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Abdullah M. Almuhaideb and Saqib Saeed

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A Process-Based Approach to ABET Accreditation: A Case Study of a Cybersecurity and Digital Forensics Program

Abdullah M. Almuhaideb
Department of Computer Science
College of Computer Science and Information Technology
Imam Abdulrahman Bin Faisal University
Dammam 31441, Saudi Arabia
amalmuhaideb@iau.edu.sa

Saqib Saeed
Department of Computer Information Systems
College of Computer Science and Information Technology
Imam Abdulrahman Bin Faisal University
Dammam 31441, Saudi Arabia
sbsaed@iau.edu.sa

ABSTRACT

ABET accreditation has become a well-known standard for academic programs not only in the U.S. but also across the globe. Instantiating the processes to systematically improve the quality of programs is a daunting task for higher education institutions. In this contribution, we provide a detailed process-based framework that can assist aspiring institutions to embed quality in their processes leading to ABET accreditation. Our contribution is a novel framework for a process-based approach to quality assurance, as most of the published literature is primarily concerned with the experience of ABET accreditation of a solitary program. However, in this paper, we have presented a generic framework that ABET aspiring programs can instantiate in their preparation for ABET accreditation. We have validated these processes in our successful ABET accreditation application of the Bachelor of Science in Cybersecurity and Digital Forensics program. Our existing ABET-accredited programs were following old ABET criteria and the Bachelor of Science in Cybersecurity and Digital Forensics program must apply based on the new criteria proposed by ABET. Another novelty of our contribution is that it is based on our work for the first application cycle for ABET cybersecurity-related programs, so the findings of our contribution may assist other aspiring cybersecurity related academic programs to well prepare in their ABET accreditation pursuits.

Keywords: ABET, Accreditation, Assurance of learning, Cybersecurity, Security education, Computing education

1. INTRODUCTION

There is a recent focus on quality assurance culture in higher education irrespective of the academic discipline. Accreditation is considered as one of the core elements of quality assurance programs in higher education institutions; however, there is no consensus that accreditation is an optimal tool to foster quality in higher education. But accreditations and rankings have become an important indicator for prospective students to make their higher education choices, which is one of the main reasons for accreditation. Furthermore, governmental regulatory bodies in different countries also require higher education institutions to gain recognition through national and international accreditations.

Accreditation activities require financial and human resources, and this cost of quality is justifiable in the long run. However, in most instances, the goal of an accreditation drive becomes just to gain accreditation rather than capitalizing on this opportunity for long-term quality gains. As a result, ad hoc practices emerge which may lead to a successful accreditation drive, but this fragmented approach does not yield quality assurance target benchmarks in the long run. The Accreditation Board of Engineering and Technology (ABET) is a non-profit organization that accredits academic programs only. Currently, ABET has accredited 4,144 academic programs in 32 different countries. There are four commissions under ABET, namely Applied and Natural Science Accreditation Commission (ANSAC), Computing Accreditation Commission (CAC), Engineering Accreditation Commission (EAC), and

Engineering Technology Accreditation Commission (ETAC), which oversee the accreditation process of relevant academic programs (ABET, 2020). ABET provides a standardized criterion to be satisfied by aspiring programs to achieve ABET accreditation, but it does not guide institutions on how to realize processes and policies to foster a quality culture. As a result, each new academic program striving for ABET accreditation has to rely on a trial-and-error method in adopting an ABET compliant quality management system. Keeping this in view, in this paper, we propose a framework to establish a process-based approach to ABET accreditation. Such an approach can help new academic programs in fostering a quality culture that is aligned with ABET. This process-based approach results in improvements that are long term and not short-sighted just for acquiring an accreditation.

This framework was established based on our experience of accreditation of computer science (CS) and computer information systems (CIS) programs at the College of Computer Science and Information Technology (CCSIT), Imam Abdulrahman Bin Faisal University (IAU) (IAU, 2020). To evaluate the effectiveness of this framework, we applied these processes in the ABET accreditation application of the Bachelor of Science in Cybersecurity and Digital Forensics program (CYS). During the 2019-20 application cycle, ABET for the first time invited cybersecurity-related academic programs to apply for accreditation. The successful outcome of ABET accreditation of the CYS program helped us to test our framework's effectiveness. So, in this paper, we explain different processes of our framework which will benefit new academic programs to foster a quality culture.

The rest of the paper is structured as follows: Section 2 discusses related work and the problem statement, followed by materials and methods in Section 3. Section 4 outlines our framework where different processes are designed to facilitate the accreditation process, followed by discussion and conclusions in sections 5 and 6, respectively.

2. BACKGROUND

Extensive studies have been carried out in the context of quality assurance-related activities in higher education focusing on pedagogical enhancements (Saeed, Aamir, and Mahmood, 2011; Gull et al., 2018), student evaluations (Siddiqui, Saeed, and Wahab, 2015), and curriculum updates (Tse et al., 2020). Salto (2018) highlighted that the top management of education institutions may go beyond the regulatory requirements imposed by regulatory authorities to implement stricter self-regulation, which can be characterized as over compliance. Hughes and Diaz-Granados (2018) highlighted that many U.S. universities are offering a master's program in psychology, so there was a need to implement an accreditation process to ensure quality. Crawford, Horsley, and Parkin (2018) highlighted different mechanisms to involve students in fostering an inclusive quality culture in higher education institutions. Eaton (2018) highlighted the need to include an enhanced set of tools for quality assurance in academic programs to counter academic misconduct. Al-Widyan and Qdais (2018) shared their experiences of the implementation of a total quality management approach to improve academic and administrative quality. Hou et al. (2018) investigated the impact of the self-accreditation policy introduced by the Ministry of Education in Taiwan and highlighted the positive impact of this policy on the education institution's internal processes. However, the selection of reviewers, ad hoc termination of processes, and inconsistencies in review decisions were found as major challenges. Blouin and Tekian (2018) argued that a continuous quality improvement process is more important than student outcomes, which is the focus of many accreditation agencies. Blouin et al. (2018) presented a conceptual model for medical education in which student outcome attainment resulted in self-assessment activities that provided a basis for continuous quality improvement. They carried out an empirical study in Canadian medical schools and found that process improvement due to accreditation ultimately led to continuous quality improvement. Prados, Peterson, and Lattuca (2005) provided a historic account that initial accreditation bodies in the U.S. put strong regulatory criteria. However, revised ABET engineering criteria provided flexibility by focusing on the outcome assessment and continuous improvement aspects in an academic program. Kam (2011) discussed various models and best practices to employ in quality assurance and quality control processes of accreditation in engineering, technology, and computing domains. Alaskar (2018) carried out a study to measure the perception of the stakeholders involved in the accreditation process in nursing schools in Saudi Arabia. He found considerable variation in the perception of faculty and management which highlights a perception gap among higher education management and faculty. Hayward (2006) carried out an empirical study to identify the status of the quality assurance adoption in Tanzanian private universities. Although these institutions had already adopted self-assessment and external reviews, he found that internal quality audits and tracer studies were partially used by them. Collis and Moonen (2008) argued that heavy use of web 2.0 technologies by students can become a vital tool to harness quality in higher education. Kanji, Malek, and Tambi (1999) conducted a study to understand total quality management (TQM) deployment initiatives in the higher education institutions in the United Kingdom and found that TQM constructs reflect the quality of a higher education institution. Anderson, Johnson, and Milligan (2000) carried out an empirical study of the Australian institutions and proposed a role model for improvement of accreditation processes in the Australian higher education sector.

