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Research Article

Outcomes-Based Assessment and Lessons Learned in ABET-CAC Accreditation: A Case Study of the American University in the Emirates

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ABET accreditation is sought globally for engineering and technology academic programs due to the quality, added value, and competitiveness it adds to students, program, and the university locally, regionally, and globally. Aligning with its mission to prepare students as global citizens for future career aspirations and lifelong learning through quality teaching, the American University in the Emirates (AUE) focuses on outcome-based education to ensure the employability of graduates and hence soon realized the significance of the Accreditation Board of Engineering and Technology-Computing Accreditation Commission (ABET-CAC) standard toward the Computer Science (CS) program. While pursuing ABET accreditation was challenging, the outcome was positive, and currently, the Computer Science Program, with its two specializations in Network Security and Digital Forensics is ABET-accredited. The process required support from all units within the institution and was a great learning experience for all stakeholders. ABET draws generic requirements to be fulfilled by a program seeking accreditation without a detailed procedure to achieve them. However, there is little information about achieving these requirements, especially criterion 4: continuous improvement, which most programs fail to comply with according to ABET. This study presented a comprehensive and reproducible methodology that addresses our successful efforts in aligning the CS program with ABET-CAC requirements by emphasizing criterion 4. This article reported the evaluation of Student Outcomes number one and two for the academic year 2020–2021 through a comprehensive framework. The framework showed data collection, data reporting and analysis, actions, and recommendations for the next academic cycle. The framework showed a mathematical model for calculating the Student Outcomes (SOs) attainment based on the mapped Course Learning Outcomes (CLOs). Finally, the recommendations were reported. We believe this article established a solid foundation that would be beneficial for insinuations pursuing ABET accreditation.

1. Introduction

Academic accreditation is a quality assurance process that assures the compliance of a recognized set of requirements standards by a university, college, or academic program. Accreditation indicates that a graduate from a certain accredited program demonstrated a certain level of demanded skills, abilities, and merits. International accreditation bodies grant a credential that certifies compliance against certain predefined criteria to ensure quality and academic rigor at the academic institution or program level [1]. This credential is of interest to several stakeholders like students, alumni, prospective students, governmental licensing bodies, professional societies, and recruiters and employers. Accreditation does not guarantee that a graduate is a professional from the accredited program; however, it indicates that a program meets the minimum level of quality standard, it helps students to evaluate several institutions and programs for enrollment, and it assures a continuous improvement process conducted annually to improve student, faculty, and the program.

ABET does not outline a specific framework or methodology to be followed to obtain the accreditation [2]; however, it specifies a set of standard requirements that can be fulfilled with a high level of flexibility in implementation to adapt capabilities, different academic practices, and available resources variations across multiple university and programs worldwide. ABET focuses on Outcome-Based Education (OBE) that a successful student should acquire upon completing the learning experience [3]. Therefore, the curriculum, instructional efforts, and assessments should be observable and measurable [4, 5]. The process of improving the outcomes based on the achievement is called continuous improvement process, which is the core of OBE [6]. ABET Computing Accreditation Commission (CAC) [7, 8] accredits Computer Science, Cybersecurity, Information Systems, and Information Technology programs. All programs share the same criteria and requirements to be fulfilled except for Student Outcome (SO) number six to allow variation between different specializations.

Most accreditation bodies allow reasonable flexibility for fulfilling their standard requirements and criteria to adapt variations of resources and capabilities for different university programs. This would lead to an ad hoc process and variant academic practices resulting in a trial-and-error approach that will be costly, especially for new institutions that lack robust academic processes to fulfill accreditation requirements. Several authors shared their successful experience with obtaining ABET-CAC for various computer science programs [9–13]; however, there is a little number of publications that show a systematic fulfillment of ABET-CAC requirements.

This article shares the accumulated experience at the AUE to promote OBE, and the lessons learned for systematically obtaining ABET-CAC, which can foster and establish a sustainable environment of academic excellence that sustains quality, and achieves the desired outcomes that will help to alleviate any potential deficiency for ABET accreditation seekers. The computerization of this process helps institutionalize and sustain the continuous process. This study can be of interest to any academic program seeking ABET accreditation.

This article is structured as follows: Section 2 presents preliminary preparation to apply for ABET, Section 3 shows the fulfillment of ABET criteria, Section 4 summarizes the lesson learned and observations, and Section 5 concludes the findings of this case study.

2. ABET Preliminary Preparations

A university program seeking ABET accreditation needs to fully understand the accreditation application procedure, the requirements, and the assessment process [14, 15]. A request for program evaluation was submitted to check the program eligibility for accreditation which was answered positively. Then, the CS program started the journey with ABET by adopting ABET standard Student Outcomes (SOs) as per the ABET-CAC Version 2.0 2018–2019 Accreditation Policy and Procedure Manual (APPM). ABET-CAC accreditation requires an annual evaluation of some of the SOs to assess program outcomes achievement, the actions taken, and the process followed to enhance the attainment of the SOs, thus, the program. A detailed SSR that addresses the 9 criteria was submitted to ABET. The continuous improvement addressed the evaluation of the six SOs in an academic cycle of four years, starting in 16/17 and ending in 19/20. This study will show the assessment of SO1 and SO2 for the last academic year 2019-2020.

3. ABET Criteria

The following shows how the CS program addressed the nine criteria as per ABET-CAC Version 2.0 of 2018–2019 APPM. ABET has nine criteria to be fulfilled, and this section shows how we successfully addressed them.

3.1. Students. ABET is concerned about evaluating and monitoring student progress to secure and assure the achievement of program's SOs, therefore, the Program Educational Objectives (PEOs) [16]. Student advising addresses student study plan, curriculum, and professional development opportunities for students that qualify them for the market. To do that, a rigid policy that determines student admission, student transfer, work in lieu, and a solid enforced procedure that ensures the documentation of all graduates to meet graduation requirements has been deployed.

