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Development of engineering programs learning outcomes in light of the Kingdom of Saudi Arabia's Vision 2030

Hamed M. Almalki [1,*], Ashraf E. Balabel [2] and Mostafa A. Kamel [3]

[1] *Department of Industrial Engineering, College of Engineering, Taif University, P.O. Box 11099, Taif 21099, Saudi Arabia.*
[2] *Department of Mechanical Engineering, College of Engineering, Taif University, P.O. Box 11099, Taif 21944, Saudi Arabia.*
[3] *Department of Civil Engineering, College of Engineering, Taif University, P.O. Box 11099, Taif 21944, Saudi Arabia.*

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Abstract

Quality in higher education academic programs in general and in particular engineering education programs is one of the essential issues in the process of developing and modernizing the education system within the vision of the Kingdom of Saudi Arabia 2030. The development of engineering programs outcomes is also one of the challenges facing engineering colleges in Saudi universities. To achieve a comprehensive educational quality practice that leads to bridge the gap between engineering education outcomes and labor market requirements, engineering programs outcomes should be developed in line with the changes of the modern era and the requirements of the accelerated technological labor market. This target is one of the basic and strategic pillars for achieving this ambitious vision through the effective role of Saudi universities in this context. In the present study, the development of learning outcomes in the previous period for engineering education programs is reviewed through the National Center for Academic Assessment and Accreditation (NCAAA) as well as through the Accreditation Council for Engineering and Technology (ABET). A model for developing study plans and redesigning various engineering programs to achieve a distinct level of the quality of engineering education is presented through the National Transformation Program 2020. Through this philosophy of change to formulate learning outcomes for engineering programs and their diversity, the updated assessment methods have been reviewed and proposed to measure those outcomes in a distinct way. This study will offer a guide that helps the teaching staff to choose the most appropriate assessment methods with setting the priorities of the measurement methods for each educational outcome of the curriculum. The presented scientific paper provides a model for continuous evaluation plans of the educational process in engineering programs to achieve the goals of engineering programs that seek to distinguish their graduates and raise their productivity and increase their competitiveness in a way that suits the nature of the current labor market.

Keywords: Educational quality; Higher education; Engineering learning outcomes; Engineering educational programs; Continuous assessment plans

1. Introduction

The accreditation of the higher educational programs is one of the most challenging issues facing the higher educational institutes. The accreditation process is considered as a quality assurance process where the evaluation of each program has to be examined by an external commission according to its standards and criterion. Different international and national higher education accreditation organizations are found worldwide according to the type of the educational program and the required educational standards (Sywelem & Witte, 2009).

* Corresponding author: Hamed M Almalki

Department of Industrial Engineering, College of Engineering, Taif University, P.O. Box 11099, Taif 21099, Saudi Arabia.

Recently, the demand for higher education in Saudi Arabia has increased due to the fast changes of the modern era and the requirements of the latest technological labor market. The ability of the higher educational institutes to respond to this increased demand as well as fulfilling Vision 2030 is one of the most important challenges. Moreover, the achieving a higher educational quality that leads to bridge the gap between engineering education outcomes and labor market requirements is another challenge (Aldiab, Chowdhury, Kootsookos, & Alam, 2017).

The engineering education is the main item in achieving the objectives of Saudi Arabia vision 2030 as it is highly associated with a nation's sustainable economic and industrial development. Recently, different engineering conferences have been organized to addresses the importance of engineering education and its challenging issues. The recommendations were directed to some important trends and advancements that should be enhanced in the upcoming years in engineering education to provide novel and sustainable Saudi Arabia economic opportunities. One of the most important issues in engineering education is the curriculum improvement in view of Saudi vision 2030 and in line with the National Transformation Program 2020.

The design and the development of the curriculum are important issues in engineering education programs due to their impact on the learning outcomes and experiences provided to the graduated students. Each engineering education program should have program learning outcomes that aligned with the required graduate attributes. Development of engineering program learning outcomes that are clearly communicated, observable, demonstrable and measurable is the aim of most higher education institutions (Fitzpatrick, Byrne, & Kennedy, 2009),(Haddad, Kalaani, & El-Shahat, 2016). Moreover, a mapping of program outcomes with graduate attributes should be made.

Among the international and national higher engineering education accreditation organizations are the *Accreditation Board for Engineering and Technology* (ABET) *and National Center for Academic Accreditation and Assessment* (NCAAA).

ABET was established in 1932 under the name of Engineers' Council for Professional Development (ECPD) and changed officially to ABET in 1980. It is a non-governmental organization that accredits engineering programs all over the World. In 2007, ABET began officially to accredit international programs outside the United States. The purpose of ABET Accreditation is to ensure that essential learning outcomes are directed to academic programs offering a specific engineering degree while encouraging innovation approaches to engineering.

NCAAA is established under the Royal Decree dated 9/2/1424H. It is an independent legal entity with administrative and financial governance. NCAAA acts as the authority that responsible for quality assurance and academic accreditation in higher educational institutions and programs. ABET and NCAAA have similar accreditation criteria. Both of them have a specified program learning outcomes. These outcomes were recently revised by ABET and NCAAA for programs seeking accreditation in 2019 and later.

ABET has currently modified its old student learning outcomes (a-k) to only seven (1-7) students' outcomes with significant changes in their content. This change might have the potential to develop and improve all engineering education programs worldwide. Moreover, this modification requires a new strategy regarding to the assessment and evaluation process for the new outcomes. Table 1 illustrates the old and the new ABET outcomes with their relations.