ABET is considered one of the prestigious accreditation bodies, and many ABET accreditation case studies relating to engineering and computing academic programs are published (ABET, 2020). Shafi et al. (2019) discussed the successful ABET experience at the College of Computer Science and Information Technology, Imam Abdulrahman Bin Faisal University, for two programs, namely, Bachelor of Science in computer science and Bachelor of Science in computer information systems. Both programs share the first two years, and male and female students are taught by different faculty members. Hadfield et al. (2019) discussed how new ABET criteria can assist in improving the computer science curriculum. Khan, Mourad, and Zahid (2016) discussed their experience of ABET accreditation for the civil engineering program. Veiga et al. (2018) developed a framework for continuous performance improvement which was tested for ABET accreditation of an industrial engineering program in Brazil. Felder and Brent (2003) outlined their experience of aligning curriculum with ABET engineering criteria.

Almuhaideb and Saeed (2020) documented their experiences of establishing quality assurance practices in outcome-based education.

In the context of cybersecurity accreditation initiatives, a few studies are published in the literature. Clark, Stoker, and Vetter (2020) highlighted the challenges of cybersecurity and documented the proposed changes in the National Centre of Academic Excellence in Cyber Defense program structure. Raj et al. (2019) outlined the benefits and challenges associated with the cybersecurity programs' accreditation process. Mogoane and Kabanda (2019) highlighted that, due to the shortage of skilled cybersecurity professionals, there is internal and external pressure on the academic institutions to establish cybersecurity programs. Therefore, such mushroom growth of CYS programs must not compromise on the quality. As a result, the role of accreditation is very critical to ensure that graduates possess the desired skills. Gibson et al. (2019) outlined four approaches to acquire ABET accreditation of cybersecurity undergraduate programs based on the practices followed by four pioneering programs. Chiaramonte, Caswell, and Schechtman (2014) stressed the need for formal accreditation of cybersecurity programs to ensure quality. Wood et al. (2010) presented that cybersecurity programs can follow ABET information systems program criteria to acquire ABET accreditation for their programs. Ahmad and Qahmash (2020) compiled a list of critical success factors to achieve ABET accreditation and a sustainable quality assurance process.

Despite these contributions, each institution must embark on its ABET accreditation journey from scratch because these contributions share the experiences at a very abstract level and there is always ambiguity for the institutions whether they are following the right track. To employ a quality management system in academic institutions, there is a need for effective processes. Designing appropriate processes requires knowledge and critical thinking. There is a very sparse body of knowledge documenting establishing quality management systems in academic programs.

Establishing a quality management system in an organizational context is a challenging task and requires a holistic approach (Bernik, Sondari, and Indika, 2017). To facilitate the development of educational institutions, different accreditation standards have emerged which provide a clear objective to be achieved. Although each of these educational standards is aiming at improving quality, their requirements vary. ABET is a well-known accreditation body that is striving to have standardized academic programs in computing, engineering, and applied and natural science domains (ABET, 2020). The accreditation standards establish a criterion, but its implementation process is left at the discretion of the acquiring institution. As a result, each institution aiming for ABET accreditation must go through many trial-and-error runs to reach the intended criteria. In the process, sometimes ad-hoc practices emerge which is not the intended purpose of such accreditation drives and does not contribute to the quality of an academic program.

Keeping this in view, our research question was how we can establish a quality framework for academic programs seeking ABET accreditation. Such a framework can enable aspiring (especially new) programs to foster an ABET aligned quality management system.

3. MATERIALS AND METHODS

The findings of this paper are the result of a long-term action research project which was originated based on ABET accreditation pursuit of the academic programs in our department in 2014. Action research is a systematic process that focuses on improving the work practices by critically reflecting on the practices to improve the working environment (Avison et al., 1999). Action research has been used in different domains, such as information systems (Baskerville and Wood-Harper, 1996), healthcare (Whitehead, Taket, and Smith, 2003), sports (Gilbourne and Richardson, 2005), tourism (Paül, Trillo-Santamaría, and Pérez-Costas, 2016), and education (Thota and Whitfield, 2010; Wahlgren and Aarkrog, 2021). Although action research has widely been used in educational projects specifically to improve the learning environment (Elliot, 1991; Mills, 2000), no study focused on quality assurance processes in educational settings. Case studies have been used as an important research approach, where a case is explored in-depth to provide a detailed understanding (Hartley, 2004). In this paper, we specifically discuss the case of Bachelor of Science in Cybersecurity and Digital Forensics to provide an in-depth description of quality practices employed for the accreditation process.

The literature contains what is required to achieve ABET accreditation, but how to achieve it was mainly a missing link, and this motivated us to develop a framework that can be replicated by other aspiring institutions to improve their quality. During the earlier phases of the project, an extensive focus was on studying and planning interventions to establish a quality management process. Based on this, different actions were implemented to establish a quality management system. After the implementation, the effectiveness of these interventions was evaluated by individual and group interviews from faculty members and college management. Later, critical reflections were carried out to improve the interventions for the next cycle. These improved interventions were evaluated during the 2018 computer science and computer information systems ABET program evaluation, and, through this, we completed the second cycle of action research. The framework presented here is a result of critical reflection after this second cycle. We have evaluated this framework by applying it during the ABET accreditation of our Bachelor of Science in Cybersecurity and Digital Forensics program.

4. REALIZATION OF THE PROCESS-BASED QUALITY ASSURANCE FRAMEWORK

ABET accreditation requires adherence to general and program criteria. The general criteria aim at students, program educational objectives, student outcomes, continuous improvement, curriculum, faculty, facilities, and institutional support, whereas program criteria outline specific program-related requirements. The aim is to impart a quality culture for continuous program improvement.

4.1 Accreditation Framework

The accreditation framework is illustrated in Figure 1, and this highlights that the program's educational objectives and student outcomes should be rooted in the institutional mission. In order to better attain student outcomes, a set of performance

indicators are defined. Moreover, different educational practices and strategies need to be adopted across the program modules to ensure that the required skills are harnessed among the students. A variety of assessments are conducted at different levels in an academic program to ensure that appropriate strategies and practices are in place. The assessment data contributes to the evaluation of performance indicators, and as the result of these assessments analysis, the continuous improvement plan is developed which may lead to update any of the components in the spiral.

Figure 1. Conceptual Framework for Program Continuous Improvement

To institutionalize quality improvement tasks across the academic program, management should define some units to establish corresponding processes. We propose establishing an advising unit, academic accreditation unit, quality assessment and exams unit, curriculum unit, department board (and college council), and external advisory committee. The advising unit should plan and implement effective advising procedures to support students in the learning process. The academic accreditation unit (AAU) should plan and implement procedures to collect and evaluate accreditation data and implement appropriate action plans. The quality assessment and exams unit should ensure the quality of assessment is aligned with course learning outcomes of respective courses. The curriculum unit acts as custodian of the program curriculum and continually updates the curriculum to meet the needs of national and international accreditation bodies. The department board is the main approving body comprised of senior faculty members of the department managing an academic program. The external advisory committee is comprised of external stakeholders from industry, employers, and alumni, which provides continuous improvement to keep the program abreast with industry needs. Furthermore, to meet these accreditation criteria, we designed a set of processes to deal with each criterion. The most important processes are listed as follows:

1. Process for Student Advising
2. Process for Revision of PEOs
3. Process of Student Outcomes Revision
4. Process of Student Outcomes Attainment
5. Process for Continuous Syllabus Improvement
6. Process for Updating CYS Curriculum
7. Process for Executing End-of-Term Presentation
8. Process for Reviewing Course Portfolios