The AUE was able to achieve Student's requirements through an in-house developed information system (Akademia) managed by an in-house team of developers that documents all the information related to the successful fulfillment of this criterion. Akademia stores student record information such as student personal contact information, admission type, academic standings, CGPA, English language proficiency, currently enrolled courses, study plan, attendance, and course assessments. Akademia is also able to produce an unofficial transcript and grade report. Academic advisors have access to their advisees using the portal and can work closely with students on various aspects of their academic affairs. Besides that, the advisor's role is to recommend the best courses and follow the study plan. To conclude, the usage of Akademia allows for the institutionalization of the program and will lead to a sustainable operation.

3.2. Program Educational Objectives (PEOs). PEOs are broadly defined objectives that state what a student is expected to attain within a few years upon graduation [16]. The PEOs should be aligned with the institution's mission and the needs of students, market, alumni, and other stakeholders related to the CS program [17, 18]. The PEOs and the institution's mission must be published online and should go through a systematic review from the involved stockholders.

3.2.1. The AUE Mission Statement. "The AUE is committed to offer quality, multidisciplinary, research and career-oriented academic degree programs that prepare students for successful employment and continuing higher education" [19].

3.2.2. CCIT-College Mission Statement. "CCIT strives to be an active community, national and regional member; being committed to graduate practice-oriented specialists, and Information Technology professionals through novel computing and information technology programs" [20]. "The college endeavors in applied research bridging the gap between theory and practice to solve computing and information technology challenges and fosters innovative graduates that drive change. The college engages in continuous learning opportunities for its community" [20].

3.2.3. PEOs. The design process of PEOs considered that they are achievable and measurable. The Program Education Objectives were designed in a way that is achievable and measurable as the following:

(1) Pursue a graduate degree or professional career in computer science or related disciplines
(2) Effectively participate in research or projects as individuals, team members, or leaders
(3) Maintain high standards of work ethics, social responsibilities, and professionalism
(4) Apply computing knowledge, skills, and competence in solving technical problems
(5) Engage in various domains of life to serve local, regional, and international communities

3.2.4. Alignment of PEOs with the AUE Mission. The AUE mission focuses on providing society with successful leaders, researchers, and innovators by providing focused, high-quality education that enables students for higher education and/or professional careers. The PEOs are comprehensively consistent with the AUE mission by focusing on preparing students to continue higher education, effective research, maintaining ethical standards, and solving problem skills. Table 1 shows the mapping between AUE institution, CCIT Goals, and CS's PEOs.

3.2.5. CS Program Constituencies. CCIT utilizes several constituencies for its computer science program, including students, alumni, employers, industrial advisory board, faculty, and standing committees. The constituencies and their relationships to the program are described as follows:

A. Alumni:

Alumni are an exemplary component to measure the attainment of PEOs through their inputs, feedback, and professional accomplishments. Alumni input is highly significant for continuous process improvement.

B. Employers:

Employers have indicated they are clearly interested in having students prepared upon entering the workforce. Clearly, the technical and personal preparation of the students is instrumental. Employers are also surveyed to get their feedback and ideas on the state of our graduates and the relevancy of the program's outcomes and objectives.

C. Industrial Advisory Board:

The Industrial Advisory Board comprises employers, industry partners, and academicians. The industrial advisory board is expected to reiterate the importance of understanding general trends in technology, the ability to pursue lifelong learning awareness of quality standards, the ability to work in teams, possession of high ethical standards, and the possession of good communication skills.

D. Curriculum Development and Accreditation Committee (CDAC):

In order to evaluate PEOs and achieve the continuous improvement of the program, CCIT receives inputs from CDAC. The committee is periodically reviewing the CLOs, SOs, learning resources, mapping of courses and SOs, mapping of CLOs and SOs, and finally the PEOs for its appropriateness to college mission which should be approved by the Institution of Effectiveness IE [21].

3.3. Student Outcomes. SOs are the main objectives to be achieved and assessed by ABET. SOs are usually equivalent for Program Learning Outcomes (PLOs). SOs determine what knowledge, skills, and behaviors the student should demonstrate by the time of graduation. The ABET SOs are standardized, systematic, and broad statement to be achieved. Therefore, they require a breakdown to be measured accurately. The CS program adopted the ABET-CAC SOs documented in Version 2.0 of 2018–2019 review cycle and published on the program web page as the following:

(1) Analyze a complex computing problem and to apply principles of computing and other relevant disciplines to identify solutions
(2) Design, implement, and evaluate a computing-based solution to meet a given set of computing requirements in the context of the program's discipline
(3) Communicate effectively in a variety of professional contexts

Table 1: Summary of constituent input to PEOs.

University goals [19]	College goals [20]	Program goals
To offer quality and career-oriented academic programs to meet market demands.	Deliver quality academic programs that fulfill market needs in the information technology knowledge domain	Apply computing knowledge, skills, and competence in solving technical problems
Provide a holistic education and prepare students for pursuing higher education to further their knowledge and skills.	Graduate qualified students who are eligible for pursuing their higher academic study in various information technology fields	Pursue a graduate degree or professional career in computer science or related disciplines
	Implement a professional, ethical, and socio-technical approach to the curriculum	Maintain high standards of work ethics, social responsibilities, and professionalism
To establish and enhance interrelationships among the universities, businesses, and communities.	Develop relationships and collaborations with universities, businesses, local and regional communities	Engage in various domains of life to serve local, regional, and international communities
To develop knowledge, based on basic and applied research in various fields of study.	Create applied research in the field of information technology	Effectively participate in research or projects as individuals, team members or leaders

(4) Recognize professional responsibilities and make informed judgments in computing practice based on legal and ethical principles

(5) Function effectively as a member or leader of a team engaged in activities appropriate to the program's discipline

(6) Apply computer science theory and software development fundamentals to produce computing-based solutions

Note that the first five SOs are standardized and common SOs for any programs seeking ABET-CAC accreditation. The 6th SO is an ABET standard SO for Computer Science and similarly named computing programs.

3.3.1. Performance Indicators (PIs). The SOs are generic and broad objectives that cannot be measured straightforward, instead, it requires a breakdown of Performance Indicators (PIs). ABET [22] defines PIs as "Specific, measurable statements identifying student performance(s) required to meet the outcome; confirmable through evidence". An SO requires breakdown for at least two or more PIs for proper measurement and assessment. The SOs assessment took several approaches by different programs worldwide, some are using the CLOs and treat them as PIs as in our case and [23]. Others are formulating their own PIs to assess SOs [12, 24]. Some programs use a mixed-mode of mapping between CLOs⟶PIs⟶SOs [13].

