence. Other programs focus on a small handful of courses (often 10 or less) to collect and analyze SO data from the program. The collection and analysis of course-level data is not dictated by ABET yet there is an understanding that the faculty teaching courses in the program are knowledgeable of the goals for

program accreditation. Namely, the faculty should all participate in the continuous improvement process which is a requirement for accreditation. In some cases, ABET reviewers have asked basic questions about the accreditation process to a wide range of faculty, especially new Assistant Professors, who have taught core engineering courses. These courses invariably have a linking of the course objectives, course learning outcomes and the ABET student outcomes. These courses may not be Senior Design, but they do contribute to the attainment of student outcomes that are expected by the time of graduation. The skills, knowledge and behaviors that students acquire are throughout the engineering program, with introduction to the developing communication skills and understanding engineering ethics as early as the Freshman year, typically accomplished in an introductory engineering design/graphics course.

It is understandable that some faculty become disconnected with the ABET continuous improvement process, especially where there is little or weak connection between the course they teach and the collection/analysis of data used to assess SO. Faculty are often helping student develop as engineers, which is a process that is not reserved for the senior design courses. In many cases, faculty could contribute more strongly to the ABET continuous improvement cycle. In some cases, they may need to just document what they currently do in a course or they may need to modify assignments to more clearly collect and analyze SO related activities where students are gaining skills and knowledge. In order to broaden participation in the ABET process, a conscious decision was made by the department faculty to collect and analyze two SO for each require undergraduate course.

Overview of Student Outcomes

ABET has developed and issued the SO and has provided detailed guidance on interpretation of each SO. For this paper, the SO are stated here, and a single word in each is highlighted to stress the main area of each SO. For example, SO3 is “communication” and SO4 is “ethical”.

SO1 an ability to identify, formulate, and solve complex engineering **problems** by applying principles of engineering, science, and mathematics
SO2 an ability to apply engineering **design** to produce solutions that meet specified needs with consideration of public health, safety, and welfare, as well as global, cultural, social, environmental, and economic factors
SO3 an ability to **communicate** effectively with a range of audiences
SO4 an ability to recognize **ethical** and professional responsibilities in engineering situations and make informed judgments, which must consider the impact of engineering solutions in global, economic, environmental, and societal contexts
SO5 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
SO6 an ability to develop and conduct appropriate **experimentation**, analyze and interpret data, and use engineering judgment to draw conclusions
SO7 an ability to acquire and apply new knowledge as needed, using appropriate **learning** strategies

Distribution of SO

Initially faculty self-selected the SO for the course the teach. There were many courses covering SO1 and few covering SO4, SO5, SO6 and SO7. In discussion with faculty, many commented that the courses emphasized solving engineering problems, yet the faculty were also teaching the courses to build the student capabilities in many other areas like communication, ethics, teamwork, and learning. The faculty may not have placed a large percentage toward the overall final grade in the class, but the courses were broad in scope in educating engineers. After the 2019 notebook collection, the undergraduate curriculum committee reviewed all of the courses and proposed to redistribute the SO by removing all but two for each course. The two SO were the only ones for which data was to be collected and analyzed.

Figure 1 shows the distribution of SO. The goal was to have each required undergraduate class have no more than two SO. The instructor can cover more than two, but the course will collect and analyze data to support only those that have been identified. If the faculty wish to collect and analyze data for more, it will be accepted and used. By focusing on two, it is anticipated that the quality of the data will be improved.

Senior Design courses continue to cover as many SO as they have in the past, since the courses have played a significant role in ABET accreditation. The committee considered reducing the collection and analysis burden to only two SO, but this was not adopted since the data had been consistently been collected and analyzed for many years. The instructors had a well documented system that was best to leave alone. It would be more of a disruption to reduce the collection and analysis of Senior Design data since it was so well established.