4.1.1 Process for student advising. Academic counseling is considered an important component for every higher education institution, and ABET gives this aspect an extensive focus during accreditation application. Academic advising should start with the student's admission to the program. The advising

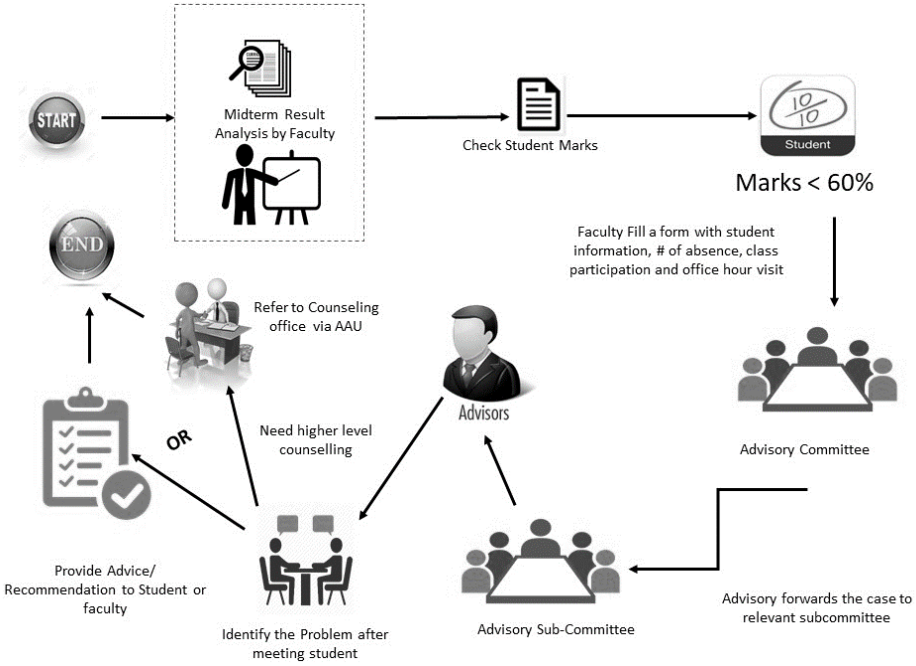

Figure 2. Proposed Student Advising Process

could address curricular matters, registration issues, program regulations, academic performance, and academic progress. The academic programs may establish an advising unit to guide the students on the right career path by facilitating both academic and personal counseling. Moreover, the advising unit may organize an orientation session to welcome new students to provide an overview of the college and the unit services. A model process of student advising is shown in Figure 2.

4.1.2 Process for revision of program educational objectives. Program educational objectives (PEOs) are broader statements that are expected to be achieved after some time of graduation. Normally, each program defines them at the program preparation, however, ABET is very specific in establishing a process for revising PEOs, as shown in Figure 3. The revision of PEOs is mainly driven from four sources:

- University, College, and Program Mission: Any updates to university, college, or program mission statements are considered during the revision of PEOs.
- Closing-the-Loop Action Plan (from the previous cycle): This document is prepared after the completion of every Student Outcomes (SOs) evaluation cycle. It documents actions/suggestions/recommendations to improve SOs attainment. This plan can address shortcomings and suggest improvements to PEOs, SOs, PIs, rubrics, curricula, educational strategies, and processes for measuring SO attainment.
- Indirect Assessments: These consist of feedback collected through surveys from various stakeholders, including graduating students, alumni, faculty members, and employers.
- External Advisory Committee: Each program should have an external advisory committee that includes experts from industry and academia. It provides recommendations and suggestions to improve various aspects of the program.

Data originating from these four sources need to be forwarded to the program curriculum unit by the academic accreditation unit. As a result of the analysis, the curriculum unit may consider updating PEOs. "Updated PEOs" need to be forwarded to the department board for recommendations and finally to the college council for approval. The department board and the college council might provide feedback to make further modifications to "Updated PEOs."

4.1.3 Process of student outcomes revision. Like the revision process of PEOs, the process for revision of Student Outcomes (SOs) is also critical in the continuous improvement process of an academic program. A model process is shown in Figure 4. The revision of SOs can be driven from six sources:

- Approved PEOs: The approved PEOs of the program are based on Figure 3.
- ABET Guidelines on SOs: Guidelines and sample SOs provided by ABET.
- Closing-the-Loop Action Plan (from the previous cycle): This document outlines continuous improvement actions based on SO assessment results in the previous cycle.
- Indirect Assessments: This consists of feedback collected through surveys from various stakeholders, including alumni, faculty members, and employers.
- Direct Assessments: This consists of feedback collected through the curriculum assessment and exit exam.

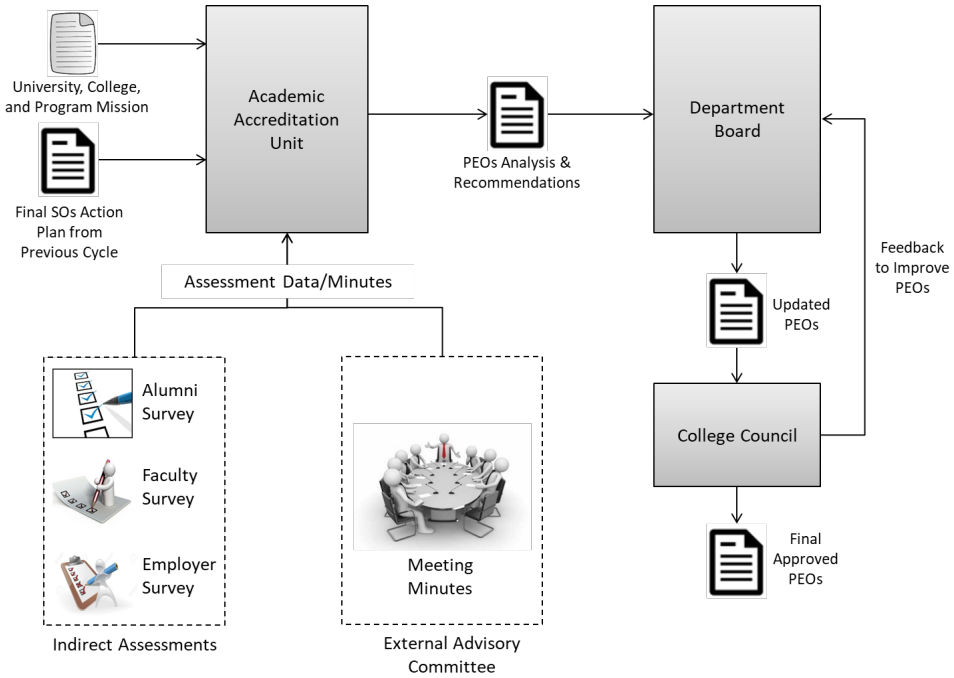

Figure 3. Process for Revision of Program Educational Objectives (PEOs)

