ABET accreditation requirements and preparation: Lessons learned from a case study of Civil Engineering Program

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Rana A. M. Alhorani¹, Wejdan Abu Elhaija², Subhi M. Bazlamit¹ and Hesham S. Ahmad¹

Abstract: With the need for specialized civil engineers rising in local and regional markets, Al-Zaytoonah University of Jordan (ZUJ) had launched the Civil and Infrastructure Engineering (CIE) program in 2009. The CIE program has aspired to be among renowned universities worldwide through the recognition of the Accreditation Board for Engineering and Technology (ABET). The CIE curriculum was adapted to meet the requirements of ABET. As a consequence of preparing for the first-time accreditation of the CIE program, the authors have learned several valuable lessons. This article constitutes a roadmap to those seeking first-time ABET (or other) engineering accreditation for their programs by reviewing the work of other successful first-time accreditation efforts and analyzing similar processes that were necessitated at ZUJ in preparation for the accreditation. In particular, the article describes the processes used and corresponding results of the ABET Site Visit completed in November and provides a good resource for conducting a sustainable continuous improvement process. Throughout the self-assessment process, feedback was gathered and information was solicited from internal and external formal/informal sources. Periodic collections of specific inputs regarding the program educational objectives, curriculum, and outcomes were requested through meetings, discussions, questionnaires and archives of the CIE Department in the period from 2016 to 2019. Data analysis was performed using Likert scale, statistical analysis, qualitative analysis and judgment to evaluate and perform the necessary reviews and revisions in the accreditation process.

Subjects: Engineering Education; General Engineering Education; Continuing Professional Development

Keywords: Engineering education; professional development; continuous improvement; Engineering accreditation

1. Introduction
The ABET accreditation is an assurance that the professionals who serve in the global workforce have a sound educational foundation and can lead the way in innovation, emerging technologies and anticipating the public's needs in terms of welfare and safety (ABET Accreditation Website, 2020; Iqbal et al., 2016; Setting the Standard Worldwide, 2020). Engineering programs must demonstrate compliance with the eight ABET general criteria established before 2001.
Amendments to these standards were made in 2019–2020 (Coelho & Huggins, 2019, Criteria for Accrediting Engineering Programs, 2019–2020; Leitch et al., 2017; Wyne et al., 2018).

The Faculty of Engineering and Technology (FET) at Al-Zaytoonah University of Jordan (ZUJ) continues to build on its credibility and consolidate universities’ leading position in the field of regional and international education by reviewing its current engineering programs in order to achieve a higher quality of education and to join the worldwide circle of renowned universities offering ABET accredited programs. It was the fall semester of 2016–2017 Academic Year (AY) when the FET decided to embark on a project to prepare the CIE program for ABET accreditation.

Several papers on ABET accreditation for engineering programs have been published over the past years. Previous work provided plans for evaluating student performance in various engineering programs for ABET accreditation (Biney, 2007; Cheville & Thompson, 2014; Conry & Harrington, 2019; Damaj et al., 2017; Echempati, 2019; Egilmez et al., 2019; Gamadi et al., 2019; Hamilton et al., 2019; Heileman & Abdallah, 2019; Hosseinzadeh & Al-Badi., 2018; Jaeger-Helton et al., 2019; Lutz et al., 2019; McCullough & Wigal, 2019; Miller, 2016; Qamar et al., 2016; Schoepf et al., 2016; Stone & Chang, 2013; Traum et al., 2019), a review of new ABET requirements (Bachnak et al., 2019; Estes et al., 2018; Kiliç & Taptik, 2020; Milligan et al., 2016; Turner et al., 2018), a program improvement process and ABET preparation (Burbano et al., 2018; Claire L. McCullough, 2020; Claire McCullough, 2018; Cook et al., 2018; Heyder et al., 2017; Kelnhofer et al., 2010; Sones, 2015; Sundararajan, 2014). While there is little research on effective preparation procedures and sustainable improvement processes for engineering programs for ABET accreditation, this article outlines a roadmap for those seeking first-time ABET accreditation for their programs by reviewing the successful work of others. The article describes initial preparations for the ABET assessment process, program curriculum development and a continuous improvement process, and lessons learned during the ABET accreditation process from a case study of a civil engineering program.

