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Surveying Different Student Outcome Assessment Methods for ABET Accredited Computer Engineering Programs

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Abstract: In an effort to improve the quality of their academic programs and graduates, an increasing number of academic institutions are obtaining Accreditation Board for Engineering and Technology (ABET) accreditation for their computer engineering programs. This paper acts as a guide for managers and institutions as they get ready to start the accreditation process for their programs. There is an issue with the lack of knowledge regarding the mechanics of implementing student outcome evaluation methodologies since it causes confusion and resource waste, especially in the beginning. Furthermore, there is a paucity of literature available that discuss the methodology and the use of successful accrediting techniques for computer engineering programs. Given this, it is important to document the approaches, teaching techniques, and strategies employed by various computer engineering departments as they pursue accreditation. To the best of our knowledge, such information is not publicly available in published form, although there are fee-based training courses by ABET that provide instruction on how to approach this topic. Here, we investigate the detailed information of five different computer engineering programs and two other related programs using their self-assessment reports (SARs). These SARs span over the last 10 years and represent the outcome of different approaches toward getting accreditation. The study plan involves comparing (objectively and subjectively) the different parameters of the student outcome assessment (criterion 4) to show their convergence and divergence in dealing with accreditation requirements. We found that the selection of an assessment method depends on the goals and context of the educational program. Factors such as the learning outcomes to be assessed, the level of detail needed, available resources, and the preferences of instructors and students should be taken into account. A program may opt to use multiple assessment methods to attain a more thorough and precise evaluation of student outcomes. Ultimately, the most effective approach is one that is customized to the program's specific needs and situation.

***Keywords*:** engineering accreditation, SAR, continuous improvement plan, student outcome, program educational objectives

1. Introduction

Data on student learning outcomes are gathered and reported by engineering programs all around the world in order to undertake program evaluations for quality assurance and accreditation. Accreditation organizations like Accreditation Board for Engineering and Technology (ABET) usually require institutions to produce program evaluation data for at least two years and to demonstrate how this data has been used for ongoing quality improvement. To improve the overall

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quality of programs and achieve accreditation, any higher education institution must create and implement assessment processes that address several critical issues [1-5].

(a) It is crucial to choose a fair and suitable assessment approach. Comprehensive assessment systems have the potential to boost trust in assessment outcomes while also taxing institutional resources. A lightweight technique, on the other hand, is preferable in terms of resources but may result in skewed or affected outcomes.

(b) The method chosen for carrying out assessments is crucial. For all concerned parties, the assessment structure can be developed utilizing top-down or bottom-up methods. The term "top-down approach" refers to the process of higher management and carefully chosen experts designing the assessment mechanism and then sharing it with other stakeholders, including faculty members. The bottom-up technique entails all stakeholders with varying levels of competence right away in the design process. Various artifacts, such as appropriate Program Educational Objectives (PEOs), Student Outcomes (SOs), and Performance Indicators (PIs), must also be defined. Additionally, proper direct and indirect assessment techniques, related rubrics, and their frequency must be designed.

(c) For decision-makers to receive reliable assessment results, the assessment technique must be impartial and fair. All stakeholders must be included, and it may be altered to meet their socioeconomic, geographic, and industry-specific needs.

(d) The level of faculty participation in the assessment process should be taken into account while creating the technique. Faculty members must be included because this approach is likely to raise the workload, at least at the beginning. Additionally, using rubrics for evaluation has some benefits because it offers a uniform instrument for measuring student achievement. However, because they are challenging to develop, rubric-based assessments may encounter opposition from stakeholders.

(e) To create and implement an efficient evaluation technique, management support at all levels is essential. The most crucial part of support is giving the right resources and, to a certain extent, independence to those who develop assessment methodology in the early phases. A curriculum update and revision of curriculum artifacts like PEOs, SOs, PIs, and corresponding rubrics are probably a result of designing and putting into practice an assessment process. In order to collect and answer input from all engaged stakeholders, upper management is frequently required to get involved.

(f) The assessment methodology must be created to measure student performance in relation to a predetermined target value that has been established through justification and logic. This is difficult since evaluation data is obtained using a variety of direct and indirect techniques and is frequently gathered using various–and perhaps conflicting–rubrics/scales.

From the above, the ability to provide data, feedback, and recommendations to continuously enhance the program across repeated evaluation cycles is possibly the most significant result of the assessment mechanism. This means that proposals for continual improvement must be generated through the assessment process and then included in the Continuous Improvement Plan (CIP). Although ABET has a clearly stated, complete requirement for potential programs and provides some training to spread best practices, they do not impose a specific technique to meet these requirements. ABET accreditation's major concern is identifying a proper assessment method, measuring program achievement, and carrying out ongoing improvement based on the attainment of SOs. In this paper, we describe the experience of doing so for the SO assessment of seven ABET accredited programs offered by different universities.

2. Related works

Table 1 lists numerous pieces of research that have been undertaken to enhance the main areas of academic accreditation. One goal is to help other educational institutions satisfy accreditation criteria. As described in [1-4], several scholars have documented their ABET certification experience in this regard. Program evaluation is one of the essential duties to make sure that an academic program can produce the required student results [5-9]. A recent impact on accreditation efforts across all sectors has been the coronavirus disease 2019 (COVID-19) pandemic and the deployment of remote tools and procedures for accrediting purposes [10-14]. Finally, there are numerous studies in the education literature that concentrate on procedures for continuous improvement [15-18] and education that is outcome-based [19-22].

The literature is lacking in information about the procedures on how to implement SO assessment that adhere to the ABET standards in a particular context. With this in mind, it is obvious that a thorough design and execution of the assessment processes are needed, and this paper's key contribution is to explore these methods. This study, in contrast to earlier cited research attempts in Table 1, adopts an in-depth characterizing approach to offer guidance on all important assessment process issues, including design, evaluation, and continuous improvement as executed by different worldwide ABET accredited computer engineering programs.

Table 1. Literature survey

The subject of the study	Reference	Major contribution(s)
Documentation of ABET accreditation experience	[1]	The authors have analyzed the Engineering Council's and ABET's certification standards, both of which are Washington Accord signatories, and have noted areas of overlap and distinction. They advocated for the requirement of congruence among certified programs of various Washington Accord member bodies.
	[2]	The authors have emphasized how an academic program might be better prepared for ABET accreditation by having a thorough awareness of accrediting procedures and policies.
	[3]	In order to get insights into the mapping process, the authors created a data set of mapping PEOs and student results using ABET self-study reports of 32 certified programs model based on ABET standards to draw attention to shortcomings in academic programs seeking ABET accreditation.
	[4]	The authors have spoken about the challenges involved in creating a self-study report for the accreditation program and have provided a general model based on ABET criteria to draw attention to areas where academic programs that want to apply for ABET accreditation need improvement.
Program assessment	[5]	Based on their successful experience, the author has proposed an assessment approach for PEOs and student results for ABET accreditation.
	[6]	To assist universities in their preparation for ABET certification, the authors have identified 11 important success indicators for pursuing ABET accreditation and built their prioritization based on fuzzy analytical hierarchical processing and full consistency technique.
	[7]	Based on assessments made in course files, the authors employed several data mining methods to forecast how well students will achieve in achieving their learning objectives.
	[8]	The rubric-based evaluation methods for ABET SO attainment for a computer science curriculum have been shared by the authors.
	[9]	Instead of using conventional evaluation mechanisms in course-based evaluations, the authors recommend using a discussion-based performance assignment to evaluate six non-technical abilities related to ethical, legal, security, and social issues.
Remote ABET tools and methods	[10]	Due to the COVID-19 epidemic, the authors have suggested a digital quality management system for program assessment in order to support virtual accreditation visits. They suggested that academic institutions and accreditation agencies use this model in remote accreditation procedures after it was applied to three engineering programs.
	[11]	The authors have described the difficulties that the COVID-19 pandemic has caused with the virtual ABET accreditation procedure and have offered suggestions for how to prepare accreditation documentation for such virtual ABET visits.
	[12]	Because of the COVID-19 pandemic, the authors have offered a design methodology to replicate power engineering labs in online learning. They describe how the experiment contributed to meaningful ABET student results in their model, which includes a simulated environment based on textbook examples.
	[13]	The authors have created a web-based tool that can make the processes of gathering assessment data and reporting easier.
	[14]	The authors conducted research at the Education University of Hong Kong on how online collaborative learning affects students' ability to achieve learning objectives. They observed that online collaborative learning promotes the accomplishment of learning outcomes.
CIP	[15]	By merging ABET criteria and gamification theory, the author suggested a continual improvement cycle that has a favorable effect on students' learning behavior.
	[16]	The program enhancement plan was developed and put into action by the authors to satisfy the requirement for continuous improvement for ABET accreditation of an undergraduate modeling and simulation engineering program.
	[17]	The author has argued for putting professors at the center of the process of ongoing improvement. The author also suggested setting up distinct committees for each program outcome. These committees ought to be in charge of managing curriculum change initiatives, summative data collecting, and assessment review.
	[18]	In order to achieve ABET accreditation, the author has proposed a two-tier continuous improvement strategy, with the first tier concentrating on curriculum improvement and the second tier concentrating on improvement in the measurement process.