The CS program at the AUE measures the attainment of SOs by mapping the CLOs to SOs. The CS program uses analytical rubrics for all course assessments. Rubrics can be defined as a descriptive scoring scheme that shows the circumstances for grading student assessments [25]. Appendix A-Table 1 shows the rubric of the software engineering final exam, where evaluation criteria/traits are the four CLOs of the course.

The CLOs for a course assessment serves as the evaluation criteria in the assessment rubric, while the description performance level of the same CLO will vary from one assessment to another based on the given questions. Practically, various assessments are evaluated through various rubrics that contribute toward the attainment of certain SO. Hence, the evaluation of SO attainment is strictly computed based on the following model hierarchy:

$$\text{Rubrics} \longrightarrow \text{CLOs} \longrightarrow \text{SO}. \tag{1}$$

As shown in Appendix A-Table 1, each CLO has a grade in the assessment; each scale has an interval grade to accommodate student's answers. Once the grade is computed for that CLO using the given rubric, the grade of that CLO will contribute to the final attainment of the SO based on the stated mapping between CLOs⟶SOs. The achievement of CLOs is accurately computed based on the description given on the analytical rubric that describes the criteria to evaluate the student's responses for grading purposes.

Figure 1 shows the direct attainment model of SOs based on the CLOs analytical rubrics and the stated mapping between CLOs⟶SOs. Following this model, all the CLOs for all the mapped courses are evaluated for all types of assessment at a high level of granularity using analytical rubrics. Even if two assessments evaluate the same CLO, we could end up with two different rubrics for each CLO due to the differences between assessment questions. To ensure that the designed rubrics are appropriate to the course level and assessment, the Faculty Member (FM) designs the rubric, which will be reviewed and approved by the department chair.

In all cases, a single SO is evaluated by various mapped CLOs from various courses, and each CLO achievement is computed through appropriate rubrics (that act as a PI) designed for each assessment per course.

3.3.2. SOs Evaluation Cycle of Cohort 2021–2024. The mapping between SOs and PIs are of high importance as it will indicate the extent of SOs achievement. Thus, the CS program considers the core courses of CS program that every CS student should study and excludes specialization and Math courses. The specialization courses are not studied by all CS students, and Math courses are barely contributing to SOs attainment. Therefore, we exclude them. The

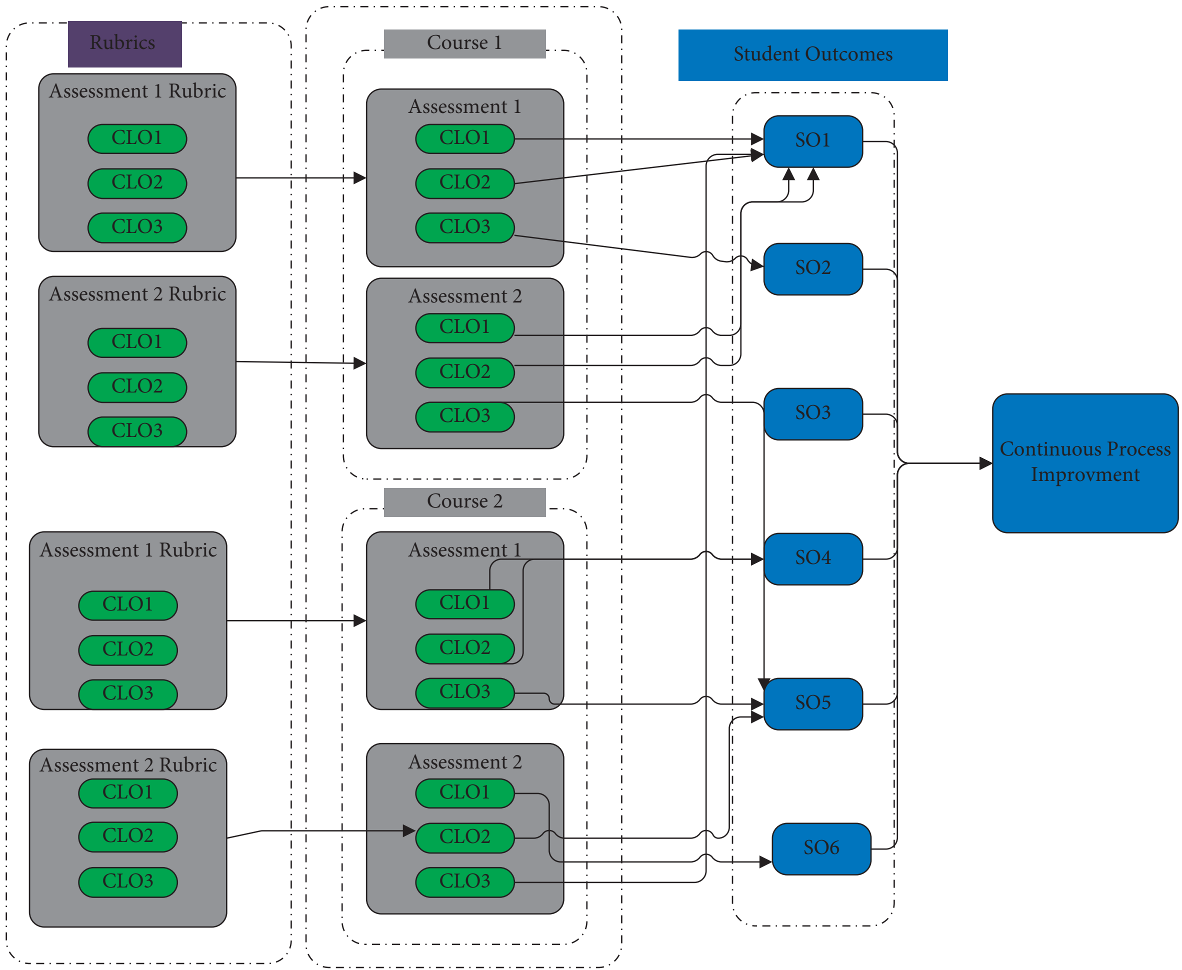

Figure 1: SOs direct attainment model.

attainment of SOs can be fully computed once the CS cohort is graduated in a four-years cycle. Appendix A-Table 2 shows the SOs evaluation cycle plan for the cohort 2021–2024.