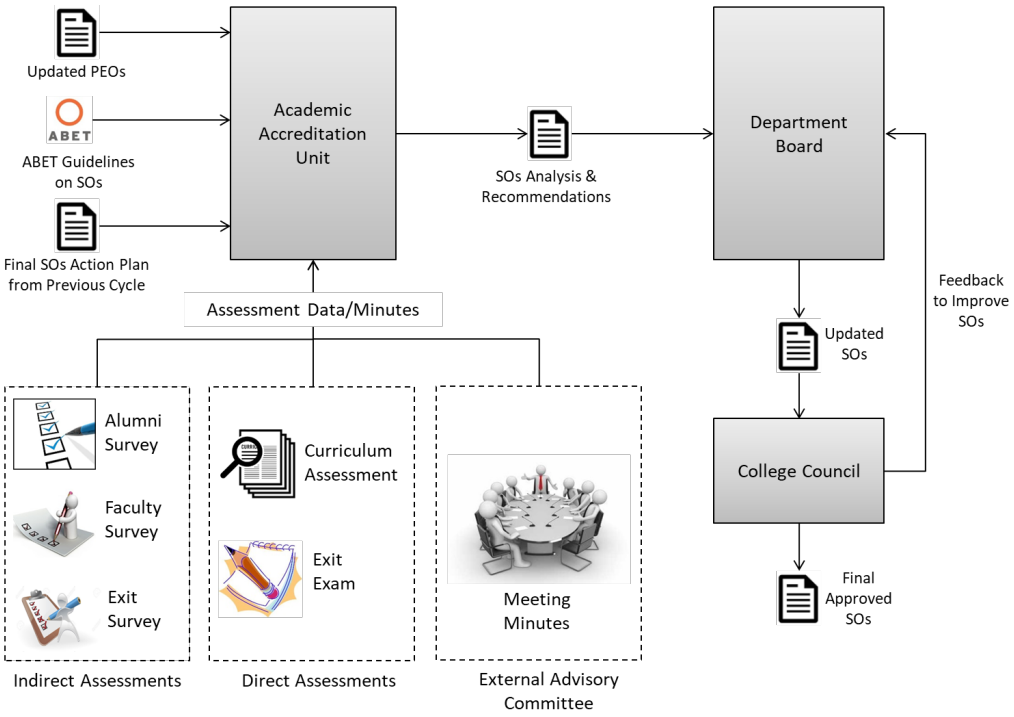

Figure 4. Process for Revision of Student Outcomes (SOs)

- External Advisory Committee: The discussion in the program external advisory committee can initiate SO update.

Data originating from these six sources needs to be analyzed critically. The academic accreditation unit needs to formulate a document, which is forwarded to the curriculum unit along with the Direct/Indirect assessment data and external advisory committee minutes. The curriculum unit is then responsible for producing "Updated SOs" by consulting recommendations and data provided by the academic accreditation unit. Later the "Updated SOs" are forwarded to the department board for recommendations and finally the college council for approval. The department board and the college council might provide feedback to make further modifications to "Updated SOs".

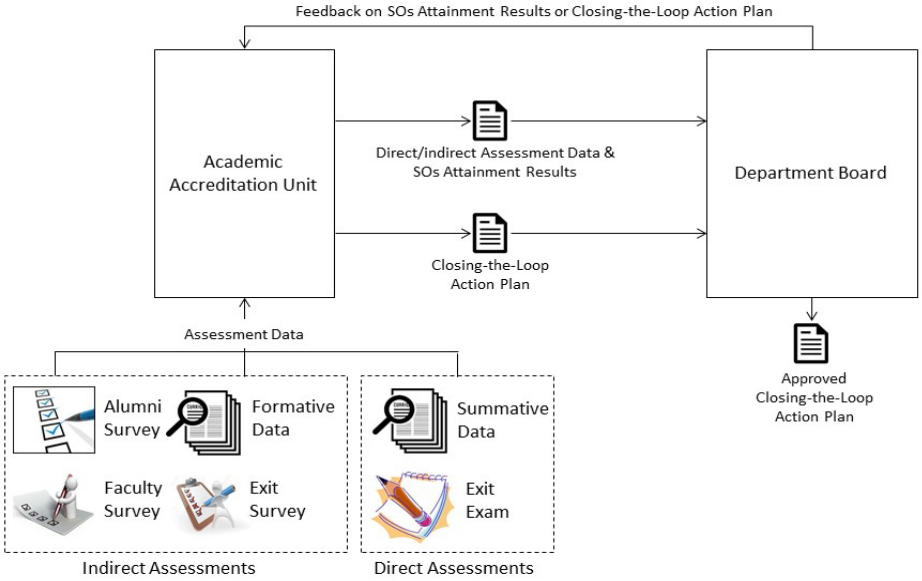

Figure 5. Process of Student Outcomes Attainment (Shafi et al., 2019)

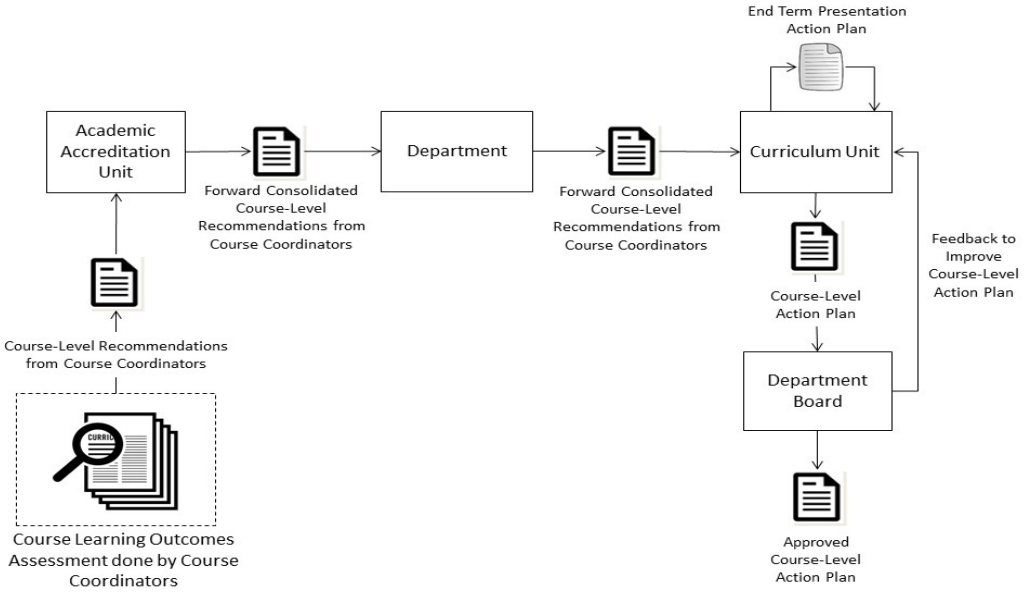

Figure 6. Process for Continuous Syllabus Improvement (Shafi et al., 2019)

4.1.4. Process of student outcomes attainment (Per Cycle). The process for attainment of SOs collects data from different direct and indirect assessments, as shown in Figure 5. Direct assessments include summative data and exit exam results whereas indirect assessments include alumni, faculty, and graduating students. The academic accreditation unit analyzes these assessment data to prepare attainment results and closing-the-loop action plans to realize better attainment results in the next cycle. The deliverables are presented to the department board for approval and, after approval, it becomes a baseline for further follow-up.