Table 1. *Continued*

The subject of the study	Reference	Major contribution(s)
Outcome-based education	[19]	Because outcome-based education is student-centered, the authors suggested including micro-level knowledge structures into the curriculum for teaching power electronic engineering.
	[21]	Summative evaluations can be utilized to determine students' achievement in an outcome-based education because learning transformation should be visible and formative, according to the authors.
	[21]	The transition from traditional education to outcome-based education has a positive effect on students' learning experiences, according to research conducted by the authors.
	[22]	In order to assist instructors in China in applying principles from computational theory to the development of practical skills, the authors created an outcome-based computational thinking curriculum for educators.

3. Guidelines for student assessment procedures

The systematic evaluation of student learning during a degree program is known as the learning outcomes assessment. Its main objective is to keep the institution's academic standards high. Three questions are resolved by an effective assessment of learning outcomes:

• What abilities, dispositions, and knowledge will successful graduates possess?

• How do students fare in terms of these learning objectives?

• How can programs be strengthened so that students have a better academic experience?

The entire institution benefits when the learning outcomes assessment is done correctly. This ensures that the students understand the course material for their degree program. By offering academic and professional programs that are receptive to both students' needs and those of society; and also giving them the resources that they need to steer curricular renewal and development, these help faculty. The institution as a whole gain from it by receiving official documentation of student learning and achievement, which confirms the institution is genuinely carrying out its mission and achieving its objectives. The assessment of learning outcomes is done in six steps, see Figure 1.

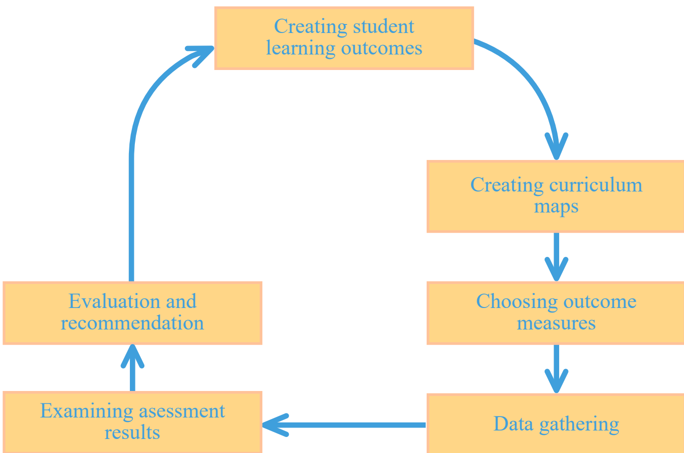


Figure 1. Assessment steps of learning outcomes

(1) Creating student learning outcomes: The first stage in assessing student learning outcomes is to create outcomes that reflect the fundamental concepts and subject matter of the curriculum. Student Learning Outcomes (SLOs) have typically been produced previously, therefore this stage of the process allows for a review and potential adjustment. The creation of SLOs needs to make the most of the faculty's breadth of expertise and aid in determining the structure and course of the program. The needed activities for developing SLOs are: A comprehensive and manageable amount of SLOs (usually between 3 and 8 depending on program length/level)

is required for constructing SLOs; Evidence of faculty involvement in creating learning objectives; Verification that the outcomes are significant, observable, measurable, and acceptable for the course or program level.

It is beneficial to take into account the standard of learning acquired by students who successfully complete a post-secondary program while creating SLOs. SLOs must appropriately represent the level of expectation because academic programs typically have higher expectations for outcomes. SLOs are frequently based on Bloom's taxonomy, which classifies various learning methods into lower- and higher-order levels.

(2) Creating curriculum maps: A curriculum map is a tool that can assist in curriculum development, student learning assessment, and program improvement. It can improve knowledge of the degree program and provides an essential road map for student learning when shared with part-time teachers and students. It can be supplemented with new curriculum sheets or periodically updated and published on the departmental website. Understanding how students are introduced to the ideas outlined in a program's SLOs is crucial. The first step in figuring out where students are introduced to the material they need to grasp is to map students learning outcomes to program courses.

(3) After defining learning outcomes and a curriculum map, the next step is to choose outcome measures. Outcome measures are specific tools and methods used to collect data and information about students' performance in relation to learning outcomes. Learning outcomes describe the knowledge, skills, and abilities that students should have after instruction or program completion. There are two types of outcome metrics: direct and indirect measures. Direct measures evaluate actual examples of student work, such as capstone projects, performances, and portfolio evaluations; while indirect measures evaluate secondary data on student learning, such as surveys of graduates and employers. Both direct and indirect measures are important in evaluation and provide a more complete picture of what students are learning. Each SLO should have a minimum of two measurements.

(4) Data gathering: The next stage of the assessment process is data gathering. In this step, student work and indirect measurements are gathered, work is rated, and data is stored. Although the data-gathering procedure may appear to be a difficult endeavor, with proper planning, it can go more smoothly and yield high-quality data and details regarding the programs' learning results. Three fundamental processes make up the data collection process: acquiring the essential student work and other data, checking the findings, and electronically storing the data. Both direct and indirect measures use the Gathering, Evaluating, and Storing (GES) procedure, albeit some of the specific phases will change. For each learning outcome and metric, direct data must be collected. Indirect data must also be collected. For each performance criterion, a secure electronic database containing measurements and examples of student work is maintained.

(5) Examining and assessing assessment results: The next stage of the assessment process is data analysis. Data can be better understood through analysis, which also enables inferences to be drawn. It provides a summary of the information, increases the value of the data acquired, and offers guidance for choices on program improvement. Although data analysis might be rather difficult, it is typically simple when used for evaluation. An estimate of the number of students who participated in the assessment activity for each outcome measure and the proportion of students who met or surpassed the performance threshold for each outcome measure are required activities for analyzing assessment data.

(6) Evaluation and recommendation: The cycle's sixth stage involves disseminating program evaluation findings. This phase focuses on interpreting strengths, identifying obstacles and potential improvement areas, and making recommendations. Working with the program faculty to comprehend assessment results is the first stage. The other two processes are choosing which stakeholders to share the results with and producing the necessary materials for those groups. A cyclical assessment process is built on prior effort and action. When a program uses the information from its evaluation results and makes modifications, the "assessment loop" is complete. Evaluation results frequently, though not always, point to the need to change the academic curriculum or the assessment procedure and take into account available resources.