The first cohort evaluation was achieved early between 2016 and 2020. Once the first cohort graduated, we concluded to reduce the academic cycle from four to three years. Appendix A-Tables 3 and 4 show the core courses and CLOs mapping against SOs which will be used to compute the attainment of SO1 and SO2.

3.4. Continuous Improvement. ABET defines continuous improvement as "The program must regularly use appropriate, documented processes for assessing and evaluating the extent to which the student outcomes are being attained. The results of these evaluations must be systematically utilized as input for the continuous improvement of the program. Other available information may also be used to assist in the continuous improvement of the program." [7]. Anand et al. [26] defined continuous improvement as "a systematic effort to seek out and apply new ways of doing work, which is actively and repeatedly making process improvements." Processes are also defined as a "designed sequences of tasks aimed at creating value-adding transformations of inputs–material and information–to achieve intended outputs" [26]. The continuous improvement must not only be strict with measuring the outcomes but also with the process that aims at measuring the outcomes [27].

The continuous improvement process is entirely dependent on data collected from the assessment. Gardiner [28] defined assessment as "the systematic collection, review, and use of information about educational programs undertaken for the purpose of improving students' learning and development." The advisory committee for academic assessment at Kent State highlighted that assessment is the key to improvement that should provide evidence of student achievement to accreditation groups [29]. Garry [30] stated that assessment establishes an evidence culture.

The continuous process improvement has no value if the data collected does not reflect the assessed outcome. Rogers [31] stated that data collection must consider the environment, assessment practices, and efficiency. Roger highlights that there should be a reason to collect certain data that address the assessed outcome at hand; that is, without a clearly defined outcome to measure, there is not enough data to collect! Almuhaideb and Saeed [6] stated that most continuous process improvement collects a huge amount of data, but they fail to draw suitable actions for continuous improvement's action plan. Herewith, we report our continuous process improvement at CCIT.

3.4.1. SOs Assessment Methodology. We at the CS program at AUE are collecting, analyzing, and interpreting the evidence of students' achievements of the SOs, along with the other supportive data to assess the extent to which SOs have been attained. The procedure of computing SOs attainment is based on direct (Summative) and indirect (Formative) data assessment. The direct data assessment is computed by collecting data directly from assessments as final exam, midterm, and quiz that will contribute to CLOs achievement.

The indirect data assessments are computed by collecting data through forms that reflect perceptions/opinions from various types of surveys, faculty member reviews, observations and lessons learned. Figure 2 shows the types of SOs assessments we implemented in the academic year 2019/2020.

Notice that ABET does not set any threshold for SO attainment. We at the CS program consider the success criterion of 70%, that is, 70% of the students achieved each CLO 70% and above. The philosophy behind the selected threshold is that 70% is equivalent to C grade scale, i.e., (2/4), which is the minimum grade required for graduation. The below subsections present direct and indirect assessment computation methods at high level of detail, which can be used as a guide to computing SOs attainment using CLOs as PIs.

3.4.2. Direct Assessment Computation Method. As mentioned earlier, direct assessment is based on summative data collected by FM via various courses assessments. Table 2 shows an example of how we calculate the CLOs achievement for the *X* course that is attended by 50 students. The column Weight shows the total grade for each assessment type according to the *X* course syllabus where the total of all weights is 100%.

The assessment questions column shows the number of questions in each assessment type along with the assigned grade by the FM where each question is mapped to a different CLO. As evident from Table 2, the quiz has two questions worth 25 marks. The CLO column shows the mapping of each question toward the corresponding CLO, and the percentage grade shows the percentage weightage of each question with respect to the original assessment Weight. For instance, Question 1 in Quiz becomes (12/20) which is as follows:

$$\frac{15}{(15+10)} * 20. \tag{2}$$

The percentage grade is aggregated for all the assessments questions as per the mapped CLO as evident from Table 3 to calculate the contribution of each CLO of this course toward achieving the mapped SO as will be shown later.

Based on the CLOs⟶SOs mapping of this course, CLO1 and CLO2 are contributing to achieving SO 1. In order to compute the SO1 attainment by the *X* course, we aggregate the total percentage grade of all CLOs that are mapped to SO1. After that, we calculate the number of students who achieved the desired threshold, i.e., 70% and above.

For example, 70% of the CLOs that are mapped to SO1 in the *X* course is calculated as $(25.3 + 45 = 70.3) = 49.21$. Consequently, we count the number of students who scored 49.21 and above for the said CLOs. The number then is divided over the total number of students attending this class, i.e., 50. Assuming the number of students who achieved 49.21 and above is 33, then the SO1 attainment via the *X* course is $33/50 * 100 = 66\%$ which is below the target threshold.

Practically, several courses contribute to the attainment of the SOs. Appendix A-Table 5, shows an example of computing SO1 attainment through the aggregated results of CLOs achievements in Fall and Spring of the academic year 2019/2020 for three courses only.

The CS program considers the number of students fulfilling certain CLO as a weight while we compute the SO attainment. The student number in each section signifies and differentiates the course's contribution toward final SO attainment. For example, the SO1 attainment via the three courses will be computed as the following:

$$\begin{aligned} \mathrm{SO1} &= \frac{(66.6 * (15+46.6) * (15+73.3) * 15) + ((55.5*9+77.7*9)+77.7*9)+(76.1*21)}{(15+15+15)+(9+9+9)+(21)} \\ &= 67.74\%. \end{aligned} \tag{3}$$

In general, the following formula is used to compute the final SO1 attainment at the curriculum level.

Attainment of *i-th* SO is as follows:

$$\mathrm{SO}i = \frac{\sum_{j=1}^{Ni} \mathrm{SO}\, ij * Tj}{\sum_{i=1}^{Ni} Tj}, \tag{4}$$

where Ni is the total number of courses mapped to SOi, $SOij$ is the percentage of students achieving more than 70% for the *i-th* SO in the *j-th* course.