4.1.5 Process for continuous syllabus improvement (per term). This process ensures that there is continuous improvement in the syllabus delivered to the students. As Figure 6 highlights, course level recommendations are collected from coordinators, and consolidated syllabus improvements are forwarded to the department where a curriculum unit prepares a course-level action plan and a

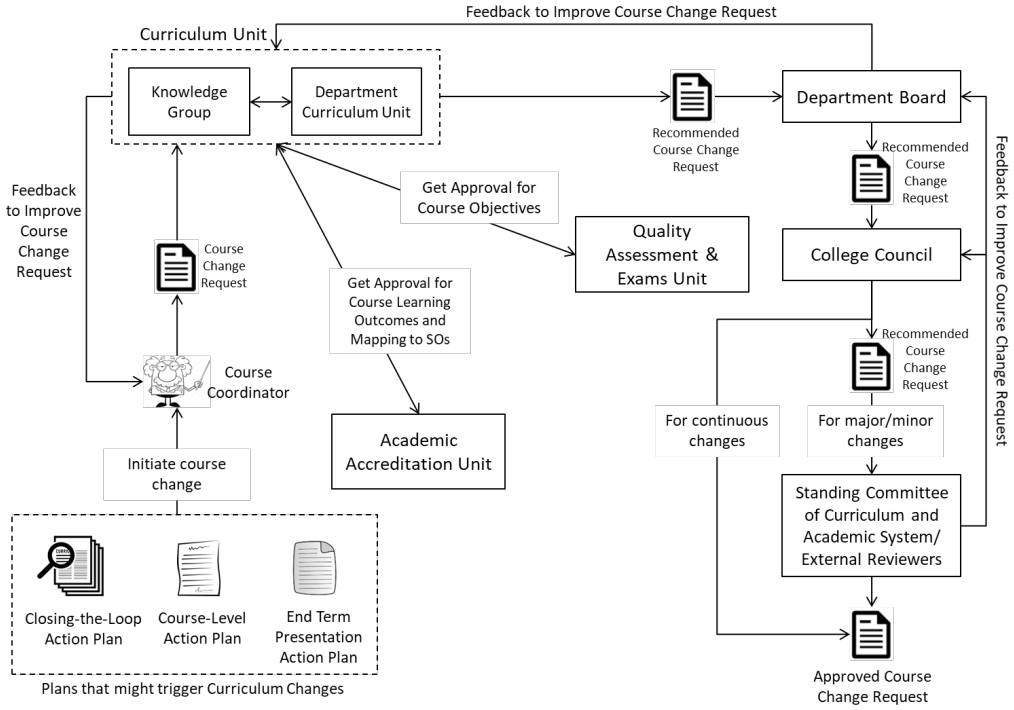

Figure 7. The Process to Update Curriculum

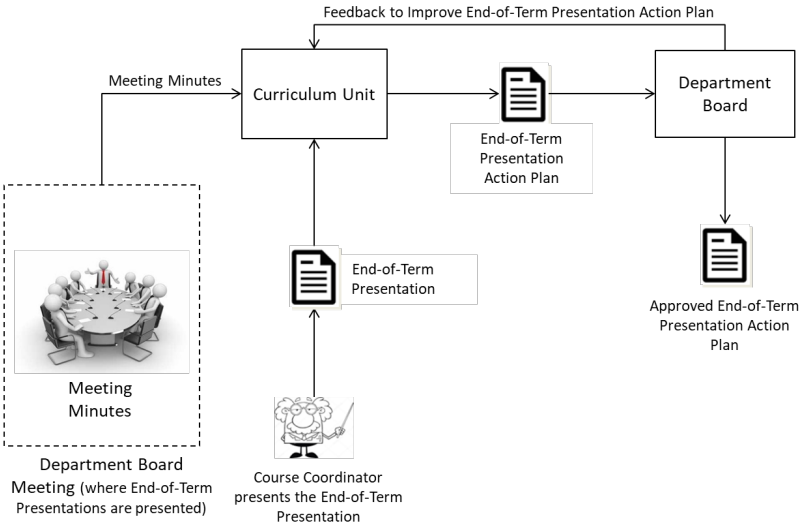

Figure 8. Process for Executing End-of-Term Presentation (Per Term)

comprehensive end-of-term presentation action plan. This plan is forwarded to the department for approval.

4.1.6 Process for updating curriculum. The process for modifying/updating the curriculum is outlined in Figure 7. This process is executed anytime a major/minor change is required in the curriculum. The curriculum here refers to a set of courses. The process for modifying one or more courses might be initiated from three sources:

- Closing-the-Loop Action Plan: This document outlines continuous improvement recommendations and may suggest curriculum revisions based on attainment data in the previous cycle.
- Course-Level Action Plan: This document is designed after the conclusion of each term, and it includes recommendations for continuous improvements.
- End-of-Term Presentation Action Plan: This document outlines action plans based on the instructor's presentation and the departmental discussion at the end of each term.

Once it has been decided to update one or more courses, the course coordinator needs to submit the corresponding "Course Change Request" to the curriculum unit. The "Course Change Request" is a document that records modifications to the existing course specifications that are maintained and published by the department in the program curriculum booklet. The curriculum unit reviews and forwards the "Recommended Course Change Request" to the department board that in turn sends it to the college council. The curriculum unit can utilize the services of the academic accreditation unit and the quality assessment and exams unit to get approvals for course learning outcomes. Both the curriculum unit and the department can send back the course change request for further improvements by providing their feedback. Minor changes may be approved by the college council, whereas major changes may need to be sent to university forums for approval.

4.1.7 Process for executing end-of-term presentations (Per term). The process for executing the end-of-term presentation is depicted in Figure 8. This activity needs to be conducted every term. After the conclusion of each term, each course coordinator is required to conduct an end-of-term presentation about his/her course. This presentation details the overview of grading, the performance of students, and course learning outcomes attainment. Most importantly, this presentation also discusses the issues and challenges faced during the execution of the course. Course coordinators are required to include recommendations to future course instructors, the department, and/or the college to improve the course delivery and performance of students in the course. These recommendations might also include updating the curriculum of the presented course or any related course in the curriculum. At the end of this activity an "End-of-Term Presentation Action Plan" is established which addresses shortcomings and suggests improvements to the program. Later the "End-of-Term Presentation Action Plan" is forwarded to the department board that reviews and approves the "Approved End-of-Term Presentation Action Plan." The department board might return the action plan for improvements to the curriculum unit. This process is the backbone of the continuous improvement cycle of the program curriculum.

4.1.8 Process for reviewing course portfolios. The process for reviewing course portfolios is depicted in Figure 9. This activity needs to be conducted every term. At the end of each term, the course coordinator needs to submit the "Course Portfolio" to the curriculum unit. The curriculum unit needs to review the submitted course portfolios according to the portfolio checklist. Once accepted, the curriculum unit needs to forward these portfolios to the academic accreditation unit for archiving.

4.2 Bachelor of Science in Cybersecurity and Digital Forensics Program Case Study

To validate our framework, we have created the processes in line with our proposed accreditation framework for the Bachelor of Science in Cybersecurity and Digital Forensics

