Continuous Improvement in the IMSE Program of Kuwait University

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Abstract

Continuous improvement of an engineering program is essential and a critical process. Development and implementation of such a process is not only required by the Accreditation Board for Engineering and Technology (ABET), but it is also a necessary condition for the maturation and development of any engineering program. This paper describes the process employed by the Industrial and Management Systems Engineering (IMSE) program at Kuwait University to continuously improve its program. The employed process includes identification of the lowest score among the seven student outcomes specified by ABET. Next, the courses in the IMSE curriculum addressing this student outcome are identified, and the instructors teaching these courses took remedial actions. In the following semesters, this outcome was measured, and it was found that there is a significant improvement on this outcome. Other engineering programs can benefit from the process described in this paper.

Keywords: Student outcomes; quality; ABET; industrial engineering program; continuous improvement .

Introduction

Quality is a crucial parameter which differentiates an organization from its competitors. Quality plays as a key to survival in all standard of organization. Quality is the single most important factor for long-term success and survival. There are numerous recognized programs that set requirements for quality and excellence, e.g. the Baldrige National Quality Program (BNQP 2014), (EFQM), Six Sigma, ISO 9000 Quality Management System (QMS), and Customer Service Excellence (CSE) program. Regular enhancement is a pivotal criterion in all quality and excellence models; a system that has no progress will become obsolete and eventually not be in use. Several productions on the application of numerous quality programs in higher education are by Furst-Bowe and Bauer (2007), Ruben (2007) on BNQP, EFQM (2003) and CEHE (2008) on EFQM, Mazumder (2014) on Six Sigma, Kasperaviciute (2013) and Caraman et al. (2008) on ISO 9001 QMS, Elves (2014) on CSE and Haseena and Ajims on IISTE (2015). The function of quality in education has expanded over the years. Global competitiveness has led to educational establishments seeking to apply excellence and quality programs that have the same fundamentals to ensure harmonization and mutual recognition. Furthermore, expectation for superior graduates is increasing. The emergence of developmental diversity in the organization and various significant transformations related to communication and technology impacted around all aspects of education, e.g. Patil and Codner (2007) and Christoforou and Yigit (2008).

Accreditation is a quality assurance process that colleges, universities and education institutions or programs undergo to confirm that they meet a strict and recognized set of service and operational standards. Regular accreditation of programs fosters the continual improvement of education. To establish excellence, quality, and harmonization in Engineering Education within academic institutions, accreditation agencies were established worldwide. Accreditation is assessed by private, nongovernmental accrediting agencies that have been created specifically to review education institutions and programs. Examples are the Accreditation Board for Engineering and Technology (ABET) of the USA, Japan Accreditation Board of Engineering Education (JABEE), the Accreditation Board for Engineering Education of Korea (ABEEK), the Engineering Accreditation Council of Malaysia (EAC) and the Canadian Engineering Accreditation Board (CEAB). The Bologna Process has been instrumental in establishing a mutual accreditation framework (Augusti, 2006) which led to the establishment of a non-profit organization European Network for Accreditation of Engineering Education – ENAEE (Augusti, 2007). The International Engineering Alliance (IEA) promotes a set of graduate attributes and qualified competency profiles for engineers, engineering technologists, and engineering technicians (IEA, 2013). This supports mutual recognition among accreditation bodies and facilitates the advancement of outcome-based accreditation criteria. The ABET accreditation program is the most widely used for engineering programs; initially its utilization was defined to the evaluation of engineering programs in the USA, but in the 1980s the scope extended to non-

USA programs. Formerly, the international engineering programs were determined in terms of substantial equivalency, and later they were awarded the same designation as their peer programs in the USA. Therefore, engineering programs worldwide have sought to administer the ABET principle, e.g. Christoforou and Yigit (2008), Al-Nashash et al. (2009), Abu-Jdayil and Al-Attar (2010), Aqlan, Al-Araidah, Al-Hawari (2010), Abdulaal et al. (2011), Harmanani (2016), Nath and Agrawal (2020), and Ahmad and Qahmash (2020). It should be emphasized that a realistic model for assessment and continuous improvement must be dynamic and be able to evolve as learning and improvements take place, Crossman and Verma (2006).