2. Initial preparations for the ABET assessment process

The Faculty of Engineering and Technology at Al-Zaytoonah University of Jordan initiated two program committees, one at the department level Department Accreditation Committee (DAC) and another at the faculty level Joint Accreditation Committee (JAC), to lead and guide the process for achieving ABET accreditation. The committees’ role is to simplify the process, make it more appealing for the faculty and increase the faculty’s awareness of ABET accreditation’s importance.

The CIE Program Educational Objectives (PEOs) were developed with input from the various program constituents and established based on the University’s and the FET’s mission statements. The PEOs represent skills and attributes that the CIE graduates will attain within a few years following their graduation. They are expected to join the workforce in local and regional civil engineering industries, where they will be responsible for solving real-world engineering problems. Therefore, the program’s curriculum must equip them with the analytical, communication, engineering ethics, and project management skills required to fulfil this obligation. The CIE program also recognizes that most of its graduates will seek professional careers while others will continue their education. Both groups will be required to engage in lifelong learning. The educational objectives of the CIE program are geared towards supporting this mission by graduating civil engineers who are expected to:

(1) Pursue careers in civil and infrastructure engineering, implementing technical solutions while demonstrating collaborative and communication skills with leadership

(2) Seek higher degrees in civil and infrastructure engineering and embark on lifelong learning

(3) Seek professional licensure, apply their skills ethically, and being aware of the impact of civil and infrastructure engineering projects on society as well as environment
The CIE program at ZUJ aims to meet the international licensing criteria of the American Society of Civil Engineers (ASCE), the Jordanian Engineers Association (JEA) and its counterparts in the Arab region. The faculty and department committees, JAC and DAC, decided to adopt the ABET student outcomes for engineering programs, represented by Student Outcomes (SOs) (1) through (7). Student Outcome (8) has been added to ensure those core concepts used in project development and management, leadership and licensing are acquired by CIE students by the time of graduation. The eight approved student outcomes are listed below.

1. an ability to identify, formulate, and solve complex engineering problems by applying principles of engineering, science, and mathematics
2. an ability to apply engineering design to produce solutions that meet specified needs with consideration of public health, safety, and welfare, as well as global, cultural, social, environmental, and economic factors
3. an ability to communicate effectively with a range of audiences
4. an ability to recognize ethical and professional responsibilities in engineering situations and make informed judgments, which must consider the impact of engineering solutions in global, economic, environmental, and societal contexts
5. an ability to function effectively on a team whose members together provide leadership, create a collaborative and inclusive environment, establish goals, plan tasks, and meet objectives
6. an ability to develop and conduct appropriate experimentation, analyze and interpret data, and use engineering judgment to draw conclusions
7. an ability to acquire and apply new knowledge as needed, using appropriate learning strategies
8. an ability to understand and explain the key concepts used in project development and management, public policy, public administration, leadership principles and licensure.

The SOs assessment is primarily conducted at the course level by the respective faculty member with participation from DAC. During the assessment process, the course instructor performs the following:

1. Acknowledges the PEOs and SOs;
2. Reviews and updates the course syllabus to reflect any changes or recommendations made based on the program improvement plan of actions stated in the previous semesters;
3. Identifies Performance Indicators (PIs) that best represent the requirement of each of the SOs mapped to the course;
4. Decides on, in coordination with the DAC, the direct and indirect assessment tools appropriate for the course;
5. Conducts the assessments using scoring rubrics and/or rating scale;
6. Collects and documents the assessment results together with supporting student work in course portfolios for evaluation process; and
7. Suggests corrective actions for continuous improvement based on the student’s performance targets set by the department.