Tj is the total number of students attending the *j-th* class. Notice that $\sum_{j=1}^{Ni} Tj / \sum_{i=1}^{Ni} Tj = 1$.

At the end, the final value of SO attainment is subjected to the correctness and consistency of the mapping and grading.

3.4.3. Indirect Assessment. This type of assessment concerns with opinions, observations, and lessons learned. Indirect assessment can be classified into the following two main

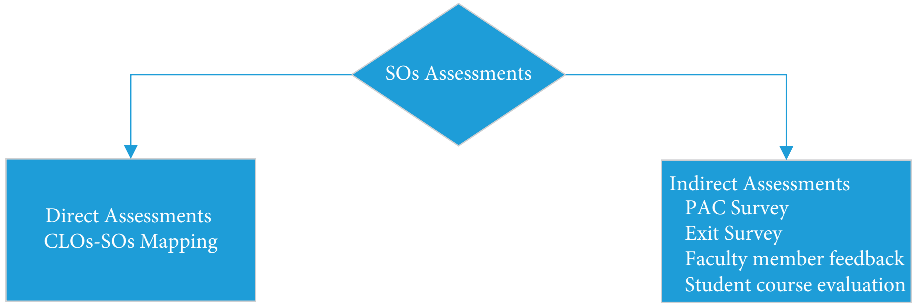

Figure 2: SOs assessment model.

Table 2: The academic assessments distribution for the *X* course.

Academic assessments	Weight	Assessment questions	CLO	Percentage grade	Mapped SO
Quiz	20	Q1 = 15	2	12	1
		Q2 = 10	1	8	1
Assignments	30	Q1 = 1 2	1	12	1
		Q2 = 13	2	13	1
		Q3 = 5	3	5	2
Midterm	20	Q1 = 8	1	5.3	1
		Q2 = 15	2	10	1
		Q3 = 7	3	4.6	2
Final exam	30	Q1 = 20	2	10	1
		Q2 = 20	3	10	2
		Q3 = 20	3	10	2

Table 3: Aggregation of percentage grade against the course *X* CLOs.

CLOs	Total percentage grade	SO
1	25.3	1
2	45	1
3	29.6	2
Total	100	

types: Internal and External assessment. The outcomes of the indirect assessment will be taken as input for the decision-making process by the CDAC, Department, and the College.

Internal-indirect assessment:

A. Faculty Member Course File Review:
After the conclusion of each semester, the faculty members are required to provide a comprehensive course review for each course taught. The faculty members also complete an in-depth review for all the CLOs to ensure their appropriateness that is further consolidated and reviewed by the Program Chair. This process also includes the completion of an internal G5 form that documents any minor or major modifications in the course syllabi. The addressed aspects of the course review are as follows:

(1) Appropriateness of the CLOs
(2) Extent to which the syllabus was covered
(3) Extent to which learning outcomes were met
(4) Appropriateness of textbooks and other learning resources
(5) Appropriateness of assessment instruments in relation to learning outcomes
(6) Appropriateness of the balance of assessment
(7) Appropriateness of prerequisites
(8) General comments on any problems encountered with the course

Upon the thorough review completed by FMs, the program chair reviews the provided feedback and discusses it with the concerned FMs of each course. The outcomes are used as inputs for the continuous process improvement.

B. Student Course Evaluation:
Another important indirect measure utilized is the course evaluation by the students. By the end of the course offering, students are asked to fill out an online survey that evaluates the faculty member's capabilities, the challenging level of assessments, the relevance of the course to the program, course learning materials quality, and the CLOs.

C. Student Exit Survey:
In addition to the above stated indirect measures, the students exit survey serves as an important tool for indirect assessments and evaluates students' opinions about SOs achievement at the time of their graduation.

External-indirect assessments

Indirect assessments also play a vital role in the continuous improvement process established at CCIT. Such assessment also includes the role of the advisory committee as denoted below:

Program Advisory Committee (PAC): The CS program has a wide range of advisory members from industry and academia who provide feedback about the program, market needs, demands, and trends. The feedback from PAC help in annual assessment, evaluation, improvement report of the college activities, and revaluating PEOs, SOs, and PIs.

3.4.4. Assessment Results

(1) Direct Assessment Evaluation of SOs. Table 4 shows the SO1 and SO2 attainment figures for the academic year 2019/2020 using the abovementioned SO attainment calculation methodology.

The detailed contribution of selected courses toward achieving SO1 is given in Appendix A-Table 6, along with the improvement opportunities. We only report SO1 due to the given space of this publication. Notice that the "CLO achievement" column reports the average CLO achievement within the same course.

Indirect Assessment evaluation of the SOs

Exit Survey Results

An annual exit survey that targets capstone project students is used to collect data and analyze their responses about their perceptions to what extent they have achieved the targeted SOs. In addition, the survey asked open-ended questions to students where they could write their feedback. Appendix B shows the exit survey. Figure 3 shows a summary of student responses for SO1 attainment with a sample size $N = 12$. The survey asked several questions about whether FM, group projects, courses, and assessments have helped them to achieve SO1. The analysis results of SO1 suggest the following:

(1) Students believe that they are confident and have accumulated knowledge to solve related-SO1 computing problems.
(2) Students believe that the technical knowledge provided is good enough. However, students moderately think the CS program has successfully taught them how to tackle computing problems.
(3) Students believe that group-based projects have helped them to achieve their goals.

PAC Survey Results

A survey was sent to the PAC members asking them about adding/dropping courses from the CS program, teaching certain selected topics that are demanded in the market, a recommendation for SOs fulfillments during the COVID-19 pandemic, and some other related questions. The following shows selected responses:

(1) The PAC recommended some new knowledge areas for offering: AI and Machine Learning, Cybersecurity protection frameworks, Big Data, Cloud Computing, and Robotics.
(2) Adding additional technical labs and hands-on assignments.

Table 4: SO1 and SO2 attainments in AY 2019-2020.