4. Research methodology

In this paper, we investigate the detailed information of seven different computer engineering programs using their self-assessment reports (SARs), see Table 2. These SARs span over the last 10 years and represent the outcome of different approaches toward getting accreditation. The study plan involves comparing (objectively and subjectively) the different parameters of the SO assessment (criterion 4) to show their convergence and divergence in dealing with accreditation requirements. These parameters are:

- Assessment processes: The systematic collection, analysis, and interpretation of information about student learning and development for the purpose of improving educational programs and services.
- Frequency of direct assessment processes: The number of times that direct assessment processes, such as tests or assignments, are administered to students over a given period.
- The expected level of attainment: The level of achievement that students are expected to reach at a certain point in their education, based on established standards or learning outcomes.
- Number of selected topics for direct assessment: The number of specific areas of knowledge/skill that are targeted for assessment through direct methods, such as exams or projects.
- Number of surveys/year (indirect assessment): The number of surveys administered to students, faculty, or other stakeholders each year to gather information about their perceptions and experiences related to various aspects of the educational program.
- Documentation: The written records, reports, or other materials that provide evidence of assessment activities, outcomes, and recommendations for improvement.
- Assessment and analysis tools: Tools and techniques used to collect, analyze, and interpret assessment data, such as statistical software, rubrics, and surveys.
- Length of assessment cycle: The period between the initiation and completion of an assessment process, which can vary depending on the type and scope of the assessment activity.

Table 2. The sampled programs

	Navajo Technical University	**University of Florida**	**University of Colorado Colorado Springs**	**Fitchburg State University**	**Saint Louis University**	**University of Washington**	**Umm Al-Qura University**
Country	USA	USA	USA	USA	USA	USA	KSA
Program delivery modes	In-person - Day mode	In-person - Day mode	In-person - Day and evening modes	In-person - Day mode	In-person - Day mode	In-person - Day mode	In-person - Day mode
	Distance learning			Distance learning			
Graduation requirements	120 credit hours 4 years program	118 credit hours 5 years program	128 credit hours 5 years program	120 credit hours 5 years program	125 credit hours 5 years program	180 credit hours 4 years program	165 credit hours 5 years program
PEOs	4	4	3	7	3	4	4
SOs	ABET (a to k)	ABET (a to k)	ABET (a to k)	Criterion 3 of ABET Criteria Version 2.0 (1 to 7)	ABET (a to k)	Criterion 3 of ABET Criteria Version 2.0 (1 to 7)	ABET (a to k)
Program curriculum	Math & basic science: 32 hours	Math & basic science: 42 hours	Math & basic science: 35 hours	Math & basic science: 18 hours	Math & basic science: 36 hours	Math & basic science: 45 hours	Math & basic science: 35 hours
	Engineering topics: 48 hours	Engineering topics: 65 hours	Engineering topics: 75 hours	Engineering topics: 43 hours	Engineering topics: 57 hours	Engineering topics: 70 hours	Engineering topics: 72 hours
	Others: 19 hours	Others: 18 hours	Others: 18 hours	Others: 59 hours (not an Engineering department)	Others: 18 hours	Others: 65 hours	Others: 58 hours
Faculty qualifications	PhD: 4 Others: 1	PhD: 70 Others: 3	PhD: 7 Others: 2	PhD: 7 Others: 2	PhD: 5 Others: 1	PhD: 69 Others: 10	PhD: 26 Others: 5
Faculty workload (average)	5 courses per semester	2 to 5 courses per academic year	5 courses per academic year	18 credit hours per semester	18 credit hours per semester	3 courses per academic year	10-16 credit hours per semester

4.1 *Electrical engineering program at Navajo Technical University*

The degree to which the learning outcomes for the Electrical Engineering (EE) program are met is assessed using a variety of direct, indirect, quantitative, and qualitative assessment methodologies. The term “direct assessment methods” refers to those where a conclusion can be drawn directly from student-submitted work, such as measurement of SOs–a, b, c, and e–through homework, tests, and/or projects where methods used and conclusions reached are readily interpreted and understood using a quantitative approach to evaluate. A conclusion is inferred using indirect assessment methods, such as SO D, where a professor supervising student projects would be able to determine if students performed well in diverse teams or not. Most frequently, these assessments are made using rubrics for the desired conduct displayed at various levels of achievement. Figure 2 shows the sequence of the steps taken to perform the SO assessment, these are extracted from the SAR of this program [23].

The SO assessment tools for the program are listed in Figure 2-Part 1. The faculty, the Engineering Advisory Board, independent evaluators, and the Dean of Instruction are generally the institutions in charge of data collection, analysis, and evaluation. Several of the techniques are still being used to evaluate the EE program. A timetable of when various SOs were reviewed is provided in Figure 2-Part 2. Every year, data is gathered, and each year, some activity related to each outcome would take place. In Figure 2-Part 3, the activity cycle is depicted, while Parts 4 and 5 determine the attainment levels and the chosen course to be evaluated. The example for SO as in Figure 2-Part 6, is used to report the results for each SO. The activity for the current ABET accreditation cycle is shown in each table. Each table contains performance indicators, courses and/or extracurricular activities that give students a chance to exhibit the indicator, the location where summative data are gathered, the schedule, the method of assessment, and the performance target. Figure 2-Part 7 displays a representative evaluation result, primarily from the spring 2017 capstone class.

1

Table 4.A.1. Summary of Electrical Engineering Student Outcome Assessment Tools

Tool Name	Frequency	External or Internal	Documentation and Maintenance of Results
Academic Program Review (APR)	Annually	External	Electronic and hard copy; maintained by Dean of Instruction
Engineering Advisory Board (EAB)	Twice per Year	External	Minutes of meetings maintained by Dean of Instruction
Alumni Survey	Annually	External	Electronic and hard copy; maintained by Assessment Committee Chair
Exit Survey	Twice Per Year	Internal	Electronic and hard copy; maintained by Dean of Instruction
Student Performance	Twice per year	Internal	Electronic copy; maintained by Assessment Committee Chair
Program Assessment	Annually	Internal	Electronic copy; maintained by Assessment Committee Chair
Focus Groups	Annually	External	Electronic and hard copy; maintained by evaluators and Dean of Instruction

2

Table 4.A.2. Six-Year Program-Level Assessment Plan for Electrical Engineering

Program Outcomes	2017	2018	2019	2020	2021	2022
(a) An ability to apply knowledge of mathematics, science, and engineering			x			x
(b) An ability to design and conduct experiments as well as to analyze and interpret data			x			x
(c) An ability to design a system, component, or process to meet desired needs within realistic constraints such as economic, environmental, social, political, ethical, health and safety, manufacturability, and sustainability		x			x	
(d) An ability to function on multidisciplinary teams		x			x	
(e) An ability to identify, formulate, and solve engineering problems			x			x
(f) An understanding of professional and ethical responsibility	x			x		
(g) An ability to communicate effectively	x			x		
(h) The broader education necessary to understand the impact of engineering solutions in a global, economic, environmental, and societal context		x			x	
(i) A recognition of the need for, and an ability to engage in life-long learning		x			x	
(j) A knowledge of contemporary issues		x			x	
(k) An ability to use the techniques, skills, and modern engineering tools necessary for engineering practice	x			x		

Figure 2. Assessment methods used at Navajo Technical University [23]

3

Table 4.A.4. Cycle of activity for each student outcome over the 6-year period

Activity for each Student Outcome	Yr 1	Yr 2	Yr 3	Yr 4	Yr 5	Yr 6
Review of performance indicators that define the outcome	X			X		
Review the map of educational strategies related to performance indicators		X			X	
Review mapping and identify where data will be collected		X			X	
Develop and/or review assessment methods used to assess performance indicators		X			X	
Collect data			X			X
Evaluate assessment data including processes				X		
Report findings				X		
Take action where necessary				X		

4

Exemplary Performance is indicated by 100% scoring on Figures 4.A.1 through 4.A.11.