3. CIE curriculum and the continuous improvement process

3.1. Designing the CIE curriculum
The curriculum is designed to prepare students for successful careers in civil and infrastructure engineering. The main objective of the curriculum is to harness the knowledge of civil engineering, develop students’ problem-solving abilities, and enhance the analytical and critical thinking skills
of graduates at both the course and program levels to advance in their future career pursuits. Achieving the program outcomes depends on designing its curricula to meet the interests of all constituents of the program and incorporating dynamic changes in the industry. The CIE curriculum demonstrates compliance with ASCE criteria, which require graduates to have adequate knowledge of mathematics, physics, chemistry and statistics. The CIE curriculum also considers preparing students to apply basic sciences in the implementation of civil engineering concepts. These concepts include the analysis and design of engineering systems in at least four CIE disciplines. The CIE curriculum includes modern civil engineering computer applications that implement sustainable engineering analysis and design for practical engineering problems. The CIE curriculum is also designed to develop students’ understanding of project management concepts, leadership, professional licensing, and ethical issues and to make students able to participate in lifelong learning. The CIE curriculum structure supports the achievement of program student outcomes as follows:

At the beginning of the curriculum, the focus is on basic skills and competencies in mathematics and the basic sciences. Students are taught the principles of their profession that apply to civil
Table 1. The CIE program assessment tools

| Assessment Methods | Assessment Tools | How to Assess       | Responsibility               |
|--------------------|------------------|---------------------|-----------------------------|
| Direct             | Exam questions and quizzes | Grading Rubrics | Faculty                     |
|                    | Term design projects | Rubrics            | Examination committee; Faculty; External examiner |
|                    | Presentation assignments | Rubrics            |                             |
|                    | Homework assignments | Grading Rubrics    | Faculty                     |
|                    | Oral exams, experiment reports, and term research reports. | Rubrics            |                             |
| Indirect           | Course Assessment Survey by student (CAS) | Rating scale | Faculty                     |
|                    | Student Advisory Board (SAB) survey | Rating scale | The FET Quality Assurance Office (FET-QAO) |
|                    | Senior exit surveys and exit interviews | Rating scale |                             |
|                    | Alumni survey     |                     |                             |
|                    | Employer survey   |                     |                             |
|                    | Industrial Advisory Board (IAB) survey | Rating scale; Judgmental review |                             |
|                    | Student Surveys on Faculty Teaching Performance (SSFTP) | Rating scale | The University Accreditation and Quality Assurance Office (AQAQO) |

engineering and infrastructure projects, including the projects' impact on the environment and society. As students progress through the curriculum, the content of their courses becomes more specific and reflects the real-world experience of the profession through applications of modern engineering design tools and practical standards to all disciplines of civil engineering.

The CIE curriculum also includes courses and opportunities designed to develop student's abilities to conduct appropriate experiments, analyze and interpret data, and draw conclusions using their engineering judgment in all civil engineering disciplines. In such opportunities, students are taught to communicate effectively with various audiences. They are assigned tasks to work effectively in teams and appreciate ethical and professional responsibilities in various engineering environments. The CIE courses’ content and student assessment forms are periodically updated to include modern civil engineering techniques and practices, particularly in capstone design projects and senior design courses.

3.2. Designing the continuous improvement process

The overall continuous improvement process used for the CIE program is illustrated in Figure 1. The CIE Department utilized direct and indirect assessment tools to evaluate the program outcomes. The DAC with the input from the program constituents has responsibility for administering the program, making decisions, and implementing teaching and learning strategies to achieve the student outcomes, which support the program long-term educational objectives.

To assess both the recognition of PEOs and the achievement of SOs, the FET Quality Assurance Office (FET-QAO) conducts annual surveys such as the Faculty Survey, Industry Advisory Board (IAB) Survey, Student Advisory Board (SAB) Survey, Employer Survey, Exit Survey, Alumni Survey, University Board of Trustees (UBoT) Survey. Table 1 shows the tools used to evaluate PEOs and SOs for the CIE program.

