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Work in Progress: Evolution of an ABET Assessment Program for Chemical Engineering at Texas A&M University-Kingsville, a Regional Hispanic-Serving Institution

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Introduction

Engineering baccalaureate programs in the United States have been accredited by the Accreditation Board for Engineering and Technology (ABET) through review of engineering degree programs for the last eighty years. Significant changes in the accreditation process dictated by ABET have occurred recently, such as the revision of the student outcomes. As part of these changes, engineering faculty have implemented revisions to their assessment programs to ensure they are in line with ABET expectations. DeNucci and Garcia describe a detailed system of performance indicators developed for the new student outcomes, which was prepared to ensure clarity of the student work evidence [1]. In a similar manner, Pejcinovic describes an extensive system of criteria and performance indicators that were adopted for an electrical and computer engineering department [2]. The faculty of a new engineering program at Angelo State University posited that a highly structured and clear assessment program is necessary for success in seeking initial accreditation, including the subdivision of SOs into clear and unambiguous parts for measurement of outcomes [3]. Other engineering faculty have described the substantial reliance on design courses for determination of student outcome attainment [4, 5]. The objective of this Work-in-Progress paper is to present the faculty experiences in the 2021 ABET review and the new assessment program that arose in response to this 2021 ABET review in our program. The impetus for this new program, the program details, and a summary of assessment results obtained over the first three semesters, are presented in this paper.

The ABET conducted program reviews for the chemical engineering program at Texas A&M University-Kingsville (TAMUK) most recently in 2015 and 2021. In 2015, the ABET program review resulted in a concern that the topic of process safety and process hazards required greater emphasis in one or more courses in the chemical engineering program. This concern was addressed by incorporating process safety and process material hazards into two capstone design courses starting in 2016. No other concern, weakness or deficiency was raised about the department ABET assessment in the 2015 ABET review. When the 2021 ABET review occurred, a weakness was assigned for our program in Criterion 4: continuous improvement. The weakness was attributable to (a) faculty not assessing all elements of certain student outcomes (SOs), (b) inconsistency in which aspect of SOs were assessed by different instructors teaching two different sections of the same course, and (c) faculty averaging their assessment scores in an ad-hoc manner. ABET determined that the department assessment results did not represent a systematic assessment process that was applied in a consistent manner throughout the program.

The new assessment program was developed as one possible method to address the weakness identified by ABET. Additionally, this change is consistent with reports of other departments changing their programs to make them more robust. In particular, DeNucci cited that the magnitude of a program change will depend upon the scope of the legacy program that is undergoing change [1]. The new assessment program has addressed the items (a) through (c)

that led to the weakness in continuous improvement. Aspects of this new program are readily portable to other programs that may require updating as a result of ABET reviews currently ongoing or occurring soon.

Development of revised ABET program for chemical engineering

The faculty of the chemical engineering program at TAMUK, in consultation with the Frank H. Dotterweich College of Engineering Associate Dean for Undergraduate Affairs (DUA), chose the following guidelines to direct the revision of the assessment program, focusing on Criterion 3 (student outcomes) and Criterion 4 (continuous improvement). First, the ABET SOs should be assessed at a sub-level using performance indicator statements, particularly the SOs that are multi-faceted, such as SOs 2, 3, 4, and 5 (addresses weakness elements (a) and (b)). This sub-level approach allows a more direct demonstration of whether student work meets an objective, as opposed to assessing performance for an entire SO with a single evaluation. Secondly, the rubrics used in SO assessments should be developed specific for each SO and for each performance indicator at the sub-level. In the prior assessment program, faculty tended to use generic rubrics or rubrics developed individually, without coordination from other faculty. Third, the DUA emphasized that the ABET assessment program did not need to have all SOs assessed every year, but rather an assessment program could be developed in which all SOs would be assessed over a two-year or three-year cycle. Fourth, the DUA encouraged that all courses in the curriculum did not need to be used for assessment of the program, but rather courses at different levels should be considered at levels of introductory (formative), reinforcement (formative), and final assessment (summative). Courses later in the curriculum, such as those during the senior year, would be those courses most appropriate for final summative evaluation of SOs. All of these suggestions from the DUA were Criterion 3 aspects that had not been used in the previous ABET evaluation program.