Satisfactory Performance is indicated by achieving 80 to 90% scoring on Figures 4.A.1 through 4.A.11.

Learning Performance is indicated by 60 to 70% scoring on Figures 4.A.1 through 4.A.11.

Performance Needing Improvement is indicated by anything below 60% scoring on Figures 4.A.1 through 4.A.11.

5

Courses	a	b	c	d	e	f	g	h	i	j	k
EE-423: Capstone Design II	x	x	x	x	x	x	x	x	x	x	x

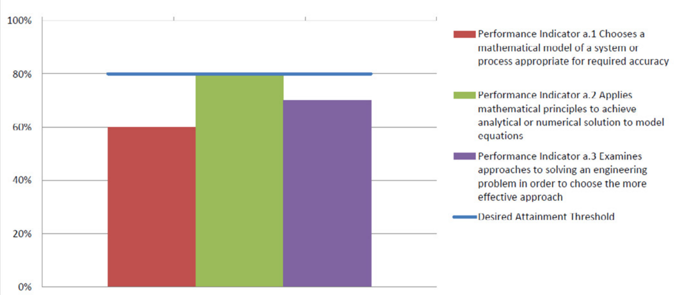
6

Table 4.A.5 Student Outcomes (a) - An ability to apply knowledge of mathematics, science, and engineering

Performance Indicators	Educational Strategies	Method(s) of Assessment	Where data are collected (summative)	Length of assessment cycle (yrs)	Year(s) / semester of data collection	Target for Performance
Chooses a mathematical model of a system or process appropriate for required accuracy	EE101, EE102, EE103, EE201, EE202, EE203, EE212, EE301, ENGR301 EE303, EE312, EE313, EE320, EE396, EE406, EE422, EE423	Quiz, Test and Homework problems, Course Projects, Final Design Project Report (Rubric)	EE 423	3 years	2019/2022 for all listed classes but Capstone where attempt to collect every year is made	80%
Applies mathematical principles to achieve analytical or numerical solution to model equations	EE101, EE102, EE103, EE201, EE202, EE203, EE212, EE301, ENGR301 EE303, EE312, EE313, EE320, EE396, EE406, EE422, EE423	Quiz, Test and Homework problems, Course Projects, Final Design Project Report (Rubric)	EE 423	3 years	2019/2022 for all listed classes but Capstone where attempt to collect every year is made	80%
Examines approaches to solving an engineering problem in order to choose the more effective approach	EE101, EE102, EE103, EE201, EE202, EE203, EE212, EE301, ENGR301 EE303, EE312, EE313, EE320, EE396, EE406, EE422, EE423	Quiz, Test and Homework problems, Course Projects, Final Design Project Report (Rubric)	EE 423	3 years	2019/2022 for all listed classes but Capstone where attempt to collect every year is made	80%

7

Figure 4.A.1 Capstone Results Summary for Student Outcome (a) 2017



__Assessment Results Summary (2017)__: The results from Capstone show that EE students were in needing improvement level (60%) for indicator a.1, satisfactory level (80%) for a.2, and students achieved learning level (70%) for Indicator a.3.

__Evaluation and Actions (2017)__: Evaluation was performed during the Assessment Workshop on May 15 & 16. According to the old requirements of the capstone, students were not asked to show how to choose math models in the tasks assigned to EE students. Therefore, EE students did not write too much about the math modes in the report. However, math models are required in some other courses in the EE program, which will be assessed in the future. The department will ask faculty members to improve students learning related to Indicator a.1 on how to choose math model in a system, and also Indicator a.3 on how to choose the most effective approach to problem solving. The new Rubric for evaluating Performance Indicators of Student Outcomes will be provided to faculty for guidance.

Figure 2. *Continued*

4.2 *Computer engineering program at University of Florida*

There are three steps in the direct assessment of results process: assessments given by course instructors are used directly to collect quantitative data; they are confirmed by the course committees, and performance is normalized to the Likert scale. In order to address any weaknesses, instructors incorporate the findings of their assessments and the Course Committee's evaluations into their lessons. When students consistently perform below expectations, knowledgeable instructors start to investigate to see if the issue is with the learning or the evaluation process. If learning is the problem, these professors would take into account the topics covered and the methods used to address them to offer alternatives. The Course Committees qualitatively assess each course's objectives and outcomes, and then they report their findings to the ABET Coordinator. At the program level, the ABET Coordinator takes these concerns into account. Each outcome is taken into account across all courses, and areas for improvement are taken into account for particular courses, the curriculum as a whole, the facilities, or the assessment and improvement process itself. Each semester, direct assessments are conducted. Student focus groups and exit surveys are used for indirect evaluations. Annual indirect assessments are carried out. An average Likert score of 3.0 or above and 80% of students (on average) achieving each outcome in each assessment are the standards for the expected level of achievement. Figure 3 shows some steps taken to perform the SO assessment at University of Florida [24].

1

		Outcomes										
Course #	Course Name	a	b	c	d	e	f	g	h	i	j	k
COP-3504	Introduction to CIS (CIS-3020)			x		x						x
COT-3100	Applied Discrete Structures	x										x
COP-3530	Data Structures and Algorithms	x				x						x
CDA-3101	Introduction to Computer Organization	x		x		x						
CEN-3031	Introduction to Software Engineering				x			x				
COP-4600	Operating Systems			x								x
COT-4501	Numerical Analysis	x	x			x						
CEN-4007C	Comp. Networking Fund. (CEN-4500C)		x									x
CGS-3065	Legal and Social Issues in Computing						x		x	x	x	
CIS/CEN-4914	Senior Design	x	x	x	x	x	x	x	x	x	x	x
EEL-3111C	Circuits 1	x										x
EEL-3135	Discrete-Time Signals and Systems	x										x
EEL-3308C	Electronic Circuits 1		x	x						x		
EEL-3701C	Digital Logic and Computer Systems			x								x
EEL-4712C	Digital Design	x		x		x						x
EEL-4744C	Microprocessor Applications	x		x		x		x				x
EEL-4914C	Senior Design		x	x	x	x	x	x	x	x	x	x

Table 4-4. Course-Outcomes Assessments Mapping.

2

SUMMARY OF OUTCOMES	SAO:	ALV:
Outcome (a)	85%	3.5
Outcome (b)	90%	4.1
Outcome (c)	86%	4.1
Outcome (d)	93%	4.5
Outcome (e)	84%	4.0
Outcome (f)	95%	4.5
Outcome (g)	95%	4.3
Outcome (h)	96%	4.4
Outcome (i)	96%	4.4
Outcome (j)	95%	4.1
Outcome (k)	85%	3.8
Overall Averages	91%	**4.1**

Figure 3. Assessment methods used at University of Florida [24]

4.3 *Computer engineering program at University of Colorado Colorado Springs*

Figure 4 shows the sequence of the steps taken to perform the SO assessment at University of Colorado Colorado Springs [25]. Figure 4-Part 1 shows that a number of important courses are recognized as measuring courses for evaluating the chosen elements of the 10 objectives, including (a)-(k). Each course's instruction is followed by an evaluation process (Figure 4-Part 2). This procedure normally entails a variety of assessment methods that the instructor chooses and presents to the full faculty at the start of each semester during a faculty meeting (Figure 4-Part 3). Three surveys are used by the program to measure and evaluate the success of the instructional goals. After their final semester, each graduating senior has an exit interview. Alumni are often surveyed once every two years to gauge how well the goals are being achieved. A stakeholder survey is usually taken on a two-year basis to ascertain the opinions of employers on our graduates. A score of 75% is rated as good, 60-75%, OK and less than 60% bad (Figure 4-Part 4).