It is vital to note that ABET criterion 4 stipulates that, "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 program's continuous improvement actions. Other available information may also be used to assist in the continuous improvement of the program". The Industrial and Management Systems Engineering (IMSE) program at Kuwait University (KU) has been accredited by ABET since 2001. This paper focuses on improvement effort and demonstrates how various qualitative and quantitative analysis approach have been enforced to continuously improve its program program.

Student outcomes

The IMSE program has adopted the ABET's revised Student Outcomes (SOs) 1 to 7. The seven SOs described below are the same as those listed under the Criterion 3 of ABET's general criteria. Attainment of these SOs prepares graduates to enter the professional practice of engineering. The stated 7 SOs are:

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.

It should be noted that ABET 1-7 SOs were recently introduced. The earlier ABET Student Outcomes were SOs a-k. The earlier and newer versions of SOs were mapped by ABET using the mapping given in Table 1. We also used the same mapping.

Table 1. Mapping between SOs 1-7 and SOs a-k.

SOs (a to k)	SOs (1 to 7)
a, e	1
c	2
g	3
f, h, j	4
d	5
b	6
i	7
k	Implied in 1, 2, 6

Continuous Improvement

ABET general criterion 4 states that "The program must regularly use appropriate, documented processes for assessing and evaluating the extent to which the student outcomes are being attained". Table 2 lists all the appropriate assessment tools used to evaluate the extent to which the SOs are being attained for the process of continuous improvement. This process is documented and repeated annually. The criterion also states that "The results of these evaluations must be systematically utilized as input for the continuous improvement of the program." Section 3.1 describes the continuous improvement based on evaluations of the assessment results. Moreover, the criterion states that "Other available information may also be used to assist in the continuous improvement of the program". Section 3.2 describes the continuous improvement of the program based on other available information. Figure 1 shows the assessment process of development, evaluation, and improvement of the SOs where the definitions of the notation on the figure are given in Table 2.

The assessment process of the SOs is generally handled through a series of steps that starts with the Assessment Secretary who receives the assessment data generated from the tools shown in Table 2. Then, the data is analyzed and presented to the Undergraduate Program Committee (UPC) which evaluates the results of the analysis and recommends actions to the department chairman. The chairman then introduces relevant recommendations to the department council, which makes the final recommendations. Once these recommendations are approved by the council, they are communicated for implementation by the chairman to the relevant party either inside or outside the department.

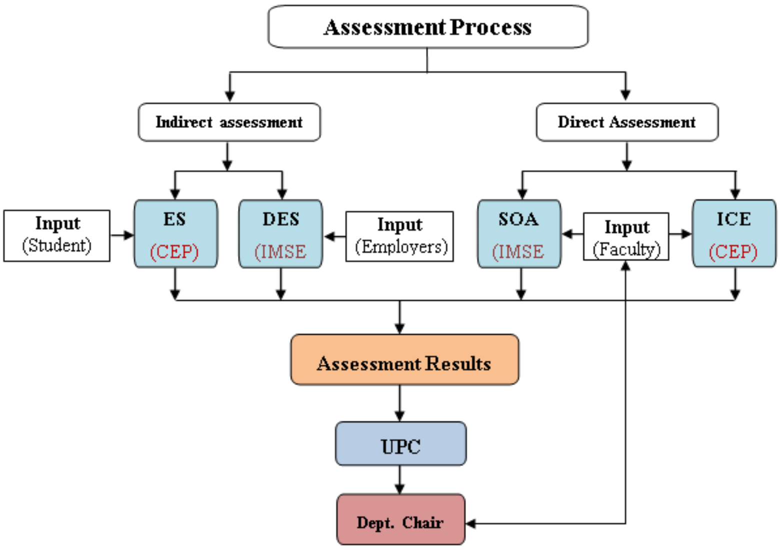

Figure 1. The assessment process of development, evaluation, and improvement of the SOs