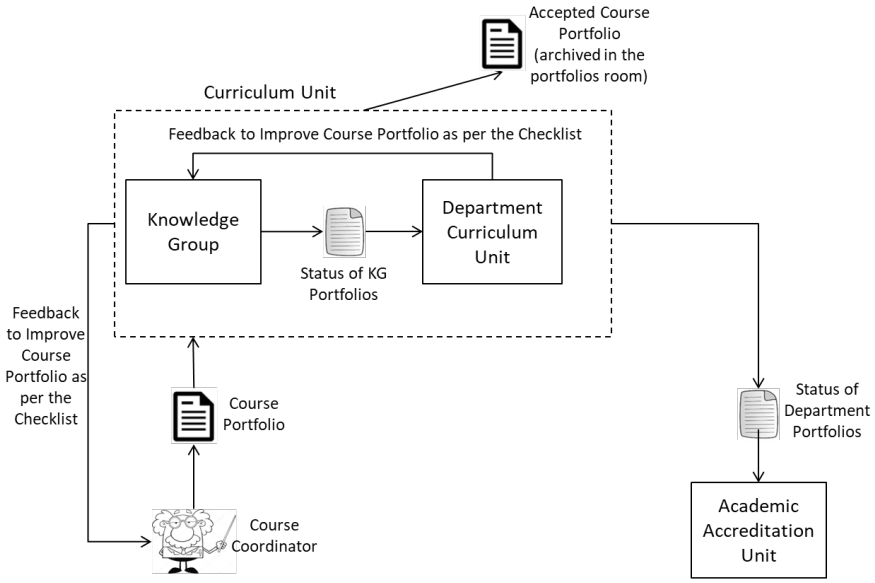

Figure 9. Process for Reviewing Course Portfolios

program. The Bachelor of Science in Cybersecurity and Digital forensics is a four-year degree program. Before these four years, however, students spend one year as a preparatory year at the Deanship of Preparatory and Supporting Studies before joining CCSIT (IAU, 2020). After completion of their preparatory year, the students start their studies at CCSIT. In CCSIT, the first two years of study are common courses for computer science (CS) and computer information systems (CIS) degree programs. The last two years are specialized for the Bachelor of Science in Cybersecurity and Digital Forensics (CYS) program. Existing ABET-accredited programs (CS and CIS) were following the old ABET criteria, whereas the CYS program adopted the new ABET criteria (ABET, 2020), so this posed additional challenges. The CYS degree program started in the year 2016 under the CS department and the first cohort graduated in 2018; however, CS and CIS programs were running since the inception of the CCSIT in 2009, they are already accredited, and their next comprehensive review is scheduled in 2023-24. ABET announced a first-time call for accreditation applications for cybersecurity programs in 2019, so CCSIT submitted the ABET self-study report in June 2019 as an off-cycle application.

4.2.1 Establishment of PEOs. The process to prepare the PEOs began in the academic year 2014-2015. A departmental committee was formed to hold brainstorming sessions with program stakeholders that are consistent with the CYS curriculum's educational philosophy and aligned with program and university mission statements. The university in its mission emphasizes the need to flourish creative knowledge, research, and professional services. It also aims to excel in theoretical and applied research with a focus on contributing back to the society or community. Our program objectives also inspire discovery, lifelong learning, and professional services with community engagements. Therefore, the CYS program's PEOs should nurture the social and ethical values of our students so that they learn to serve the local community and professional societies and contribute to the discipline in general. As per the IAU mission, the CYS program has set high-quality standards for imparting cybersecurity and digital forensics education in the region. Furthermore, CCSIT's mission aims to teach quality education to the students by focusing on creativity, research, and community partnership. These were set as the hallmarks of CYS's PEOs as the program focuses on enabling students to contribute to society by practicing cybersecurity and digital forensics professional skills by analyzing cybersecurity and digital forensics problems for the benefit of the community as an individual, team member, and leader. Lastly, the PEOs aim to prepare students to respond to ethical and social issues in their professional practices while pursuing their careers in the field of cybersecurity, digital forensics, and related disciplines, from both global and local perspectives.

As an outcome, an initial draft of the PEOs was prepared in 2014. As per process defined in Figure 3, internal reviews by department faculty led to several revisions and the draft was shared with alumni, employers, and current CYS students. Survey participants showed their satisfaction with the PEOs and these PEOs were forwarded by the academic accreditation unit to the department board and college council for approval.

In May 2016, the department invited major employers, alumni, and faculty members for a one-day meeting to discuss the initiatives of the department and gather their opinions on the Mission Statement, PEO, and SOs of the CYS program. The PEOs were re-evaluated and discussed in detail, and feedback was obtained from stakeholders. In 2017, another iteration of PEOs revision took place, and stakeholder surveys were conducted with all PEOs receiving an average score of over 4.2 on a Likert scale of 1 to 5, showing the confidence in PEOs, as shown in Figure 10.

The educational objectives for the CYS program are as follows. Graduates of the program will:

1. Apply knowledge and skills to analyze cybersecurity and digital forensics problems and design appropriate solutions following the best practices.

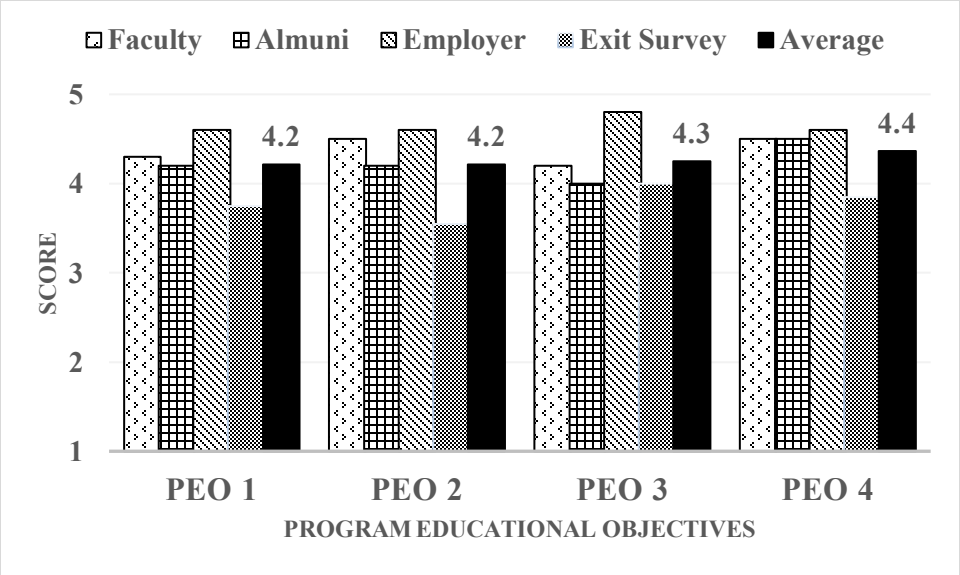

Figure 10. Stakeholders' Feedback on Program Education Objectives

2. Contribute effectively to the profession of cybersecurity and digital forensics as an individual, team member, and leader.
3. Engage actively in lifelong learning, career growth, and community services.
4. Demonstrate ethical and social values in their professional practices.

4.2.2 Establishment of SOs. Similarly, it is to be noted that there is a history regarding the evolution of SOs for the CYS

Mapping of SOs and PIs		
Graduates of the program will have an ability to:		
SO:1		**Analyze a complex computing problem and apply principles of computing and other relevant disciplines to identify solutions.**
PI	1.1	Students demonstrate the abilities to formulate and decompose a problem into appropriate components.
	1.2	Students demonstrate the abilities to solicit and formulate requirements specifications.
	1.3	Students demonstrate the abilities to estimate resources required for the proposed solution.
SO: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.**
PI	2.1	Students demonstrate the abilities to design computer-based system, process, component, or program to meet desired needs.
	2.2	Students demonstrate the abilities to develop a computer-based solution.
	2.3	Students demonstrate the competency in creating and executing test cases.
SO:3		**Communicate effectively in a variety of professional contexts**
PI	3.1	Students demonstrate the ability to write technical reports.
	3.2	Students demonstrate the ability to deliver oral presentations.
SO:4		**Recognize professional responsibilities and make informed judgments in computing practice based on legal and ethical principles**
PI	4.1	Students demonstrate the abilities to learn new skills and apply them rationally to solve the given problem.
	4.2	Students demonstrate knowledge of professional, ethical, legal, social issues and responsibilities.
SO:5		**Function effectively as a member or leader of a team engaged in activities appropriate to the program's discipline**
PI	5.1	Students demonstrate the abilities to participate in team activities.
	5.2	Students demonstrate the abilities to organize themselves and complete assignment to meet deadlines.
SO:6		**Apply security principles and practices to maintain operations in the presence of risks and threats.**
PI	6.1	Students demonstrate the abilities to evaluate variety of cybersecurity and digital forensics tools/techniques to achieve appropriate solutions.
	6.2	Students demonstrate the abilities to apply the concepts of data, software, component, connection, and system security.
	6.3	Students demonstrate the abilities to analyze and manage security risks affecting business continuity.
	6.4	Students demonstrate abilities to carry out cybersecurity strategic planning targeting organizational infrastructure security.