1 **Table 4: BSCpE- Course Mappings to Program Outcomes & Measurement Courses (CMO)**

BSCpE Outcomes	CS Core Courses									ECE Core Courses										
	1150	1450	2080	3020*	3060*	3300	4200**	4500	4720	1001	1021	1411	2205	2411	2610	3210	3420	3430	3440	3610
(a)							x		x	x	x x		x	x	x	x	x	x x		x
(b)				x	x	x		x	x		x	x		x	x		x		x	x
(c)						x	x	x	x										x	
(d)						x		x		x										
(e)				x	x	x	x	x	x	x		x		x	x		x	x	x	x
(f)			x			x				x										
(g)						x				x									x	
(h)						x				x		x				x				
(i)		x				x		x						x						
(j)		x		x	x	x		x				x		x						x
(k)	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x x		x	x x		x

2

Course	Program Outcome Assessment and Representative Criteria
CS 3300: Software Engineering I	Outcome (1) - **M-** Students will understand the cost and schedule considerations for a SW project, and planning issues for successful projects - **A**- Students will develop algorithms to solve the problems associated - with their SW project. - **T-** Students will use SW modeling theory for real world - processes and design objects in their project's design phase. - **P-** Students will use best current SW engineering practices in developing their SW project.

[7] Outcomes used in Computer Science are different from those used in in the BSCpE program. The specialized outcomes in used for the two Computer Science courses (CS 3300 and CS 4720) in Table 8 are listed below.

1. An ability to apply mathematical **(M)** foundations, algorithmic principles **(A)**, and computer science theory **(T)** to practice **(P)** in modeling and design tradeoffs of computer based systems.
2. An ability to model **(M)**, design **(D)**, implement **(I)** and evaluate **(E)** software systems and components of varying complexity (C) in a way that demonstrates comprehension of the trade-offs **(T)** involved in design and implementation choices.
3. An ability to learn to use new design methodologies **(M)**,operating systems **(O)**,languages **(L)**, and software development tools **(T)** within reasonable time constraints.
4. An ability to function effectively on teams **(T)** related to software development
5. An ability to communicate with a range of audiences, both orally **(O)** and in writing **(W)**, about technical subjects.
6. An understanding and application of professional **(P)**, ethical **(E)** and social **(S)** responsibilities and their impact **(I)** on individuals, organizations and society, locally and globally.

Figure 4. Assessment methods used at University of Colorado Colorado Springs [25]

3

Table 10: Analysis Results of Course Assessments, 2007 to 2011

Key:

G – Good: Clear and effective; goal achieved. 75% or better performance evaluation.
O – Okay: Average ability; goal partially achieved. 60%-74% performance evaluation.
B – Bad: Minimal or no ability; goal not achieved. 59% or below performance evaluation.
NM – Not measured. ECE relies on the CS Department for CS assessment data which was not measured at the time of this self-study document.
If the course collected additional data, the assessment will have two or more letters.

Outcome (a) – (k)		Corresponding Course and Assessment Outcome	Course assessment results (from course assessment tool)			
			2007-2008	2008-2009	2009-2010	2010-2011
(a)	An ability to apply knowledge of mathematics, science, and engineering	CS 4720	G	G	G	G
		ECE 2610	G,G	G,G	G,G	O,G
(b)	An ability to design and conduct experiments as well as to analyze and interpret data	CS 3300	G	G	G	G
		CS 4500	G	G	G	G
		CS 4720	NM	NM	NM	NM
		ECE 3420	O	G	G	G
(c)	An ability to design a system, component, or process to meet desired needs within realistic constraints such as economic, environmental, social, political, ethical, health, and safety, manufacturability, and sustainability	CS 3300	G	G	G	G
		CS 4500	G	G	G	G
		CS 4720	NM	NM	NM	NM
		ECE 4890	G,G	G,G	G,G	G,G
		ECE 4899	G,G	G,G	G,G	G,G

4

Table 9: ECE 4899 Average Scores for ABET Outcomes

Outcome	Source	2007-2008		2008-2009		2009-2010		2010-2011		
		N	Score	N	Score	N	Score	N	Score	Av Score
(b) an ability to design and conduct experiments as well as to analyze and interpret data	*Questions 6 & 12 on ECE 4899 Exit Questionnaire (student & faculty*	6	90.3%	11	86.4%	12	90.1%	9	78.%3	86.3%
(c) an ability to design a system, component or process to meet desired needs within realistic constraints such as economic, environmental, social, political, ethical, health and safety, manufacturability, and sustainability	*Questions 5 & 14 on ECE 4899 Exit Questionnaire (student & faculty)*	6	95.8%	11	87.1%	12	88.1%	9	85.0%	89.0%
(d) an ability to function on multi-disciplinary teams	*Question 8 on ECE 4899 Exit Questionnaire (student & faculty)*	6	97.2%	11	87.9%	12	86.0%	9	88.8%	89.9%
(g) an ability to communicate effectively	*Questions 1,2,& 3 on ECE 4899 Exit Questionnaire (student & faculty)*	6	91.7%	11	84.9%	12	87.0%	9	82.8%	86.6%

Figure 4. *Continued*

4.4 *Computer information systems program at Fitchburg State University*

Figure 5 shows the sequence of the steps taken to perform the SO assessment at Fitchburg State University [26]. 11 important courses were used for evaluation. Each year, instructors for the 11 core courses collect evaluation information in accordance with the timeline outlined below. Based on 82 course goals, this schedule offers a comprehensive program review every two years. The instruments used to evaluate students' understanding of any given course aim may include quizzes (Q), exams (E), tests (T), homework (H), assignments (A), final exam questions (F), projects (P), lab exercises (L), group work (GW), mock consulting assignment (MC), final presentations (FP) or a combination of these. A score for each aim is calculated using student performance on each tool linked to that objective in each of the essential courses. To identify areas that need improvement, a percentile rank of pupils (often 80%) scoring above a given threshold score (typically 70%) is employed.

1

The schedule of course assessments is shown in the table below.

	2015		2016		2017		2018		2019	
CIS Outcomes	Spring	Fall	Spring	Fall	Spring	Fall	Spring	Fall	Spring	Fall
CISSO-1		C1400 C2560	C1900 C2700				C2700 C1900	C2560 C1400		
CISSO-2				C3710	C4700	C3710	C4700			
CISSO-3					C4700		C4700			
CISSO-4			C4102				C4102			
CISSO-5				C3710	C4700	C3710	C4700			
CISSO-6				B2010	B2020			B2010	B2020	
CISSO-7				C3710	C4700	C3710	C4700			
CISSO-8			C3450	C3400			C3450	C3400		

2

Assessment Data Tables (Fall, 2015 to Spring, 2019)

Cycle 1: Fall, 2015 through Spring, 2017

Course Objective	Term	Course	Tool	Target Percent	Actual Percent	Action to be taken
IS in business, business fundamentals and information technology fundamentals	Fall1	C1400	H1, T1	80% should score >= 70	100%	
Computer hardware and software	Fall1	C1400	H3;T2; P1	80% should score >= 70	93%	
Networks and data communications	Fall1	C1400	H3;T1, 2	80% should score >= 70	100%	
Data management	Fall1	C1400	H7;F	80% should score >= 70	60%	Students did not have spreadsheet skills that were assumed. Review spreadsheets in future instances.
Personal productivity and problem solving and group collaboration in a business environment	Fall1	C1400	H6,7,9; F	80% should score >= 70	60%	
Business operations and management decision making	Fall1	C1400	H6;F	80% should score >= 70	60%	

Figure 5. Assessment methods used at Fitchburg State University [26]

4.5 *Computer information systems program at Saint Louis University*

Figure 6 shows the sequence of the steps taken to perform the SO assessment at Saint Louis University. Every three years, each criterion will be evaluated in order to provide two thorough evaluations over a six-year period. The SOs are evaluated in certain courses, usually through particular tasks. Using the course materials and the indicators, a SO can be defined and measured more quickly. Figure 4-Part 4 is a sample list of indicators. These materials are evaluated quantitatively using a straightforward three-level rubric. Each indication and piece of assessment material is subject to a different rubric, which is used to determine how well a particular piece of student's work satisfies the indicator.