Table 2. Assessment tools used for student outcomes

Assessment Tools	Conducted by	Assessor	Direct/Indirect	Frequency
Instructor Class Evaluation (ICE)	CEP	Faculty	Direct	Every Semester
Exit Survey (ES)	CEP	Student	Indirect	Every Year
Student Outcome Assessment (SOA)	IMSE	Faculty	Direct	Every Semester
0660-496: Design in Industrial Engineering - Employer Survey (DES)	IMSE	Employer	Indirect	Every Semester

Continuous Improvement Based on Assessment Data

The IMSE faculty members meet at least once a semester to discuss different issues related to curriculum, laboratory facilities, assessment information and accreditation. In addition to these meetings, faculty provide input to the UPC coordinator concerning equipment, facilities, and other concerns via e-mails and informal conversations. The UPC coordinator summarizes this information and discusses them with the Department Chair.

The role of the faculty members in the assessment and continuous improvement plan is as follows:

a. Faculty members are responsible for establishing course objectives and assessing whether they are being met.
b. Faculty members complete the course assessment forms ICE and SOA which measures student performance for each of the SOs.
c. Faculty members are responsible for implementing any curricular changes as a result of program review during the assessment process.

Assessment data helps and guides faculty in making curricular changes. Any low score on a particular SOs attainment raises a red flag and faculty members try to get to the root cause of the problem. If the issue affects other courses within the program, the issue is raised in the UPC meetings.

The assessments results of the SOs have been averaged over 5 semesters up to Spring 2018 to establish an intuition of the observed values across all the outcomes and courses. From the analysis of the two direct assessment tools used by IMSE department for the evaluation, namely, Instructor Class Evaluation (ICE) and Student Outcome Assessment (SOA), the results of SOA indicated that, based on the assessment results over the 5 semesters, the outcome 1 had relatively lower score compared to the other outcomes even though the performance of the outcome 1 was much higher than the threshold value of 60%. Figure 2 shows the resulting averages for the SOA results for all the SOs 1 to 7.

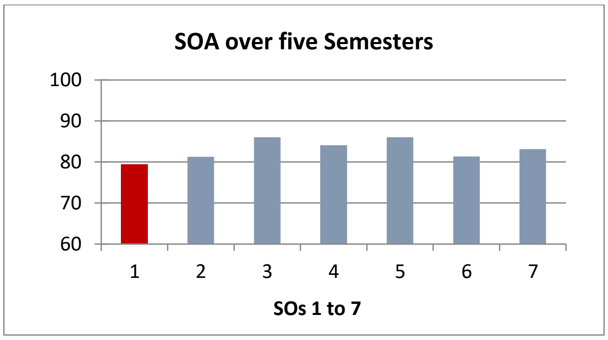

Figure 2. Average SOA over five semesters.

Since outcome 1 has the lowest score among all the SOs, it has been the focus of an improvement effort. To address this issue, the UPC committee realized the necessity to pay attention to outcome 1. This outcome is addressed by 24 courses in the curriculum of IMSE program. The courses that address outcome 1 are listed in Table 3. The first 12 courses are compulsory, and the remaining are department electives.

Table 3. Compulsory and Elective courses relevant to outcome 1

No.	Course No.	Course Name
1	660-221	Introduction to Industrial Engineering
2	660-321	Work Design & Measurement
3	660-351	Engineering Statistical Analysis
4	660-352	Production Cost Analysis
5	660-361	Operation Research I
6	660-372	Project Management & Control
7	660-434	Facilities Planning & Design
8	660-454	Production Planning & Inventory Control
9	660-457	Quality Control
10	660-461	Operation Research II
11	660-481	Systems Simulation
12	660-496	Design in Industrial Engineering
13	660-381	Data and Decision Analysis
14	660-395	Industrial Engineering Internship
15	660-445	Manufacturing Systems
16	660-446	Computer Aided Manufacturing
17	660-451	Reliability and Maintainability Engineering
18	660-456	Productivity Improvement Methods
19	660-458	Design of Experiments
20	660-459	Quality in Health Care
21	660-464	Optimization Methods
22	660-470	Supply Chain and Logistics
23	660-487	Expert Systems in Industrial Engineering
24	660-494	Industrial Engineering in Process and Service Systems