		Student Outcome (SO)						
		1	**2**	**3**	**4**	**5**	**6**	**7**
EGR 2323	Engineering Analysis I	1						
EGR 2513	Dynamics	1						
ME 1403	Eng. Graphics			3	4			
ME 2173	Num. Methods			3				7
ME 3113	Measurements & Instrumentation					5	6	
ME 3243	Materials	1			4			
ME 3241	Materials Lab			3			6	
ME 3263	Manufacturing Engineering		2		4			
ME 3293	Thermodynamics I	1			4			
ME 3543	Dynamics & Controls			3				7
ME 3541	Dynamics & Controls Lab			3			6	
ME 3663	Fluid Mechanics	1			4			
ME 3813	Mechanics of Solids	1			4			
ME 3823	Machine Element Design		2		4			
ME 4293	Thermodynamics II		2					7
ME 4312	Thermal Fluid Lab					5	6	
ME 4313	Heat Transfer	1	2					
ME 4543	Mechatronics					5		7
ME 4801	Manufacturing Practices Lab			3				
ME 4812	Sr. Design I	1	2	3	4	5		7
ME 4813	Sr. Design II	1	2	3	4	5	6	7

Figure 1. Distribution of Student Outcomes (SO) to Required Engineering Courses in the Mechanical Engineering Program

ABET Workshops

Before the beginning of a course-level collection and analysis cycle, the Department has hosted an ABET Workshop that is mandatory for those teaching a course listed in Figure 1. All faculty are encouraged to attend. There are always a few faculty who are new to the Department and new to the process. Likewise, experienced faculty benefit from being reminded about the process and procedures used to assess SO data and improve the program. At the end of the workshop, faculty are required to submit a plan for how each SO will be assessed that semester. The workshops are well attended because the Department Chair strongly encourages attendance and the workshops have seven different faculty address each of the seven SO for 15-minutes followed by 15-minutes for Q/A.

Figure 2 shows a part of the plan which is often described as a “mapping form” since it shows the

course-level learning objectives and the ABET SO. The syllabus is integral to the SO assessment plan. It is recommended that the course have 5 to 10 course objectives and that the planned collection of SO occur in 4 to 7 specific activities. When a course has fewer than 5 or more than 10 course objectives, a subcommittee has been tasked to review them. When the mapping form shows all SO evaluated in all activities, then a subcommittee is tasked to review and discuss with the instructor. It has been found if an instructor proposes a high level of data (more than 7 checked in Table 2) then the quality of the data or analysis often suffers. It is better to have a strategic plan to do a good job analyzing limited data instead of a poor job of analyzing too much data.

Course Assignments	**Course Objectives (Documented in Notebook)** (check with "x" as many as appropriate)						**Student Outcomes (Documented in Notebook and Assessed in Table 2)** (recommend limit to 4 to 7 checked with "x")						
	1	2	3	4	5	6	SO1	SO2	SO3	SO4	SO5	SO6	SO7
Homework		x		x									
I-Clicker		x	x	x	x	x	x			x			
Quiz	x	x	x	x	x	x							
Exam 1	x	x	x				x						
Exam 2		x	x	x			x						
Exam 3					x	x							
Final Exam	x	x	x	x	x	x	x						
Design Report										x			

Figure 2. Mapping of Planned Assignment with Course Objectives and ABET Student Outcomes (SO) with the Recommendation that 4 to 7 Assignments have Examples of Student Work in the Course ABET Notebook.

Examples for SO

Examples of how to assess each SO are shared in the workshop. Figure 3 shows an example for how classroom student response system (iClicker) is used to quickly collect and analyze data. The particular difficulty of the question is not the focus. The focus is on the tools faculty typically already are using in the class and how with attention to detail, relevant ABET SO data can be collected. Examples include from Blackboard quizzes, Pearson Mastering homework, or WileyPlus homework. Tools like gradescope have problem level statistical data, which can be used to support particular SO.