1

TABLE 4.2 Assessment schedule by semester for AY13 through AY18.

Sem	SO's	Courses	Dev/Eval
S13	a,b,c,d		developed
F13			
S14	e,f,g,h		developed
	a	ECE2103, ECE3130, ECE4800/4810	evaluate
	b	ECE3090, ECE4800/4810	evaluate
	c	ECE3132, ECE4800/4810	evaluate
	d	ECE3090, ECE4800/4810	evaluate
F14	a	ECE3151	evaluate
	b	ECE3151	evaluate
	c	N/A	
	d	N/A	

2

TABLE 4.1 Course assessment matrix.

Course \ SO	a	b.1	b.2	c	d	e	f	g	h	i	j	k
ECE1001 - ECE Intro I											X	
ECE2103 - Circuits II Lab	X											X
ECE2206 - Digital Lab												X
ECE3090 - Junior Design		X	X		X	X		X		X		
ECE3130 - Semiconductors	X											
ECE3132 - Electronics Lab				X								X
ECE3151 - Linear Sys Lab	X	X	X			X						X

3

TABLE 4.5 Classification of SO student performance

Average Performance	Performance Classification
2.5 - 3	Acceptable performance - no action required
2 - 2.5	Marginal performance - consider action
< 2	Action required

4

(a) an ability to apply knowledge of mathematics, science, and engineering

TABLE 4.6 Student Outcome (a) assessment indicators and descriptions.

Indicator	Course	Assessment Description
1. Ability to mathematically describe a system using scientific principles.	ECE2103	Find the frequency response of an RLC circuit.
	ECE3130	Develop an energy band diagram of a semiconductor and calculate the carrier concentration.
	ECE3151	Develop a mapping function from an autocorrelation function estimate to echo gain.
	ECE4800/ ECE4810	Exhibit through technical details found in the Project Notebook, technical reports, or technical presentations.
2. Ability to develop and analyze mathematical models for a system.	ECE2103	Find the Thevenin Equivalent of a circuit.
	ECE3130	Develop a mathematical model for a semiconductor device such as a diode or transistor.
	ECE3151	Develop the impulse response for a filter that eliminates echo in an acoustic signal.
	ECE4800/ ECE4810	Exhibit through technical details found in the Project Notebook, technical reports, or technical presentations.

5

TABLE 4.7 Assessment rubrics for Student Outcome (a).

	Rubric		
Ind	1 = Does not meet Expectations	2 = Meets expectations	3 = Exceeds expectations
		ECE2103	
1	Either the frequency response function is not correct, or the filter type is stated incorrectly.	The frequency response function is correct and the filter type is stated correctly. The calculation is either missing or has insufficient details.	The frequency response function is correct, the calculation is shown in detail, and the filter type is stated correctly.
2	Either the thevenin model is incorrect or the model is correct but the component values are incorrect.	The thevenin model is correct and the component values are correct. The calculation details are either missing or are insufficient in details.	The thevenin model is correct, component values are correct, and calculation details are shown.

Figure 6. Assessment methods used at Saint Louis University [27]

6

TABLE 4.29 Student Outcome (a) assessment results.

Course	Sem	Ind	Score	Course	Sem	Ind	Score
ECE2103	S14	a-1	N/A	ECE2103	S18	a-1	2
ECE3130	S15	a-1	2.67	ECE3130	S17	a-1	2
ECE3151	F14	a-1	2	ECE3151	F16	a-1	3
ECE4800/4810	F13-S14	a-1	1.67	ECE4800/4810	F16-S17	a-1	2.33
		Ave:	2.11			Ave:	2.33
ECE2103	S14	a-2	N/A	ECE2103	S18	a-2	2
ECE3130	S14	a-2	2.67	ECE3130	S17	a-2	2
ECE3151	F14	a-2	1.67	ECE3151	F16	a-2	3
ECE4800/4810	F13-S14	a-2	1.67	ECE4800/4810	F16-S17	a-2	2.33
		Ave:	2			Ave:	2.33
ECE2103	S14	a-3	N/A	ECE2103	S18	a-3	2
ECE3151	F14	a-3	2.33	ECE3151	F16	a-3	3
ECE4800/4810	F13-S14	a-3	1.67	ECE4800/4810	F16-S17	a-3	2
		Ave:	2			Ave:	2.33
		Average Assessment:	1.93			Average Assessment:	2.33

Figure 6. *Continued*

4.6 *Computer engineering program at University of Washington*

Through targeted assessment in courses, SOs are evaluated in the most direct way possible. Performance metrics are set by instructors for the learning objectives that are covered in their courses. They then classify student achievement into three levels–High, Medium, and Low–using those indications. Additionally, the teacher chooses and stores representative work examples from the class's top, middle, and bottom performers. Continuous targeted assessment is carried out via a sampling strategy in which all results are evaluated annually, but only with a select few courses. Each outcome will be evaluated at least twice annually with a three-year rotation between the courses participating in the assessments. Capstone courses have been the main targets for assessing SOs for the last two years. Achieving 80% of students at the High or Medium level is the attainment threshold. Utilizing performance indicators that are created for each course, student results were assessed. The performance indicator is evaluated by faculty who then utilize the results to quantify student achievement using three categories: High, Medium, and Low. There are various indirect approaches available in addition to this direct procedure for outcome assessment. Figure 7 below shows the sequence of the steps taken to perform the SO assessment at University of Washington.

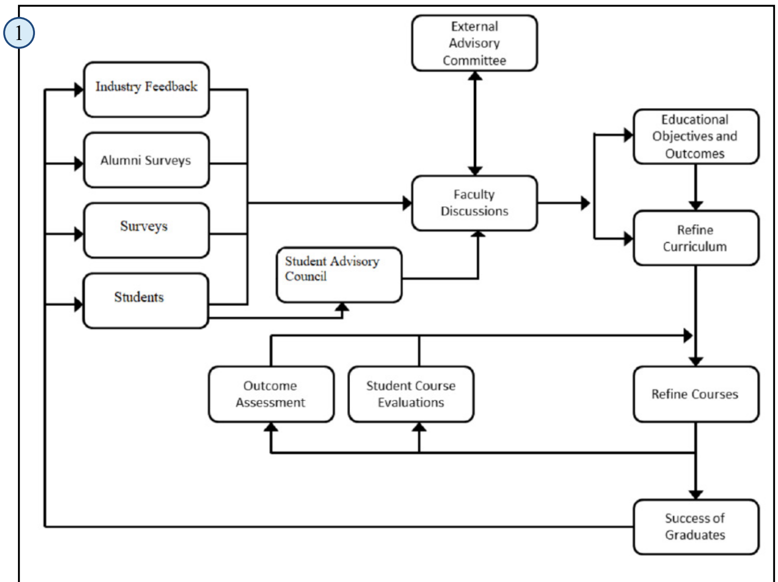
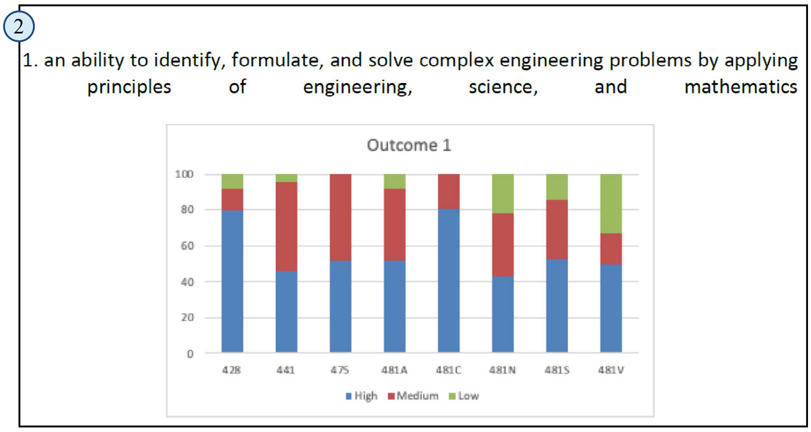