An overview of the revised assessment program is presented in summary form in Tables 1 and 2, and Figure 1. Table 1 presents the distribution of SOs amongst all required courses in the chemical engineering curriculum. The revised program uses senior-level courses as those for which SO assessments will be utilized for the summative assessment of program criteria attainment (designated A in Table 1). The earlier courses in the curriculum, designated I for introductory and R for reinforcing, are those where concepts related to specific SOs will be introduced or reinforced, and thus serve as formative assessment. Assessment in I- and R-designated courses are performed each year, while A-designated courses are assessed once every two years. SOs 1 through 3 are assessed in the first year, and SOs 4 through 7 are assessed in the second year of the two-year cycle. I-designated courses are all sophomore and first-semester junior level courses, while the R-designated courses are second-semester junior level courses. Those SOs that can be more challenging to assess in typical lecture courses, namely SO 2 (design), SO 3 (communications), SO 4 (ethics and professional responsibility) and SO 5 (teamwork), were concentrated for assessment in courses with design projects (Introduction to Engineering, Design II, and Design III, and chemical engineering labs), similar to how other engineering programs have allotted these SOs [4, 5].

The specific performance indicators (PIs) described above are presented for SOs 1 through 3 as examples in Table 2. In the prior version of the ABET assessment program for this chemical

Table 1. SO Distribution in Chemical Engineering Courses

Course Name	1	2	3	4	5	6	7
Introduction to Engineering		I	I		I		
Mass and Energy I	I	I					
Mass and Energy II	I			I		I	
Thermodynamics I	I						I
Fluid Transport	I						I
Heat Transport	R					R	
Engineering Economy (Design I)	R			R			R
Engineering Math	R					R	R
Thermodynamics II	R					R	
ChE Seminar		R		R			R
Unit Ops I			A		A	A	A
Unit Ops II			A		A	A	A
Biochemical Engineering	A	A				A	
Design II		A	A	A	A		A
Design III		A	A	A	A	A	
Reactor Engineering	A			A		A	
Mass Transport	A			A		A	
Process Controls	A	A				A	
Internship			A				A

A = assessment used for evaluation (summative);
I = introductory concept (formative); R – reinforced concept (formative).

engineering degree, SOs were not assessed in any sub-level manner, but merely on the single SO statement. It became clear during the 2021 ABET visit that some breakdown of each SO would be helpful in performing the assessments, in particular to be able to consistently cover the content of each SO statement more thoroughly. The best example of this is SO 2 which states "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, and social, environmental, and economic factors". This breakdown into manageable elements referred to as PIs serves to address the ABET-cited weakness items (a) and (b) discussed above. Between two and four PIs were developed for each SO. Then, a more detailed version of Table 1 was generated (not shown here), in which the specific PIs were designated for assessment on each course. In most cases, all PIs under a particular SO were included for assessment in one course, but in some instances, this was not feasible given the type of work or assignments in a course. An example of this includes only assigning PIs 3.1 and 3.2, but not 3.3 and 3.4, for a course that has written reports, but no student oral presentations. Once these PIs were developed, then corresponding rubrics were developed specific for each SO and sub-level PI. The evaluator of the 2021 ABET visit indicated that the rubrics in our former program were not consistent between faculty and did not necessarily correspond well with SOs. The assessment program uses a 4-point scale, with each point designated as 4-exemplary, 3-satisfactory, 2-developing, and 1-unsatisfactory. The program also designates an assessment score of 3.0 or above as outcome attained, and below 3.0 as outcome not attained, need for improvement.

Table 2. Example of Performance Indicators per Student Outcome

ID	Element Description
SO 1	*An ability to identify, formulate, and solve complex, engineering problems by applying principles of engineering, science, and mathematics*
PI 1.1	Formulate a proper solution approach to a complex engineering problem
PI 1.2	Solves complex problem with a reasonable solution using appropriate math technique
SO 2	*An ability to apply engineering design to produce solutions that meet specified needs with consideration of public health, safety, and welfare, as well as global, cultural, and social, environmental, and economic factors*
PI 2.1	Team utilizes design principles, such as alternatives evaluation and prototype testing, to obtain an engineering-based solution
PI 2.2	Design meets objectives or needs stipulated in problem statement
PI 2.3	Design adheres to applicable constraints and/or standards
SO 3	*An ability to communicate effectively with a range of audiences*
PI 3.1	Communicates in written form without grammar issues and uses appropriate report format
PI 3.2	Presents technical ideas and concepts in written form clearly
PI 3.3	Delivers oral communication fluently
PI 3.4	Effectively uses of visuals (e.g. Powerpoint)