SO	Final attainment
SO1	70.1
SO2	65.7

(3) Dropping Calculus III from the study plan and substituting it with technology related course.
(4) High emphasis on group-based projects.

Student course evaluation

At the end of the class offering, students are asked to fill an online form that measures to what extent they can achieve the course CLOs. The attainment of SO1 and SO2 using student responses was computed based on the same mapping used to compute the direct SOs attainment. Table 5 shows the indirect attainment of SO1 and SO2.

The indirect attainment of SOs shows that they pass the targeted threshold and achieve higher results than the direct attainment of SOs, which is mainly due to the confidence students have.

3.4.5. Continuous Process Improvement Implementation.

Continuous process improvement is the heart core of ABET accreditation, where most programs fail to fulfill this criterion. The FMs, program chair, and the CDAC discuss the collected results and take actions/recommendations accordingly for "closing the loop." The actions and recommendations are then submitted to the college council. Those changes related to the curriculum should be submitted to the curriculum committee at the level of the university, then to the IE for quality assurance and implementation. Figure 4 shows the process of accommodating changes in continuous process improvement.

The continuous process improvement assures and enforces the usage of the results/analysis of SOs attainment to make data-driven decisions that enhance and improve the program. SOs are assessed annually, the data are usually collected and analyzed in May, and the improvements and actions of the continuous process are executed in September at the beginning of the new academic year.

In order to institutionalize the continuous process at the program level, all the data of CLOs achievements, actions, KPIs, results, and progress for the next academic cycle is documented and saved into the "Akademia" to easily document, retrieve, and maintain the continuous process for the upcoming cycles.

All the concerned parties use the saved data to plan their action plan and assessment activities. After a year of implementing the recommendations and action plan, the FM and department chair meet again to evaluate the effectiveness of the recommendations and to analyze the new yielded results, and assess them. By the end of the academic year in May, a new set of recommendations and action plan are released to reflect the needed changes and "close-the-loop" in the continuous improvement process. Figure 5 shows an overview of the continuous process improvement implementation.

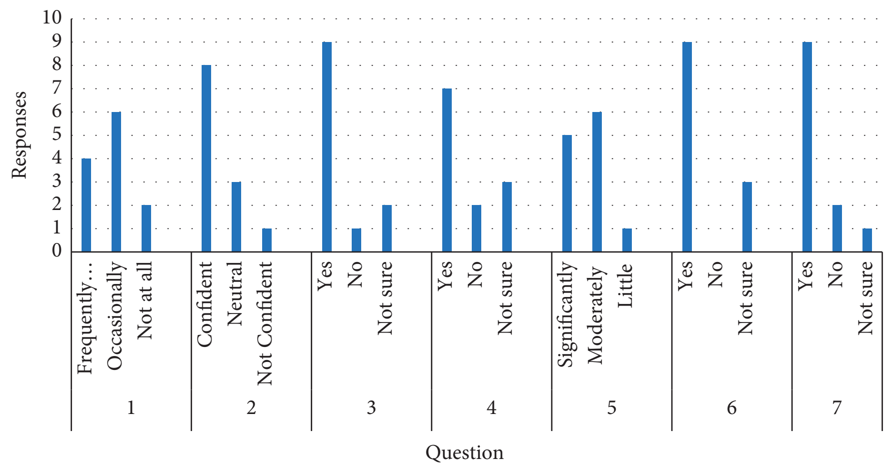

Figure 3: Summary of exit survey of SO1.

Table 5: Indirect attainment of SO1 and SO2 by student course evaluation.

SO	Final attainment
SO1	83.5
SO2	82.5

(1) Closing the loop—Action Plan. The action plan to "close-the-loop" consists of data-driven decisions to improve the SOs attainment and the program. Those improvements can affect any component of the following continuous improvement process cycle: college mission, PEOs, SOs, CLOs, PIs and the corresponding analytical rubrics, curriculum, educational practices, and pedagogy, SO and CLOs attainment computation method, threshold, and many others. Closing the loop of evaluating SOs consists of actions and recommendations that are derived from the acquired assessment results.

Actions:

(1) Reviewing the CS curriculum, CLOs, course description, and textbook was conducted to make sure they are adequate to the SOs level, mapped correctly, and can be measured precisely through the Rubrics⟶CLOs⟶SOs model.

(2) The source of updating/deleting/adding new CLOs were taken from FMs course review that is conducted at the end of the semester. Then, the college divided FMs into knowledge areas upon their specializations to conduct a comprehensive review for the CLOs and the mapping.

(3) Conducting and offering more lab exercises, hands-on, and technical-based assignments to enrich students' capabilities to further achieve both SOs. The offered assessments concentrate on problem solving, design, implement, and evaluate computing solutions.

(4) Focusing on group-based assessment as recommended in PAC and exit surveys to develop student's communication skills and further contribute to the achievements of the two stated SOs especially when students are working on complex systems that need real collaboration. Several new CLOs were proposed and mapped to SO5 that focus on group work.

(5) There is student demand for extra lab work and practical courses. Therefore, the advanced topic course (CIT 410) for the next academic year will be offered to teach data science concepts using *Python* programming language.

(6) Faculty credential: to ensure the courses are offered and taught through qualified and specialized FMs in the various knowledge areas, the college constructed a course credential matrix that specifies the background and specialization needed to teach each course offered at the program and the college "to close-the-loop" of achieving academic rigor and enhancing teaching quality, and so, SOs attainment. Adhering to the credential matrix is of top priority whenever possible for course allocation.

(7) Course credentials: course credential is a practice that is applied at the level of the AUE, and hence, at CCIT. This constrain requires that a faculty teaching a course at the undergraduate level must have at least 18 related-credit hours of courses or thesis during the faculty's postgraduate study. This will assure academic rigidity and enhance the teaching quality, and so, SOs attainment.

(8) Focusing on distance learning was recently given because of the COVID-19 Pandemic to ensure that FMs are well equipped, trained, and qualified to carry out the distance learning mission at high quality. To do so, several FMs attended professional development training that focused on distance learning.

(9) Hiring new faculties that are specialized in security and forensics for the coming academic year.