The compulsory courses are offered every semester. Moreover, a set of at least four elective courses is offered each semester. By considering the academic year 2015/2016, the performance in the courses that addressed outcome 1 is shown in Figure 3. The lowest scores of outcome 1 are for the following courses:

0660-321: Work Design & Measurement
0660-351: Engineering Statistical Analysis
0660-352: Production Cost Analysis
0660-461: Operations research II
0660-481: Systems simulation

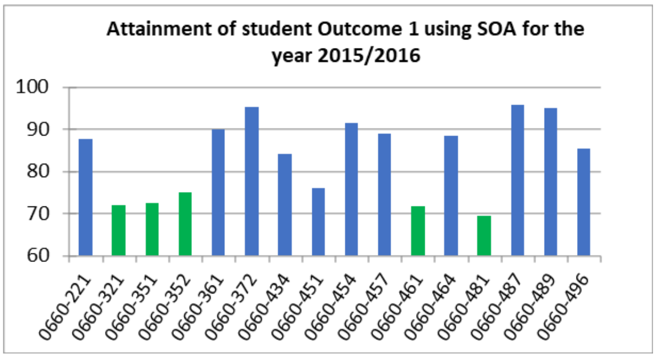

Figure 3. Attainment of Student Outcome 1 using SOA in 2015/2016

In Spring 2016, the UPC committee decided after this evaluation to take action through the department chair by notifying faculty members about putting more emphasis on outcome 1. Recall outcome 1 states that students should have an ability to identify, formulate, and solve complex engineering problems by applying principles of engineering, science, and mathematics. Faculty members, specially to the faculty members teaching the above four courses with relatively low scores, were requested to put more emphasis on this outcome.

After the end of the academic year 2017/2018, the UPC committee evaluated the results for those low performed courses in student outcome 1 using both the assessment tools (ICE and SOA) for two academic years. Figure 4 and Figure 5 show the comparison of evaluation results attained for outcome 1 between (Fall 2015 - Spring 2016) and (Fall 2016 - Spring 2018) using SOA and ICE, respectively.

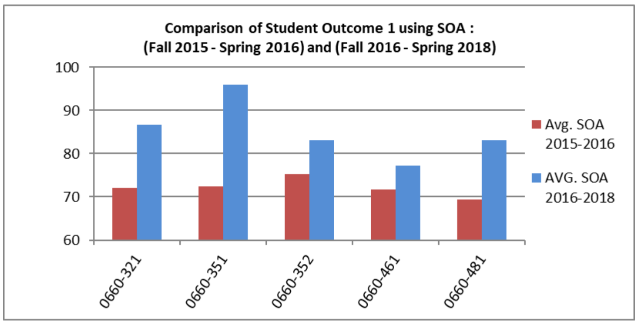

Figure 4. Comparison of evaluation results attained for Student Outcome 1 using SOA

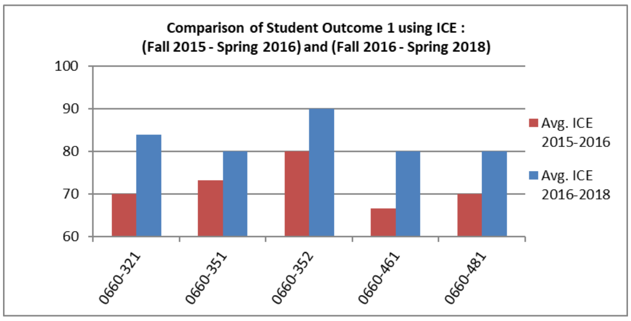

Figure 5. Comparison of evaluation results attained for Student Outcome 1 using ICE

From the results of both assessment tools (ICE and SOA) as shown in Figure 4 and Figure 5, it was found that the five courses with the relatively low performance in outcome 1 have improved considerably in the following two years (2016/2017 and 2017/2018).