In order to reduce the effort required in analyzing and evaluating program outcomes, the DAC decided to focus on selected courses within the CIE program curriculum for the continuous
| Key CIE Course | SO1 an ability to identify, formulate, and solve complex engineering problems by applying principles of engineering, science, and mathematics |
|----------------|--------------------------------------------------------------------------------------------------------------------------------|
| **Performance Indicators** | **Engineering Mechanics** | **Structural Analysis** | **Survey Engineering** |
| PI-1 Apply mathematical principles to achieve analytical or numerical solutions | Calculate moment of inertia, centroids and center of mass of rigid bodies. | Estimate deformations in statically determinate structures | Apply traverse computations and coordinates geometry concepts |
| PI-2 Understand/formulate engineering problems | Analyze structure's internal forces: truss member’s forces, shear force and bending moment diagrams for beams | Calculate support reactions and internal forces for statically determinate structures | Apply leveling concepts: contouring, profiles, cross sections and computing of areas and volumes |
| PI-3 Solve engineering problems | Analyze equilibrium problems of particles and rigid bodies (2D and 3D) | Generate quantitative response influence lines for statically determinate structures | Prepare horizontal and vertical control, land boundary, and field layout of infrastructure |
| PI-4 Apply appropriate techniques and tools for engineering tasks | Analyze equilibrium problems of particles and rigid bodies (2D and 3D) | Calculate support reactions and internal forces for statically determinate structures using engineering software | Operate systems for collecting and analyzing spatial information about the land, natural resources, and man-made features |
| **SO2 an ability to apply engineering design to produce solutions that meet specified needs with consideration of public health, safety, and welfare, as well as global, cultural, social, environmental, and economic factors** | **Hydraulics** | **Reinforced Concrete II** |
| PI-1 Identify constraints for solving design problems | Design water flow system according local/international design code requirements and specifications | Design of reinforced concrete building according to local/international design code requirements and specifications |
| PI-2 Produce design solutions | | |
| PI-3 Apply appropriate techniques and tools for engineering design tasks | | |
| **SO3 an ability to communicate effectively with a range of audiences** | **Technical Writing and Professional Ethics** |
| PI-1 Write in a technical style/format and integrate graphics with text effectively | Prepare and present a simple study on Engineering ethical and professional responsibilities (communicate effectively with different audience, conduct surveys ... etc.) |
| PI-2 Communicate effectively through appropriate body language and clarity of speech | | |

(Continued)
| Table 2. (Continued)                                                                 | SO4 an ability to recognize ethical and professional responsibilities in engineering situations and make informed judgments, which must consider the impact of engineering solutions in global, economic, environmental, and societal contexts |
|-------------------------------------------------------------------------------------|-----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| PI-1 Recognize code of ethics and/or professional responsibilities in engineering situations | Apply the codes of ethics to specific engineering situations                                                                                                                                                                                                                                                                               |
| PI-2 Recognize the impact of engineering solutions in global and/or economic situation | Determine the impact of solid wastes on public health and environment (ecological communities)                                                                                                                                                                                                                                                                                             |
| PI-3 Identify environmental and/or social issues involved in engineering problem solutions | Analyze quantities and impact of the wastewater generated from the municipal uses                                                                                                                                                                                                                                                                                                                 |
| PI-1 Recognize participant roles in a team to work together effectively | Use principal surveying instruments                                                                                                                                                                                                                                                                                                                                                     |
| PI-2 Integrate input from all team members to solve a problem as a group (collaborative leaders, coordination and communication) | Use modern engineering tools for engineering practice (use different software packages, such as Civil 3D, AutoCAD, Surfer) to generate contour lines, topographic maps from field data                                                                                                                                               |
| PI-1 Conduct appropriate experimentations | Conduct experiments for testing mechanical and physical properties of construction materials                                                                                                                                                                                                                                                                                           |
| PI-2 Use appropriate tools/standards to analyze data and validate experimental results | Analyze collected data from experiments using ASTM standards, modern engineering tools for engineering practice, and draw conclusions                                                                                                                                                                                                                             |
| PI-1 Interpret main ideas and provide details about taught topics using appropriate learning strategies (draw picture, discuss, practice, make note) | Apply of chemical, biological, and physical principles to the analysis and design of treatment processes for wastewater                                                                                                                                                                                                                                                                   |
| PI-2 Research/gather data about new topics using appropriate learning strategies (conduct searches, survey literature, summarize, practice, prepare presentations, communicate questions and findings, criticize their own/other work) | Analyze quantities and impact of the wastewater generated from the municipal uses and explain new technologies for wastewater treatment                                                                                                                                                                                                       |
| PI-1 Understand principles of project development and management | Projects Management and Value Engineering Understand principles of project development and management Specifications and Quantity Surveying Understand the importance and principles of quantity surveying, tendering, procurement strategy and cost estimation of construction work over the project management life-cycle |
| PI-2 Incorporate relevant engineering regulations/standards and professional ethics and practices | Prepare a project management plan including WBS, time scheduling, resource allocation and leveling, and project cost estimation Apply tendering process with reference to public specifications for one or more building items (Project) Understand the importance and principles of quantity surveying, tendering, procurement strategy and cost estimation of construction work over the project management life-cycle |
| PI-3 Prepare a project management plan and cost (individually or in groups) |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                             |
### Table 3. The rubric used for assessing the performance indicators PI-1 and PI-2 of SO6 in Construction Materials Laboratory course