3.5. Curriculum. The design of curriculum and course selection must be consistent along with the institution and college mission, and the PEOs and SOs. The curriculum is a

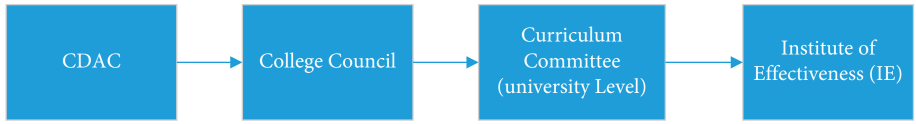

Figure 4: Continuous process of syllabus improvement.

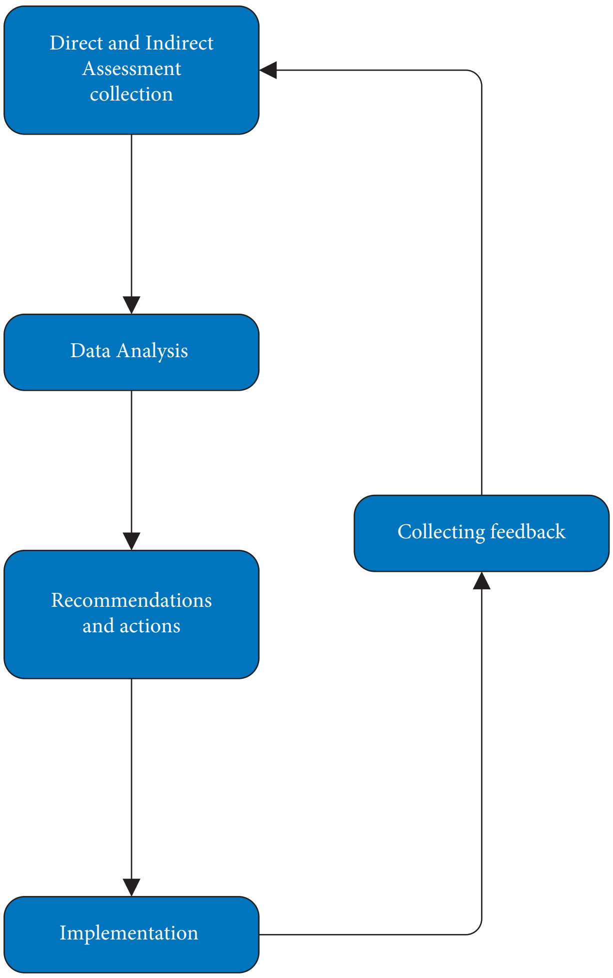

Figure 5: Continuous process of syllabus improvement.

key to successfully achieve the announced outcomes especially for national and international accreditation bodies. Therefore, we recommend referring back to the guidelines recommended by IEEE, ACM, and IEEE Computer Society [32] who jointly designed curriculum recommendations for Computer Science, computer engineering, and emerging computing programs as data science. The focus of curriculum design is on integrating three aspects. Knowledge: know-what, skills: know-how, and disposition: know-why to form a competency as a final desired outcome.

ABET does not prescribe certain courses but topics. The curriculum courses must address technical, professional, and general education components that qualify students for a career, postgraduate study, and lifelong learning [7]. The curriculum requirements slightly vary from year to year as ABET keeps improving its curriculum standard requirements. The CS program was accredited as per the ABET-CAC Version 2.0 of 2018–2019 APPM, which requires

(a) Computer science: at least 40 semester credit hours of computer science courses that assure the coverage of the certain areas such as algorithms and complexity, software development, programming languages, computer architecture, information management, networking, and operating system [33]

(b) Mathematics: at least 15 semester credit hours of math courses including discrete mathematics, and other courses that could vary as calculus, linear algebra, numerical methods, and statistics [33]

(c) Natural science: at least 6 semester credit hours that should include laboratory work

New admitted students for the CS program must go through four admission tests (Math, Computer, Physics, and English). The latter can be waived if an English certificate can be provided as IELTS or TOFEL. The CS program at AUE includes 126 credit hours which is equivalent to 42 courses that vary between the following groups:

3.5.1. General Education Courses (39 Credit Hours). These are equivalent to 13 courses studied by all AUE students. The offered courses under the College of Education reflect AUE mission, AUE fulfilment for national accreditation, i.e., CAA (Commission of Academic Accreditation), and international accreditation program at the institution level, i.e., SACSCOC. The general education courses can be classified into the following categories:

(1) Language and communication studies (12 CHs)
(2) Social science or behavioral sciences (6 CHs)
(3) Islamic studies, history, or culture (3 CHs)
(4) The Humanities or Arts (3 CHs)
(5) Information Technology or Quantitative (9 CHs)
(6) UAE Studies (3 CHs)
(7) Natural Sciences (3 CHs)

3.5.2. Core Courses (72 Credit Hours). These are mainly the courses that satisfy ABET requirements that include math courses, programming courses, and other courses in software development, algorithms, ethics, capstone, internship, and advanced selected topics etc.

3.5.3. Specialization (15 Credit Hours). The CS program includes two specializations, namely, Digital Forensics and Network Security. These two pools of courses distinguish each specialization with a set of dedicated courses that enrich and boost student knowledge in their field.

Appendix A-Tables 7, 8, and 9 show the core courses, Digital Forensics courses and Network security courses, respectively.

3.6. Faculty. The faculty body at CCIT brings diversity, knowledge, and rich experience to the CS program with more than 10 faculty members who cover several domain areas in computer science ranging from database, software engineering, cloud computing, information system, digital forensics, computer security, math, and computer engineering. The research background of the faculty is diverse (with more than 150 publications and presentations in the last five years at the time of SSR submission) that shape a good team to cover all the curricular areas of the program and also permit a competent implementation of any future improvement of the program in accordance with the development of the technology, any suggested improvement at the PEOs, SOs, and course level.

Furthermore, several faculty members own several certifications in the fields of Information Security, Software applications, Blockchain, Big data, Data Science, education, online teaching, distance learning etc., that offer more possibilities in terms of practical applications, continuing learning, and sustainable educational development.