Faculty members, teaching courses addressing student outcome 1, were requested to put more emphasis on this outcome. Putting more emphasis on student outcome 1 in the related lectures resulted in a higher score in outcome 1.

The UPC committee has also investigated the average of evaluation results of all the courses for outcome 1 and compared the results for the 5 semesters (Spring 2014 – Spring 2016) with the two years 2016/2017 and 2017/2018. It was found that the overall average results have also been improved in both assessments ICE and SOA as showed in Figure 6.

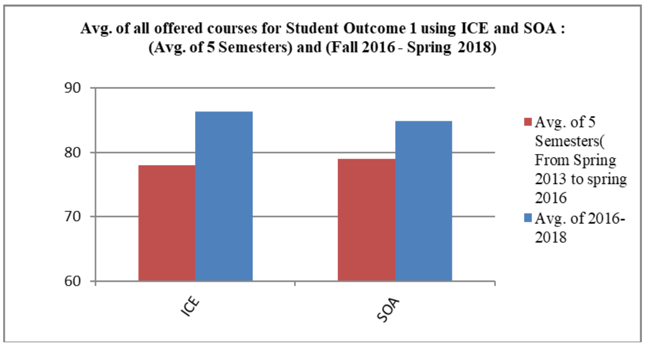

Figure 6. Comparison of avg. evaluation results from all the relevant courses for outcome 1 using ICE and SOA

Continuous Improvement Based on Other Information

This subsection describes the continuous improvement of the program based on other available information. These are summarized as follows:

a. All the student outcomes have been measured each semester by each assessment tool described earlier. It has been observed that conducting the "Student Outcome Assessment" for all outcomes each semester was cumbersome. Therefore, it has been decided to measure four of the outcomes in every Fall semester and the other three outcomes in every Spring semester such that within an academic year all outcomes are covered.

b. If the result for any of the outcomes from any of the tools falls below 70% (even if it is above the threshold value of 60%) for two consecutive years, a notification shall be sent by the department chairman to faculty members urging them to undertake remedial actions to improve performance on this outcome. If necessary, the relatively weak performing outcomes may be discussed in the department council meeting for actions. Implementation of this change shall reduce the efforts and time required of faculty and provide focus on specific SOs.

c. The total number of required credits for the program was 144 until Spring 2015, which generally required 5 years of study. As per the directive of the CEP to all engineering programs, the IMSE program reduced the 144 credits to 132. This change was motivated by a number of factors including the fact that many notable universities require four years of study which amounts to less than 132 credits. Additionally, the major employers in Kuwait, including oil and gas, banking, and government, do provide extensive orientation and training programs for new employees; e.g. in the oil and gas companies, the orientation and training duration typically extends to more than one year. Hence, a modified curriculum with 132 credits was approved and implemented starting Fall 2015.

d. The faculty members have been concerned about the weak performance of some students with respect to Mathematics and English language. Although these students are required to take remedial courses, their performances could not be improved beyond certain levels. To address this issue, the college adopted a new admission policy which took effect in the 2014-2015 academic year. According to the new policy, those students who do not pass Mathematics and English aptitude tests conducted by the university, are not admitted to the college programs. The students who pass the English test marginally still have to take remedial English course. The new policy also stipulates higher minimum admission score. Moreover, the high school GPA has a lower percentage in calculating the admission score.

e. It was observed that some of the common engineering courses and introductory IMSE courses were being delayed by many students as a result of some prerequisite requirements. For example, some students would take 0660-361: Operations Research I and 0660-461: Operations Research II before taking 0660-221: Introduction to Industrial Engineering. Another example is some students would take 200-level college courses such as Thermodynamics (0600-208) in the last semester. In order to overcome these issues, the UPC committee suggested modifications to some of the prerequisites of some courses. Table 4 shows the modifications.