Figure 11. Mapping of SOs and PIs for CYS Program

program. Initially, at the launch of the program, there were 14 SOs for the CYS program. However, as the ABET draft criteria for the cybersecurity programs were announced, in early 2018 the academic accreditation unit revised the student outcomes of CYS program. As per the process defined in Figure 4, the CYS program was aligned with the proposed ABET criteria and seven SOs were adopted for the CYS program, after department board and college council approval. Each SO was further decomposed into different performance indicators (PIs). Since the approved version of ABET SOs for cybersecurity-related programs have six SOs, in January 2019 student outcomes of CYS were again updated and the number of SOs reduced to six to remain aligned with ABET recommended SOs. This transition did not affect the curriculum mapping of the program as the two PIs (PI:7.1-Students demonstrate the abilities to analyze and manage security risks affecting business continuity and PI:7.2-Students demonstrate abilities to carry out cybersecurity strategic planning targeting organizational infrastructure security) for SO:7 have been added to SO:6 as PI:6.3 and PI:6.4. Due to this change, our data collection started with seven SOs in Term 1 (Fall 2018-2019), while in Term 2 (Fall 2018-2019) we had six SOs but the number of PIs remained the same. Six SOs (1-6) of the Bachelor of Science in Cybersecurity and Digital Forensics program along with associated performance indicators are listed in Figure 11.

4.2.3 Evaluation of SOs. In the CYS program, each Student Outcome (SO) is evaluated and assessed through a set of PIs. Figure 11 describes how the six SOs are subdivided into 16 PIs. For SO:1, there are three PIs named 1.1, 1.2, and 1.3. Each course in the CYS program curriculum has several course learning outcomes (CLOs). These CLOs, in turn, were mapped to PIs belonging to SOs. There are three levels of mapping: Introductory (I), Reinforcement (R), and Emphasis (E). Introductory assessments refer to the formative assessment of a performance indicator whereas the Reinforcement and Emphasis highlight the summative assessment of the respective performance indicator. Formative data mainly relies on subjective assessment of the instructor in attaining the required mastery by students. On the other hand, the summative data is directly collected from the students' performance in mapped course assessments. The academic accreditation unit coordinated with each instructor to collect formative and summative data for each performance indicator. The academic accreditation unit conducted different meetings with faculty members to ensure that data collection procedure was understood by the faculty.

4.2.4 Assessment results. The process for SO attainment has been executed for the first cycle that comprises of 2018-2019 (Term 1) and 2018-2019 (Term 2). As shown in Figure 5, the student outcome attainment process requires direct and indirect assessments from many sources, so this 360-degree feedback approach increases confidence in data validity. The target attainment level for each student outcome was fixed at 70%.

The results in Figure 12 show that the relevant target for each SO was achieved. The second direct assessment was an exit exam that was conducted for graduating students just before their graduation. The results in Figure 12 highlight that the performance was not satisfactory as per our expectations, which also indicated some areas of improvements. To get early indications of students' progress towards SO attainment and backtracking to investigate causes of any performance discrepancy, formative data is an appropriate tool and the trend of formative data in Figure 12 supports summative data attainment. Faculty surveys are an important indirect assessment to understand the faculty's perspective on SO attainment. As shown in Figure 12, though SO attainment for all SOs was above the target, SO:6 still needs improvement as it attained a minimum score compared to other student outcomes. The alumni survey was another indirect assessment used to measure SO attainment. The graph in Figure 12 highlights the alumni survey results. The last indirect assessment to measure SO attainment was a survey from the graduating students. As Figure 12 highlights, although the target was achieved, continuous improvement actions can be designed specifically in SO:2 and SO:5, as they scored less than other SOs.

Figure 12 also presents the overall average attainment from all direct (Summative Data, Exit Exam) and indirect assessments (Formative Data, Faculty Survey, Alumni Survey,

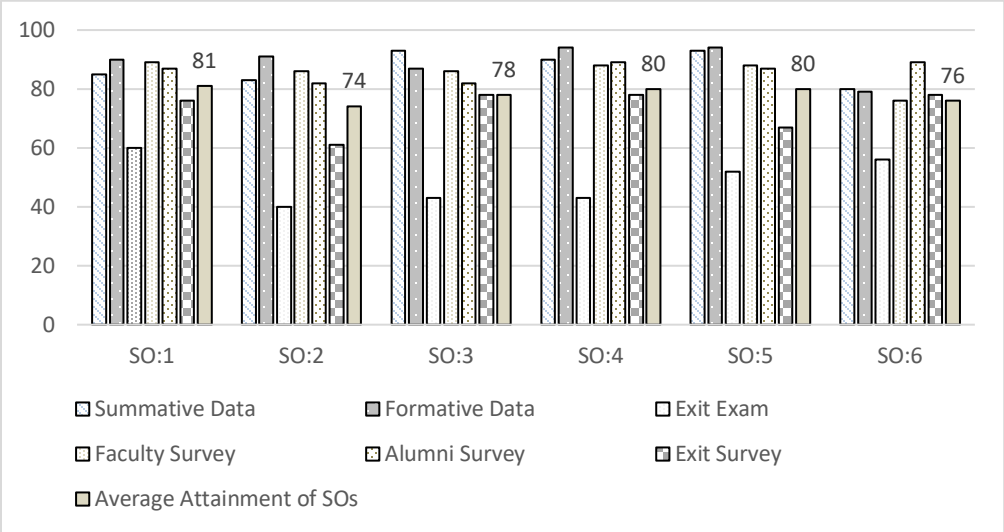

Figure 12. Data Attainment values of CYS program

Exit Survey). The overall average attainment values in Figure 12 highlight that the target of 70% has been achieved for all SOs.

4.2.5 Continuous improvement. The continuous improvement activities in the CYS program are divided into two tiers. At the higher level, as shown in Figure 5, the analysis of attainment data results in a Closing-the-Loop Action Plan. The academic accreditation unit analyzed these results and developed an action plan which was presented to the department board. The summary of these actions is presented in Table 1.

Improvement Level	Action Plan
Program Level	• Revision of Curriculum • Aligning the Common Years Curriculum Mapping Across Programs • Designing Higher Order Analytical Assessments Appropriate to a Performance Indicator • Updating the Rubrics
Action Plan for SO:1	• Project based Learning Adoption in curricula
Action Plan for SO:2	• Case Studies and Scenario Based Pedagogical approaches and evaluation strategies • Inclusion of relevant sections in internship (COOP) and capstone reports
Action Plan for SO:3	• Enhancing writing skills of students
Action Plan for SO:4	• Inclusion of relevant sections in internship (COOP) and capstone reports • Case Studies and Scenario Based Pedagogical approaches
Action Plan for SO:5	• Team management skill enhancements
Action Plan for SO:6	• Exposure to advanced software applications to enhance hands on training in lab modules • Inclusion of relevant (sub)Sections in Final Year Project Report • Exposure to Emerging Concepts in the Profession

Table 1. Closing the Loop Action Plan

Furthermore, the CYS program has a second continuous improvement cycle which runs each term, in line with Figure 8. At the termination of each term, each course coordinator of CYS courses offered in that term delivered a presentation in the department board meeting about the results and problems (if any) along with the improvement suggestions for the next course offering. Based on these recommendations and discussions, the curriculum unit developed an end-of-term presentation action plan which was subsequently approved by the department board. Furthermore, as shown in Figure 6, the academic accreditation unit provided a consolidated report of course improvement suggestions documented in course portfolios to the department. The CYS curriculum unit integrated these suggestions along with actions proposed in the end-of-term presentations, and a course-level action plan was developed. As an example, in Table 2, we present an excerpt from a course-level recommendation developed during the 2018-19 academic year.