Software tools help assess student work that can be assessed as either correct or incorrect. Yet this is primarily useful for SO1 and to limited extend other SO. For many of the SO a rubric is best with clear instructions given to students about expectations for the work. When possible, faculty should give project report outlines with specific subheadings that align with expectations. These expectations should, when possible, be aligned with the wording used by ABET for the particular SO. For example, SO2 covers engineering design and it is appropriate to suggest a more report outline that might include the following:

1. Specification
2. Appropriate Constraints
3. design variables (Iterative)

4. Multiple solutions
5. Analysis and synthesis
6. Trade-offs
7. A best solution that meets specified requirements and appropriate constraints

Having a standard outline allows instructor to quickly see where consideration of multiple solutions (as an example) can be found.

In almost all SO, a clear grading rubric can be generated which identified area following ABET's description, with rubric areas being: design constraints, design variables, alternative design consideration, iterative/creative decision making process, analysis/synthesis, accessibility consideration, applicable codes/standards, constructability, functionality and cost analysis. Faculty are encouraged to share the grading rubric with students as well as the grade brake-down for each part of the rubric. Not all team designs will cover all area, so students should know it is acceptable to self-assess some as "not applicable". Yet again, if many areas are left blank or claimed to be N/A, then the students should know there work is lacking. Having a detailed rubric aligned with ABET descriptions helps ease the burden of data collection and improves the overall quality of the assessment.

Appendix A has example of laboratory report rubric and report template provided to students to both help students know what is expected and help faculty document specific student outcomes.

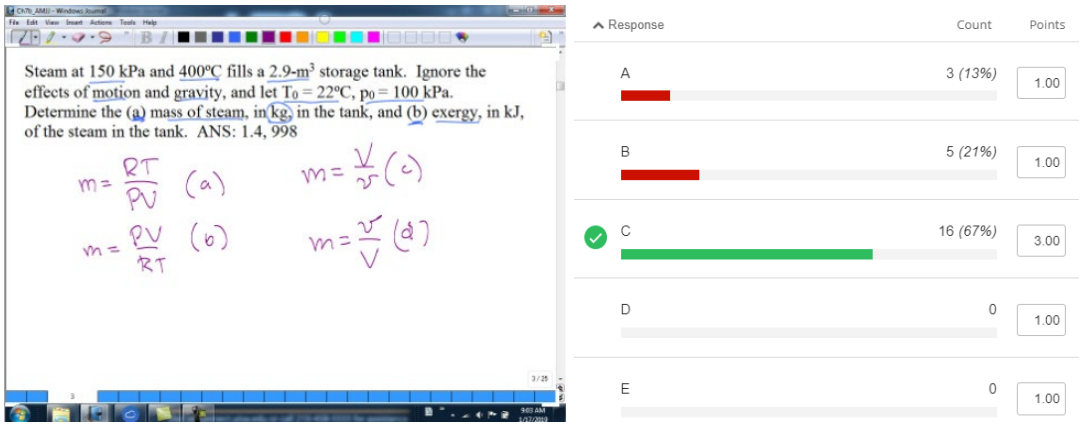

Figure 3. Example of assessment of SO1 using Classroom Response System

Summary and Conclusions

This paper summarizes how the ABET SO are distributed to all required engineering courses in the program. There continues to be heavy emphasis on senior design courses, but each course is allowed to participate in the collection and analysis of SO for continuous program improvement. More faculty are aware of the process and involved in understanding the accreditation agency expectations. Workshop help guide faculty so good data is collected and analyzed showing relevant

student work. The workshops often emphasize (1) knowing what is involved in each SO (2) planning before the semester begins on what data will be collected, (3) using available tools to reduce the data collection and analysis effort, (4) sharing detailed report templates with students, (5) sharing detailed grading rubrics with students, and (6) use words/phrases that align with ABET expectations. Instructors are encouraged to collect data early in the semester and not overly depend on data from the final exam or final report since there are limited opportunities to clarify or redo after the semester has ended. Overall more faculty are involved with program improvement and are knowledgeable about program accreditation.

References

1. Karimi, A., and R.D. Manteufel, 2020, "Most Recent Updates to ABET-EAC Criteria 3, 4 and 5", ASEE-GSW Annual Conference, Albuquerque, NM, April 23-24.