Table 4. Modifications to the prerequisite of some of the courses

IMSE Course Name	Old Pre-requisite	Proposed/ Approved Pre-requisite
0660-312: Industrial Engineering Labs	0600-304: Engineering Probability and Statistics 0660-221: Introduction to Industrial Engineering	0600-207: Electrical Engineering Fundamentals Lab 0600-304: Engineering Probability and Statistics 0660-221: Introduction to Industrial Engineering
0660-321: Work Design and Measurement	0600-304: Engineering Probability and Statistics 0660-221: Introduction to Industrial Engineering	0660-312 (Concurrent)
0660-325: Safety and Health for Engineers	0600-304: Engineering Probability and Statistics	0600-202: Statics 0600-208: Engineering Thermodynamics 0600-304: Engineering Probability and Statistics
0660-361: Operations Research I	0410-111: Linear Algebra	0410-111: Linear Algebra 0600-307: Applied Numerical Methods 0660-221: 0660-221: Introduction to Industrial Engineering
0660-481: Systems Simulation	0600-304: Engineering Probability and Statistics 0660-351: Engineering Statistical Analysis	0660-351: Engineering Statistical Analysis

The UPC committee discussed the pre-requisites of IMSE courses 0660-321: Work Design and Measurement and 0660-312: Industrial Engineering Labs. Both of these IMSE courses have 0600-304: Probability & Statistics and 0660-221: Introduction to Industrial Engineering as their prerequisites. Therefore, in order to force students to take the course 0660-312 early on in their studies and not delay it until the senior year, it was suggested to require 0660-321 to be taken either concurrently or after 0660-312.

It has been noticed in the past that many students take 0660-361 very early in their studies before many IMSE or even general engineering courses and delay 0660-221. By having 0660-221 and 0600-307: Applied Numerical Methods and Programing for Engineers prerequisites to 0660-361, it is hoped that students would take the courses during a more appropriate time frame in their studies.

Another minor modification to the prerequisite of the IMSE course 0660-481: Systems Simulation was removing the course 0600-304: Engineering Probability & Statistics. This is because 0660-481 has 0600-304 and 0660-351: Engineering Statistical Analysis as its prerequisites and 0660-351 has 0600-304 as its prerequisite. Therefore, it can be seen that there was a redundancy in the list of prerequisites of 0660-481 and it was removed.

Some Engineering Management (EM) elective courses have 0660-471: Engineering Management course as their prerequisites. Currently, 0660-471: Engineering Management is one of the courses that students typically leave until the very last semester before taking it. This is because 0660-471: Engineering Management is not a prerequisite for the 0660-496: Senior Design course and has 0660-352-Production Cost Analysis as its prerequisite. Therefore, when offering EM elective courses, there is the potential of not having enough students that are eligible to take them. To overcome this problem, first, it was suggested to allow the EM elective courses 0660-473: Quality Management and Organizational Excellence and 0660-479: Law for Engineers to be taken concurrently with 0660-471. Second, it was recommended to remove 0660-352 as a prerequisite to 0660-471: Engineering Management and replace it with 0600-209: Engineering Economy, which allows students to take 0660-471 earlier in their studies to leave enough time for taking two or more EM elective courses. Then, as a result of the change in 0660-471 prerequisites, the course number was changed from 0660-471 to 0660-371.

Conclusion

This paper described the process employed by the IMSE program at Kuwait University to continuously improve its program. Using a continuous improvement framework, the paper demonstrated how continuous improvement can be performed based on evaluations of the assessment data. ABET general criterion 4 states that "The program must regularly use appropriate, documented processes for assessing and evaluating the extent to which the student outcomes are being attained". The framework described in this paper to achieve this goal can be used by other engineering programs while going through ABET process.

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