| PI No | Performance Indicators | Beginning | Developing | Accomplished | Exemplary |
|-------|-------------------------|-----------|------------|--------------|------------|
| PI-1  | Conduct experiments for testing mechanical and physical properties of construction materials | Ability to know and use the equipment | Demonstrates minimal or no ability to know and use the equipment | Demonstrates some ability to know and use the equipment | Demonstrates an ability to know and use the equipment | Demonstrates a comprehensive ability to know and use the equipment |
|       | Ability to prepare the samples | Demonstrates minimal or no ability to prepare the samples | Demonstrates some ability to prepare the samples | Demonstrates an ability to prepare the samples | Demonstrates a comprehensive ability to prepare the samples |
|       | Ability to apply the correct procedure | Demonstrates minimal or no ability to apply the correct procedure | Demonstrates some ability to apply the correct procedure | Demonstrates an ability to apply the correct procedure | Demonstrates a comprehensive ability to apply the correct procedure |
|       | Ability to collect data | Demonstrates minimal or no ability to collect data | Demonstrates some ability to collect data | Demonstrates an ability to collect data | Demonstrates a comprehensive ability to collect data |
| Score | (0–2.5) points | (2.5–5) points | (5–7.5) points | (7.5–10) points |
| PI-2  | Analyze collected data from experiments using ASTM standards | Ability to analyze data | Demonstrates minimal or no ability to analyze data | Demonstrates some ability to analyze data | Demonstrates an ability to analyze data | Demonstrates a comprehensive ability to analyze data |
|       | Ability to deal with the obtained result and compare with standards | Demonstrates minimal or no ability to deal with the obtained result and compare with standards | Demonstrates some ability to deal with the obtained result and compare with standards | Demonstrates an ability to deal with the obtained result and compare with standards | Demonstrates a comprehensive ability to deal with the obtained result and compare with specifications |
| Score | (0–2.5) points | (2.5–5) points | (5–7.5) points | (7.5–10) points |

**Figure 2.** The direct assessment results of SO1 (sample).
improvement process. The faculty assigns two to four performance indicators that represent the best achievement of each of the SOs assigned to the courses offered. The selected courses and their associated performance indicators are shown in Table 2. According to Bloom’s taxonomy, the performance indicators of the student outcomes were classified into three levels, namely (1) knowledge and comprehension, (2) application and analysis, and (3) synthesis and evaluation.

The evaluation of each student outcome is based on both direct and indirect assessments. Various assessment tools are used to ensure student outcomes attainment for the ABET accreditation process (see Table 1). The direct assessment includes scoring of student work through written exams, homework assignments, quizzes, term design projects, presentation assignments, oral exams, experiment reports, and/or term research reports. The indirect assessment includes conducting a special survey (Course Assessment Survey, CAS) on how students rate the contribution of the course to increase their ability to achieve the performance indicators for a given student outcome. The students are asked to express their achievement level using a 1 to 5 scale, where (1) corresponds to a poor achievement and (5) corresponds to excellent achievements. In addition, the ZUJ Accreditation and Quality Assurance Office (AQAO) conducts a student survey on faculty teaching performance (SSFTP) for all offered courses at the end of each semester.