The revised assessment process, utilizing the components described above, is depicted in Figure 1 below. This process was developed to engender a more central role of continuous improvement in the department's process than it had played in the past. Figure 1 depicts a two-year cycle of assessment (Cycle B), which may lead to curriculum changes, such as the addition of new courses, the alteration of course content, or revision of pre-requisite requirements for a course. These types of changes have to go through department, college, and university-level curriculum committees for approval prior to implementation and thus the length of time from identification of a need for a change to actual implementation of the same can be six months to a year. However, this process also includes Cycle A, which includes actions that lead to more minor changes in how an instructor or set of instructors teach a course or related courses, which do not require curriculum changes. The two different cycles depicted in Figure 1 are consistent with the ABET expectation that continuous improvement should occur at both the course level and also at the curriculum and program level. The process also allows for input from outside sources, such as the department Industrial Advisory Board and the dean's office of the Frank H. Dotterweich College of Engineering at TAMUK.

Implementation and results of revised assessment program

The faculty began their assessments in the fall of 2021, using the new program, however the first semester of assessments was challenging because all aspects of the new program were not fully defined until approximately one week after end of semester. However, the assignment of SOs per course (summarized in Table 1) was very similar to the assignment of the previous program. As indicated in Figure 1, implementation of the program involves summarizing assessments on the program from all faculty once they are all completed, and discussing amongst the faculty at that time whether any changes may be needed in course implementation, SO assessments, or the program curriculum. Faculty are asked not to perform any averaging of scores (satisfying weakness (c) from the ABET review). The discussion amongst the faculty in the chemical engineering program has occurred once per semester as part of a regular faculty meeting, or sometimes as a separate meeting targeting only ABET discussions.

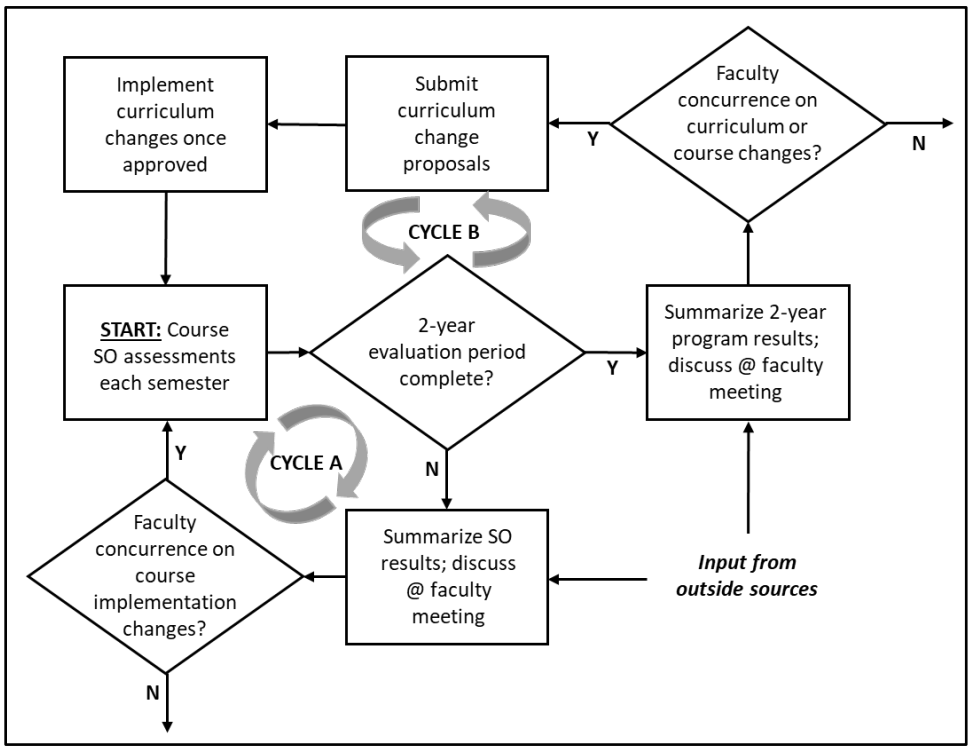

Figure 1. Relationship of activities for assessment in 2-year cycle.