Figure 4-1 Summary of Department Assessment and Improvement Processes

Figure 7. Assessment methods used at University of Washington [28]



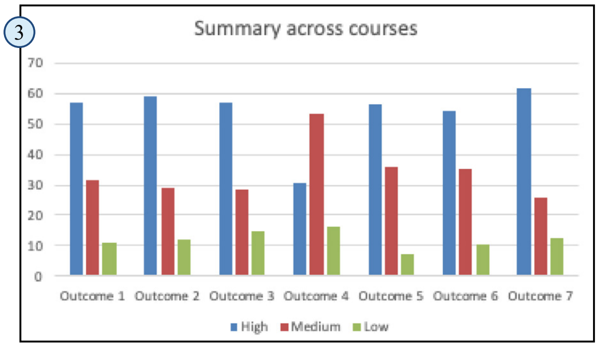


Figure 7. *Continued*

4.7 *Computer engineering program at Umm Al-Qura University*

Course Learning Outcomes (CLOs) are a group of outcomes that are specific to each course. The CLOs of a course are the skills that students are expected to master as a result of the numerous subjects that are covered in the course. An ability represented by one or more SOs may be related to an ability obtained by students in a CLO. In order to demonstrate this linkage using the 0-1 logic, a CLO-SO map is necessary. The CLO-SO mapping connects SOs to the CLOs of different core courses, so if the CLOs are satisfied to the necessary extent, the pertinent SOs are likewise presumed to be satisfied to the necessary extent. According to this assumption, monitoring CLO satisfaction and attainment across numerous courses constitutes the most crucial component of the SO assessment procedure. Another crucial component of the assessment and evaluation process is the Level of Learning (LOL). It is clear that merely declaring that a particular SO has been obtained by the students is insufficient. The well-known Bloom's Taxonomy is a useful tool for defining and rating LOL. For the gathering of assessment data and the evaluation of SO achievement, a few courses are chosen. A satisfaction requirement for the Computer Engineering program is for 60% of students to achieve the proficiency represented by 70% of their marks (i.e., C grade). The department uses a program named CLOSO from smart-accredit.com. Through a variety of mechanisms, the attainment of SOs is continuously examined and evaluated. A system of assessment and evaluation is made up of five different indirect assessment methods in addition to the direct formative and summative assessments. CLOSO assists the instructor in creating evaluations in an organized manner. The obtained assessment data is analyzed for each course using CLOSO software. There are two sorts of data generated: (a) CLO satisfaction data (the percentage of students who meet the satisfaction requirements for each assessment is calculated using CLOSO software analysis). Then, a weighted average is calculated for each CLO, (b) SO satisfaction data (use the CLOSO software to perform SO satisfaction analysis of each course using a conversion formula based on CLO-SO map for the course and produces the percentage of students satisfying the program satisfaction criterion for each SO that is relevant to the course). Figure 8 shows the sequence of the steps taken to perform the SO assessment at Umm Al-Qura University.

1

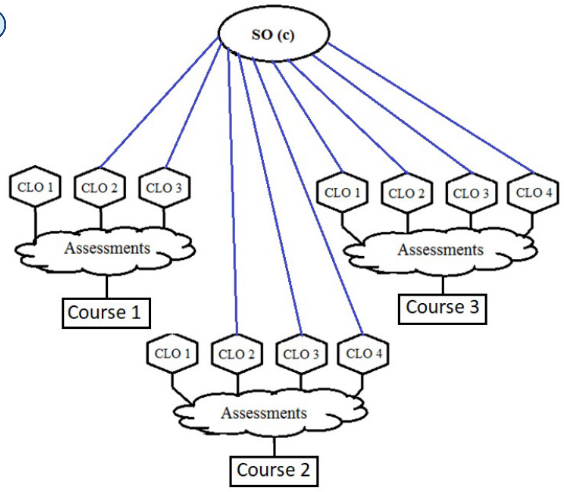


Figure 4-1 The SO assessment linked to CLO assessment

2

Table 4-5 Courses used for evaluation of SO attainment

Course No.	Course Name	Credit Hours
1403201	Circuit Theory	4
1403271	Switching Theory	4
1403311	Electronics	4
1403312	Digital Elect. Syst. & Circuits	4
1403322	Computer Comm. System	4
1403364	Basics of IC Design	3
1403371	Advanced Logic Design	4
1403372	Computer Organization	4
1403381	Numerical Analysis	3
1403401	Seminar	2
1403422	Computer Networks	4
1403450	Microcomputers Syst. Design	4
1403472	Computer Architecture	3
1403489	Microprocessors	4
1403499	Project	4

3

Table 4-6 Assessment Processes at a Glance

	SO Assessment Process	Assessment Type	Frequency	Data Responsibility	Data Collection & Processing	Evaluated by
1	Formative Assessment	Direct	Each Semester	Instructors	CLOSO	Assessment Committee
2	Summative Assessment	Direct	Each Semester	Project Advisor	CLOSO	Assessment Committee
3	Course-wise Student Survey	Indirect	Each Semester	Instructors	CLOSO	Assessment Committee
4	Course-wise Faculty Survey	Indirect	Each Semester	Instructors	CLOSO	Assessment Committee
5	Exit Survey	Indirect	Each Semester	Surveys Committee	Surveys Committee	Assessment Committee
6	Alumni Survey	Indirect	Triennial	Surveys Committee	Surveys Committee	Assessment Committee
7	Employers Survey	Indirect	Triennial	Surveys Committee	Surveys Committee	Assessment Committee

4

Table 4-10 Typical Assessment Marks Contribution Data

Assessment ID	Assessment Name	Raw Marks (Used for grading the assessment)	Marks Contribution to Final Grade (%)
1	Quiz 1	20	5
2	Homework 1	100	5
3	Quiz 2	20	5
4	Mid-Term	20	20
5	Term Project	50	15
6	Final Exam	100	50
Total marks contribution: (must add up to 100) >>			**100**

5

Table 4-17 SO attainment for P: 70% (2016-17)

Student Outcomes (SO)	a	b	c	d	e	f	g	h	i	j	k
Weighted Averages (%)	56	75	55	74	46	77	55	63	73	64	75
Maximum (%)	87	96	96	99	87	92	99	99	99	93	99

Figure 8. Assessment methods used at Umm Al-Qura University [29]

5. Analysis and comparison of SO assessment methods

The main features of the student assessment methods in Section 4 are abstracted and compared as presented in Table 3. The provided data contains information about assessment processes, frequency of assessment, expected level of attainment, number of selected topics for assessment, number of surveys per year, documentation, assessment and analysis tools, and length of assessment cycle for various educational programs or courses. The data is presented in a structured format with each piece of information labeled and numbered for easy identification. The data also includes specific numerical values and ranges for some of the metrics, such as the expected level of attainment and the number of selected topics. Additionally, the data is organized into separate entries for each educational program or course, allowing for easy comparison between them.