The course allocation to the faculty member is carefully done with respect to specialization since the university is involved in other accreditation at the institution level, i.e., SACSCOS that requires a faculty who is teaching an undergraduate course to have 18 CHs postgraduate courses that are relevant and support faculty profile to teach this course. Faculty usually teach 12 CHs (4 courses)/semester and 9 CHs (3 courses) for faculty with admin responsibilities.

3.7. Facilities. ABET requires supporting facilities like classrooms, offices, laboratories, library, and associated equipment that support the attainment of PEOs and SOs and provide a conducive academic environment. The AUE premises includes 3 blocks with 160 faculty offices, 41 classrooms, and 17 labs that secure the achievement of ABET criteria.

Any newly admitted student at the university level must be exposed to an orientation that shows how to utilize the learning management system and various types of available resources that aim at achieving the PEOs and SOs as student affairs department, success center, and so on. The student is guided to acquire resources through a librarian, faculty, and IT technician.

The Auxiliary Service Department maintains the utilization threshold and ensures proper space management. The IT department is responsible for setting up, operating, and maintaining labs. Each classroom has the basic tools for successful instruction delivery as a projector, whiteboard, instructor computer, and sound system. In addition, a specialized library team serves the needed learning resources at the CS program. The library provides several subscriptions for publishers as ACM, Ebrary, ProQuest Computing, and Emerald.

3.8. Institutional Support. ABET requires institutional support and leadership to secure the quality and continuity of the program. The AUE is fully supporting the CS program to maintain a successful program delivery. The program is led by the chair, who reports to the dean. Both assure successful academic requirements as curriculum review, supervision of faculty, monitoring policies, acquiring budget to operate the CS program, supporting faculty professional development and research, monitoring student advising, and controlling the quality of assessment. All the abovementioned responsibilities are performed in coordination with several supporting units at the university level as IE, registration, and the financial department.

3.9. Program Criteria. ABET requires any program seeking accreditation from the CAC to demonstrate the requirements of program title that is embodied by a sixth SO and special requirements of courses that cover certain domains as explained in criteria 5 through Tables 7,8, and 9 in Appendix A.

4. Recommendations

This section reports the lessons learned and observations during our accreditation journey; we truly believe that they would benefit programs seeking ABET.

4.1. Top Management Support. Top management support is needed to achieve accreditation and promote quality culture and make it a lifestyle within the institution. Abdul Kadir et al. [34] and Vykydal et al. [35] pointed out that there is a resistance to change to adopt accreditation from some academicians as a higher workload is expected. Therefore, top management should consider faculty concerns and provide proper training, motivations, and rewards, especially for programs embedding innovation, development [36], and computer-aided system [43] within the curriculum.

4.2. Standardized Process. A standardized consistent process must be developed to create and maintain a quality environment in the institution. The processes should be documented, shared, and implemented through the information system for archiving purpose that allows traceability and accountability later on.

4.3. Training. Training should be the starting point for any accreditation activity [37]. Training should explain to faculty and admin the significance and value of accreditation to break any potential resistance. Training includes workshops for introducing accreditation processes, requirements, curriculum improvements, developing measurable outcomes, writing assessments that adequately measure desired outcomes, mapping, and data collection.

4.4. Curriculum Mapping. Mapping is a challenging process due to the subjectivity and judgment of assessors [38, 39]. We at the CS program had replaced our previous SOs (also known as PLOs) with ABET standard SOs. The mapping between CLOs and SOs forced us to reformulate the courses' CLOs several times to provide meaningful mapping. It is important to include 3–5 PIs/SO from core courses only.

4.5. Academic Organizational Structure. There is a need to formulate a clear academic organizational structure that defines the responsibilities, tasks, and mandates for each involved party in this chain [40, 41]. This aims at achieving accountability and traceability, along with sustaining the operation of continuous improvement.

4.6. Documentation. We strongly recommend documenting all the proposed changes, outcomes, and taken actions through an effective information management system to trace, monitor, evaluate, and close-the-loop to continually improve the process. Archiving is needed to prove the continuous process improvement for any accreditation body, i.e., national and international; it is also needed to institutionalize the process to alleviate any potential difficulty due to faculty turnover.

5. Conclusion

An increasing number of academic programs are chasing various accreditation programs to secure quality and competitiveness. The study presents a comprehensive framework that fulfills the requirements of ABET-CAC Version 2.0 of 2018–2019 APPM. The presented framework through criteria from 1 to 9 illustrates the requirements by ABET-CAC and how our CS program was successfully addressing these requirements.

The following can summarize the successful factors that would be considered whenever a university program is seeking ABET accreditation. First, a top management awareness of the significance of international program accreditation. Second, program sustainability involves designing sustainable assessments and sustainable process improvement, which is critical and requires sustainable data collection through balanced PIs to institutionalize the process. Third, process efficiency and automation through an effective management system that will automate data collection, data analysis, actions, and improvements, closing the loop, and archiving, which will lead to a robust and sustainable continuous process improvement which is usually the main criterion for most failures of programs. Fourth, faculty members' involvement is essential to spread accreditation culture and awareness among them with the expected outcomes from everyone toward the program.

We found that faculty and staff commitment toward producing high-quality outcomes is an essential factor for earning accreditation. Finally, we believe that the presented approach is reproducible by other programs seeking ABET-CAC accreditation taking into consideration the university and college mission along with the program constituent stakeholders. Our framework presented a comprehensive continuous improvement process that can be applied elsewhere. Our future work at the college level is targeting ABET-CAC for Information Technology Management (ITM) program. [42].

Data Availability

No data were used to support this study..

Conflicts of Interest

The authors declare that they have no conflicts of interest.

Supplementary Materials

Appendix A: Table 1: analytical rubric of the system analysis and design course–project and presentation. Table 2: evaluation cycle for SOs of cohort (2021–2024). Table 3: measurement of appropriateness of SO1 of CS program. Table 4: measurement of appropriateness of SO2 of CS program. Table 5: real data of three courses contributing at achieving SO1 in the academic year 2019–2020/20. Table 6: courses that contribute at achieving SO1. Table 7: CS core computing courses. Tables 8: digital forensics specialization courses. Table 9: network security specialization courses. Appendix B: ABET-Exit Survey. (*Supplementary Materials*)

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