Subject	Recommendation	Action Plan
CYS 402 Mathematical Foundations of Information Security (Term 1)	• There is a need to add more examples for discrete logarithm problem, Miller–Rabin primality test • The Lattices topic should be removed, and more details should be given on number theory like GF fields and time complexity.	**Status:** In Process **Responsible:** Course Coordinator **Action Plan by Course Coordinator:** The action plan has been prepared considering the feedback received in Term 1, 2018-2019 and will be executed in Term 1, 2019-2020.
CYS 406 Network Security (Term 2)	• Adding more tutorials on IPsec, VPN, and SSH protocols • Remove the contents related to wireless security as it will be provided in another course.	**Status:** Pending to be completed by Term 2, 2019-20 **Responsible:** Term-2 (2019-20) Course Coordinator

Table 2. Excerpt from Course Level Continuous Improvement Action Plan

As shown in Figure 1, the CYS program has also implemented a robust advising mechanism. Each faculty member is appointed as an advisor of a group of students, and this group remains with the same advisor until graduation. After the conclusion of midterms, the advising committee collects data of low-performing students, and this data is shared with advisors who then arrange special advising sessions with these students. Furthermore, if students require special advising they are referred to a professional advisor appointed by the University Counseling Center.

5. DISCUSSION

Like other quality assurance activities, the ABET accreditation process involves many additional tasks that require human and

financial resources. To systematically develop quality assurance in academic processes, top management not only needs to make these resources available, but also to make it clear to all stakeholders that quality assurance is not a desire, but a must. Such focus by top management motivates all the actors to optimally conduct all quality-related activities. As, Bernik, Sondari, and Indika (2017) highlighted, establishing a quality management system in higher education institutions is a challenging task, so it was evident that in our pursuit for CYS accreditation faculty have to adapt to standardized practices which required a lot of training and orientation. Furthermore, establishing such processes requires logistical and organizational support to establish appropriate committees. Initially, there may be extra work to establish the processes but once processes are in place the workload on the committee members reduces. With our experience, we have found that small committees work efficiently, and this work specialization also helps to reduce the workload on individual committee members. Initially, there may be resistance from the committee members, but the management of the institution needs to motivate the staff by highlighting the important role they need to play in fostering a quality culture.

In the absence of established processes, accreditation tasks are dependent on heroes and an organization-wide quality culture is not established. We have documented several processes to encourage a quality culture in organizational settings. New academic institutions find it difficult to design an effective process, and our contribution provides a generic process guidebook that different academic institutions can instantiate based on their needs. In the absence of such a guide, the process relies on a trial and error approach. Furthermore, it is important to establish an effective organizational structure to optimally gain the benefits of these processes. A fragile organizational structure will end up with compromises on quality objectives, and the success and failure will be dependent on individuals rather than processes. Establishing these processes helped in structuring the changes required to establish a quality management system for the CYS program. The definition of such processes helps in task specialization and each task is carried out appropriately, resulting in efficiency gains. For instance, ABET has updated cybersecurity-related programs' student outcomes from its draft version to the approved version. As per our defined process of student outcome revision, we have an important input from ABET student outcome guidelines so the relevant committee identified this change from ABET early on. As a result, the student outcomes of our programs were updated from seven to six, and the program was able to collect assessment data and apply for the first call for accreditation. If there is no defined process, such changes will not be proactively handled, resulting in a slow response.

In this contribution, there are three novelty factors. First, we provide a framework composed of different processes to successfully realize the accreditation process. Second, to the best of our knowledge, there is no contribution that has shared the off-cycle review process, as other contributions mainly describe the ABET experience from scratch in a regular cycle, but no one has documented the implications of integrating the accreditation activities with some already accredited program in an off-cycle scenario. In our case, the CYS program shared the first two years with computer science and computer information systems programs that were already accredited by ABET. The CS and CIS programs were accredited based on previous ABET criteria; however, for the CYS program, the revised ABET criteria were followed. The third novel aspect of our contribution is that there is no study documenting the cybersecurity-related ABET experience. Keeping in view the enormous demand of cybersecurity professionals by employers, academic institutions need to ensure that they deliver quality programs in this domain to fill the gap (Mogoane and Kabanda, 2019; Raj et al., 2019; Clark, Stoker, and Vetter, 2020). Establishing such a quality management system can help in quality improvements. It is worth mentioning that it was ABET's first-ever call for accreditation of cybersecurity-related programs and our experience is based on this instance.

It is reported in the literature that there is always resistance from the stakeholders pertaining to quality assurance activities due to excessive workload (Newton, 2002). Specifically in the context of our ABET experience with the CYS program, although there were two programs that were already accredited in the college and it was expected that faculty will be quick to adapt to the quality assurance procedures, the same resistance was evident which required a lot of training and follow-up. Furthermore, it was also quite challenging since the first two years of academic programs were shared across CS, CIS, and CYS programs. During the assessment period, CS and CIS programs were following old ABET SOs and have different sets of PIs, whereas the CYS program was following new ABET criteria. As a result, in some of the mapped courses, instructors need to carry out data collection for multiple performance indicators.

6. CONCLUSION

The core contribution of our paper has provided a detailed operational insight to approach ABET accreditation. In the literature, there are many contributions that describe the abstract issues to approach accreditation, but the dilemma of how to design and execute tasks appropriately was unexplored. Furthermore, the experiences documented in this paper are based on the first application cycle for ABET security-related programs, so the results will be helpful for other cybersecurity-related programs to foster a quality culture in-line with ABET requirements. The findings will assist aspirant higher education institutions to optimize and align these processes with their organizational settings. The detailed case study of CYS program accreditation provides insights to policymakers and academic management on optimally planning the ABET accreditation journey.

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AUTHOR BIOGRAPHIES

Abdullah M. Almuhaideb is an assistant professor of information security, the Chair of the Computer Science Department, and the Dean of the College of Computer Science and Information Technology, Imam Abdulrahman Bin Faisal University (Saudi Arabia). He received a B.S. in computer information systems from King Faisal University (Saudi Arabia) in 2003 and an M.S. and Ph.D. in network security from Monash University (Australia) in 2007 and 2013, respectively. His research interests include mobile security, authentication and identification, and ubiquitous wireless access. He has published more than 25 scientific papers in journals and premier ACM/IEEE/Springer conferences, such as TrustCom, NCA, MobiQuitous, ICICS, and AINA.

Saqib Saeed received a B.S. degree in computer science from the International Islamic University (Pakistan) in 2001, an M.S. degree in software technology from the Stuttgart University of Applied Sciences (Germany) in 2003, and a Ph.D. in information systems from the University of Siegen (Germany) in 2012. He is a Certified Software Quality Engineer from the American Society of Quality. He is currently an assistant professor in the Department of Computer Information Systems, Imam Abdulrahman Bin Faisal University (Saudi Arabia). His research interests include human-centered computing, data analytics and visulaization, software engineering, information systems management, digital business transformation, and quality in higher education. He is an associate editor of *IEEE Access* and *International Journal of Public Administration in the Digital Age*, besides being a member of the advisory boards of several international journals.

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