- The following remarks could be extracted from this collection:
- Although they all represent computer engineering programs, there is a clear divergence among them in many aspects such as PEOs, study plans, curriculum, faculty, resources, regulations, and CIP. Nevertheless, all these programs were eligible to get ABET accreditation.
- These programs follow different approaches for criterion 4: data gathering, assessment and evaluation. These methods range from the classical (extensive) model to the lightweight (capstone project) model. Also, different software assistance tools were used in different manners for data assessment and archiving.
- SARs mostly focused on CIP which occupied about 50% of the report.
- Assessment processes: All of the educational programs (except one) use both direct (exams) and indirect (surveys, interviews) assessment processes to evaluate student learning outcomes.
- Frequency of assessment: Most programs assess students each semester or annually, with assessment cycles lasting between 2 and 6 years.
- Expected level of attainment: The expected level of attainment for each program varies, but most programs aim for at least 60-80% of students to achieve a certain level of proficiency in each learning outcome.
- Number of selected topics for assessment: Programs assess a varying number of topics or courses, with the number ranging from 1 to 17 out of a total of 33 to 53 courses.
- Number of surveys per year: the number of surveys per year ranges from 2 to 5, with the majority of programs conducting 3 to 4 surveys annually.
- Documentation: All programs use both electronic and hard copy documentation to record assessment data.
- Assessment and analysis tools: Most programs use manual assessment and analysis tools, but one program uses CLOSO software.

Overall, the data highlights the importance of regular and thorough assessment in education, with a focus on tracking and improving student learning outcomes. The data also demonstrate the wide variation in assessment practices across different educational programs, with differences in frequency, number of topics assessed, and expected levels of attainment.

Each approach has its own strengths and weaknesses, and the accuracy of the assessment depends on many factors such as the quality of the assessment tools, the validity and reliability of the data, the consistency of the assessment process, and the competence of the assessors. It is important to use a variety of assessment methods and to continuously evaluate and improve the assessment process to ensure the accuracy and validity of the results.

Also, the resource requirements will depend on various factors such as the size of the student population, the number of outcomes being assessed, the number of assessment tools used, the frequency of assessment, the type of documentation used, and the analysis methods employed. A more comprehensive and frequent assessment approach may require more resources in terms of time, personnel, and technology. On the other hand, a less comprehensive approach may require fewer resources but may not provide an accurate assessment of SOs.

Table 3. Comparison of different assessment methods

Reference	Features
[23]	1. Assessment processes: direct (exams) and indirect (surveys, interviews) 2. Frequency of direct assessment processes: annually 3. The expected level of attainment: 80% of the students achieve grade points more than 2 (0 to 4 range) in each outcome 4. Number of selected topics for direct assessment: one (Capstone Design II) out of 38 course topics 5. Number of surveys/year (indirect assessment): 3 6. Documentation: electronic and hard copy 7. Assessment and analysis tools: manual 8. Length of assessment cycle: 3 years
[24]	1. Assessment processes: direct (exams) and indirect (surveys, interviews) 2. Frequency of direct assessment processes: each semester 3. The expected level of attainment: 80% of the students achieve grade points more than 3 (1 to 5 range) in each outcome 4. Number of selected topics for direct assessment: 17 out of 42 5. Number of surveys/year (indirect assessment): 5 6. Documentation: electronic and hard copy 7. Assessment and analysis tools: manual 8. Length of assessment cycle: 4 years
[25]	1. Assessment processes: direct (exams) and indirect (surveys, interviews) 2. Frequency of direct assessment processes: each semester 3. The expected level of attainment: 60% of the students achieve grade points more than 2 (0 to 4 range) in each outcome 4. Number of selected topics for direct assessment: 8 out of 33 5. Number of surveys/year (indirect assessment): 3 6. Documentation: electronic and hard copy 7. Assessment and analysis tools: manual 8. Length of assessment cycle: 4 years
[26]	1. Assessment processes: direct (exams) 2. Frequency of direct assessment processes: each semester 3. The expected level of attainment: 80% of the students achieve score more than 70% in each outcome 4. Number of selected topics for direct assessment: 11 out of 40 5. Number of surveys/year (indirect assessment): not mentioned 6. Documentation: electronic and hard copy 7. Assessment and analysis tools: manual 8. Length of assessment cycle: 2 years
[27]	1. Assessment processes: direct (exams) and indirect (surveys, interviews) 2. Frequency of direct assessment processes: each semester 3. The expected level of attainment: 6 randomly selected students' works achieve average grade points of more than 2.5 (1 to 3 range) in each outcome 4. Number of selected topics for direct assessment: 9 out of 47 5. Number of surveys/year (indirect assessment): 2 6. Documentation: electronic and hard copy 7. Assessment and analysis tools: manual 8. Length of assessment cycle: 6 years
[28]	1. Assessment processes: direct (exams) and indirect (surveys, interviews) 2. Frequency of direct assessment processes: each semester 3. The expected level of attainment: 80% of the students achieve High or Medium level in each outcome 4. Number of selected topics for direct assessment: capstone courses 5. Number of surveys/year (indirect assessment): 4 6. Documentation: electronic and hard copy 7. Assessment and analysis tools: manual 8. Length of assessment cycle: 3 years
[29]	1. Assessment processes: direct (exams) and indirect (surveys, interviews) 2. Frequency of direct assessment processes: each semester 3. The expected level of attainment: 60% of the students achieve 70% (or C) grade marks 4. Number of selected topics for direct assessment: 15 out of 53 5. Number of surveys/year (indirect assessment): 5 6. Documentation: electronic and hard copy 7. Assessment and analysis tools: CLOSO software 8. Length of assessment cycle: 2 years

6. Conclusions

In an effort to raise the standard of academic programs, an increasing number of academic institutions are submitting applications to ABET for accreditation of their computer engineering programs. The lack of information on the implementation mechanics is a problem in this situation since it causes misunderstandings and resource waste, especially in the beginning. In light of this, documentation of the methodology, educational methods, and strategies employed by various institutes in the pursuit of accreditation is necessary. The method for assessing and evaluating

SOs, which forms the basis for activities aimed at continual improvement, is the most crucial component in the context of ABET. This paper offers comprehensive implementation details on approaches and tactics for computer engineering programs vying for ABET accreditation, thereby addressing the issue. The choice of assessment method depends on the specific context and goals of the educational program. It's important to consider factors such as the type of learning outcomes being assessed, the level of detail required, available resources, and the preferences of instructors and students. A program may also choose to use a combination of assessment methods to achieve a more comprehensive and accurate evaluation of SOs. Ultimately, the best approach is one that is tailored to the unique needs and circumstances of the program. Also, we found that there is a real need to enhance classical methods and models in SO assessment because the traditional methods may not be sufficient in reflecting the complexity of modern educational programs. With the growing diversity and evolving nature of education, traditional methods may not capture the full range of skills and competencies that students need to succeed in the workplace. Additionally, the rapid pace of technological advancements and the increasing demand for data-driven decision-making makes it necessary to adopt more sophisticated assessment methods. By enhancing the methods and models used in SO assessment, programs can ensure that their graduates are well-prepared for the challenges of the modern workforce. Modern techniques such as big data analysis, artificial intelligence (AI), machine learning (ML), multimedia and networking facilities could be utilized for this purpose.

Conflict of interest

The authors have no competing interests to declare that are relevant to the content of this article.

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