For the three semesters that have been completed since this new program has been instituted, the assessment results are presented in summary form in Table 3. The data are summarized for each semester as the count of assessments that are either above or below the designated criteria of 3.0, per each SO and by either I, R, or A assessment type. A principal result indicated in this summary format is the fact that 50% or more of assessments are below 3.0 for SOs 1, 2 and in a few cases, for SOs 6 and 7. A possible cause may be the relatively wide range of engineering student performance our program experiences, since it is not a Tier 1 school where GPA requirements for graduation are typically more stringent. Historically, the department faculty has indicated an action plan of "more example problems will be conducted during class lecture" in the effort to bring up the assessment scores in SOs 1 and 2. Based on these trends to date, the department faculty have decided to include more active learning techniques in their courses in an attempt to raise the SO 1 and 2 scores. The first two-year cycle of assessment will be completed at the end of spring 2023, and at that time, curriculum or program modifications may be identified as part of the continuous improvement cycle. The process depicted in Figure 1 has also been used more recently to instigate curriculum changes indicated by prior ABET program activity. In fall 2022, the department faculty decided to add a chemical process safety class, as well as a statistics class, to the required chemical engineering curriculum. These changes will become effective in the curriculum starting in fall 2023.

Conclusions and future work

The revised ABET assessment program for the chemical engineering program at TAMUK University was developed in late 2021, and it has been shared with the ABET evaluation team as part of the required response to weakness on Criterion 4 continuous improvement. The revised assessment program has been implemented since fall 2021, and assessment data has been collected for three long semesters. Aspects of this revised assessment program that our ABET committee developed may be useful for other engineering departments undergoing changes in their programs, leading up to their first ABET review since the 2019 Criterion 3 SO changes. Our department experience has been that ABET reviews occurred with a higher level of scrutiny in 2021 than in the 2015 review that occurred six years prior. The PIs and continuous improvement process described herein can thus serve as models for others coming upon the similar review scenario.

Table 3. Summary of SO Assessments for Fall 2021 Semester

SO	SO Assessment Category	Fall 2021			Spring 2022			Fall 2022		
		I	**R**	**A**	**I**	**R**	**A**	**I**	**R**	**A**
1	< 3.0	1	1	***5***	***2***	***6***	1	***4***	0	OY
	≥ 3.0	4	2	***5***	***1***	***6***	5	***0***	2	OY
2	< 3.0	0	***1***	1	NA	NA	***5***	***3***	0	OY
	≥ 3.0	5	***0***	8	NA	NA	***4***	***2***	1	OY
3	< 3.0	0	NA	2	NA	NA	0	0	NA	OY
	≥ 3.0	2	NA	10	NA	NA	9	2	NA	OY
4	< 3.0	NA	0	OY	***1***	0	OY	NA	0	1
	≥ 3.0	NA	1	OY	***0***	2	OY	NA	2	4
5	< 3.0	0	NA	OY	NA	NA	OY	0	NA	0
	≥ 3.0	1	NA	OY	NA	NA	OY	1	NA	2
6	< 3.0	NA	NA	OY	***1***	***1***	OY	NA	NA	1
	≥ 3.0	NA	NA	OY	***0***	***0***	OY	NA	NA	0
7	< 3.0	1	0	OY	NA	0	OY	1	***1***	***3***
	≥ 3.0	2	2	OY	NA	4	OY	2	***1***	***1***

I = introductory level; R = reinforcing level; A = assessment level
NA – that SO not assessed in any courses that category this semester
OY – off year for these SOs
Numbers in bold and italics represent an SO in which 50% or higher of the results are below the 3.0 threshold designated by the program for outcome attained.

Review of the SO assessment scores for the three semesters of data indicate an apparent trend of low levels of attainment for SOs 1, 2, possibly attributable to the wider range of student performance at TAMUK as compared to a Tier 1 university with more stringent graduation requirements. In the near future, the assessment scores from the spring 2023 semester will be available, and at this time, one full 2-year cycle of the revised assessment program will be complete. At this juncture, Cycle B of the process (see Figure 1) will occur and decisions made about any potential curriculum changes that may be needed.

References

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