Two performance passing criteria targets are used for the direct assessment; passing Criterion I requires that 65% of the class students score over 60% of the full mark for each PI, while passing Criterion II requires that the class average is at least 65% of the full mark for each PI. On the other hand, one performance passing criterion target is used for the indirect assessment. The criterion requires that at least 65% of the class students score over 60% in each PI. Table 3 shows the rubric used for assessing the performance indicators of SO6 in Construction Materials Laboratory course. At the end of each academic year, the direct and indirect assessment results together with the supporting student works are collected in the courses’ portfolios by respective faculty members (CAFs).

The assessment results are used to evaluate the extent to which the student outcomes are being attained. The DAC allocates one long meeting during each academic year for the program continuous improvement progress. The DAC members meet to discuss comments and observations about students’ achievement of the SOs using various assessment tools. Any comments received from constituents and other initiatives at the university or national level are also reviewed and discussed at this meeting. The committee discusses the program’s areas of strength and areas for improvement, decides on the necessary actions, and then completes the documents accordingly. Minutes of these meetings are documented and submitted to the program evaluator during the ABET team visit. Figure 2 shows the SO1 direct assessment achievements (Criterion I and Criterion II) and actions taken for improvement over three consecutive academic years: the spring semester of 2017–2018 AY, the fall semester of 2018–2019 AY, and the spring semester of 2018–2019 AY.

4. Lessons learned during the ABET accreditation process
The following recommendations constitute an overall derived knowledge and advice to those seeking first-time ABET or other accreditation of engineering programs. They represent closing remarks and conclusions of the accreditation effort participants in the CIE program as follows:

(1) For a sustainable improvement process, program accreditation committees are required to examine how the accreditation process and its outcomes are received by staff, who have to prepare for accreditation, and students, as the primary stakeholders who should benefit from it.

(2) The early involvement of program constituents in the accreditation effort is essential to ensure effective participation and constructive feedback.

(3) The participation of students, alumni and Industrial Advisory Board members has proved to be very beneficial in improving the program’s educational objectives. In addition, feedback from these constituents is vital to maintain the quality of the program’s continuous improvement process.
(4) The documentation is the basis of the program improvement process. Success is highly dependent on good documentation of all aspects of the accreditation process. The purpose of the documentation process is to show that the program implements ABET criteria and can continue to be improved over time to meet the needs of its constituents.

(5) Certain sets of CIE courses can be specifically used to provide evidence for the accreditation process, thereby reducing the amount of work and preparation needed.

(6) The performance indicators linked to student outcomes are the key for a meaningful assessment in the selected courses. The performance indicators need to be quantitative to facilitate the statistical evaluation of student outcomes attainment.

(7) The target criteria for the students’ performance can be based on reasonable threshold values that can be achieved and to allow improvement toward higher values in future assessment cycles.

(8) Rubrics can be used to directly assess the achievement of student outcomes in capstone design courses, practical training and laboratory courses. They are very effective in evaluating student achievement in written and oral communication skills, leadership roles and ethical responsibility.

(9) In general, the attainment of student outcomes can take place over a number of consecutive courses and not necessarily in one single course. They can be distributed in chronological order throughout the curriculum and finally culminate and blossom before graduation. It can be consistent with the pedagogical progression of knowledge according to Bloom’s taxonomy.

5. Conclusions

The quality of students’ performance is highly dependent on the quality of the program continuous improvement plan. The program administering committees are required to implement periodic evaluations that will help students achieve and attain the learning outcomes. ABET implementation serves as the road map for students and faculty members in the journey from enrolment to graduation. All constituents must know their roles and are all guided by the program’s continuous improvement process. The real challenge is not in getting accredited by ABET but rather in continually improving the program and the quality of graduates after the initial accreditation. One can always raise the level of their expectation and challenge the constituents to improve the program and the quality of graduates. The assessment of the product of an ABET accreditation process requires both short- and long-term follow-ups to keep up with advances in the industry as well as the changing expectations of the job markets. The CIE program should continuously monitor the achievements of its graduates (alumni) and maintain the inclusion of other constituents in the review processes, mainly the IAB members. These reviews should always enhance the program curriculum, educational objectives and learning outcomes.

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