In a similar manner, NCAAA has reviewed the National Qualifications Framework (NQF) and changed it since 1.1.2019 from 5 domains to 3 domains. The 3 new NQF includes a new category related to the "competence", which is considered as an important learning outcome for engineering students. Starting from the known definition of the learning outcomes that means statements of what a learner knows, understands and is able to do on completion of a learning process, which are defined in terms of knowledge, skills and competence, the three new NQF can be defined as follows:

Knowledge: means the outcome of the assimilation of information through learning. Knowledge is the body of facts, principles, theories, and practices that is related to a field of work or study.

Skills: means the ability to apply knowledge and use know-how to complete tasks and solve problems. (Skills are described as cognitive or practical).

Competence: means the proven ability to use knowledge, skills and personal, social and/or methodological abilities, in work or study situations and in professional and personal development.

These definitions are in the context of the European Qualifications Framework (EQF) for Lifelong Learning, April 2008. According to the new NQF, there are new templates for NCAAA academic accreditation process of the higher education programs.

In January 2020, NCAAA has modified its main learning domains adopted on January 2019 to another three domains including learning areas. These learning areas include knowledge, understanding, skills, and values. NQF has eight progressive levels in terms of scope and sequence, from level 1 (early childhood education) to level 8 (doctoral education). Therefore, learning outcomes are detailing specific requirements under a given learning area category. They are expressed in terms of cognitive dimensions, skills, and values according to the criteria shown in Table 2.

Table 1 Changes in ABET-Criterion 3 - Student Outcomes

Current Language **EAC Criteria effective 2018-2019 Cycle** **ABET-Outcomes (a-k)**	**New Language** **Approved by the EAD October Applicable beginning in the 2019-2020 Cycle** **ABET-Outcomes (1-7)**
(a) An ability to apply knowledge of mathematics. (e)An ability to identify, formulate, and solve engineering problems, science, and engineering.	(a & e) = (1) An ability to identify, formulate, and solve complex engineering problems by applying principles of engineering, science, and mathematics.
(b) An ability to design and conduct experiments, as well as to analyze and interpret data.	(b) = (6) An ability to develop and conduct appropriate experimentation, analyze and interpret data, and use engineering judgment to draw conclusions.
(c) An ability to design a system, component, or process to meet desired needs within realistic constraints such as economic, environmental, social, political, ethical, health and safety, manufacturability, and sustainability	(c) = (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.
(d) An ability to function on multidisciplinary teams.	(d) = (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
(f) An understanding of professional and ethical responsibility. (h) The broad education necessary to understand the impact of engineering solutions in a global, economic, environmental, and societal context. (j) A knowledge of contemporary issues.	(f & h &) = (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
(g) An ability to communicate effectively.	(g) = (3) An ability to communicate effectively with a range of audiences.
(i) A recognition of the need for, and an ability to engage in life-long learning.	(i) = (7) An ability to acquire and apply new knowledge as needed, using appropriate learning strategies.
(k) An ability to use the techniques, skills, and modern engineering tools necessary for engineering practice.	Implied in 1, 2, 6

The above illustrated mapping framework between the old and the new ABET student's outcomes is intended to facilitate the transition and reduce the needed changes to ensure low disruption in the assessment process. However, the new definition of the ABET student's outcomes should be clearly understood. Moreover, the new ABET and NCAAA student's outcomes ensure that students must be prepared to enter the professional practice of engineering labor market through a curriculum contained a major design experience that based on the knowledge and skills acquired in earlier courses. Also it should incorporate appropriate engineering standards and multiple constraints. The proposed changes to the ABET/NCAAA student's outcomes should improve the engineering education. However, the proposed outcomes might have a bad effect on the educational process if they were not well implemented or not correctly evaluated. Therefore, in the following section, a review of the assessment and evaluation methods for the student's outcomes will be introduced.

Table 2 NCAAA- (NQF) *Learning Domains* updates

NQF Learning Domains			
Old	**Definition**	**New (January 2020)**	**Illustration**
Knowledge	the ability to recall and present information	Knowledge & Understanding	This includes the knowledge and understanding of a learner in the area of learning, work or profession: Extensive deep knowledge, understanding of facts, concepts, principles, theories, processes, and procedures provided for in the area of learning, work, or profession. Depth of knowledge can be general or specialized. Breadth of knowledge can range from a single topic to Multi-disciplinary area of knowledge. Types of knowledge range from concrete to abstract, from segmented to cumulative. Complexity of knowledge type, depth and breadth.
Cognitive Skills	the ability to apply concepts and principles in thinking and problem solving	Skills	The Learning area includes skills what a graduate can exhibit in applied settings (such as in school, training, internships, work, etc.). The various types of skills are: <u>Cognitive skills:</u> These include critical thinking and problem-solving skills, inquiry, and creativity. <u>Practical and physical skills:</u> These include using appropriate materials, devices, and tools, and applying motor and manual skills with ingenuity. <u>Communication and information technology skills:</u> These include written, verbal, and non-verbal communication, numeracy skills, and the use and production of information and communication technology.
Communication, Information Technology, Numerical	includes basic mathematical and communication skills and ability to use communications technology		
Psychomotor	are important in some fields of study and are considered as an additional domain where relevant to the program concerned		
Interpersonal Skills & Responsibility	the ability to work effectively in groups, exercise leadership, and take responsibility for their own independent learning, and the ethical and moral development that is associated with these abilities	Values, Autonomy & Responsibility	These include what a learner exhibits in terms of principles, ethics and standards for personal and professional success and well-being. Academic, professional values, and ethics. Continued self-learning and autonomy. Teamwork and responsibility.

Assessment and evaluation processes are considered to be the most controversial issues in higher education today (Struyven, Dochy, & Janssens, 2005). Assessment and feedback were ranked the least satisfied by students (Struyven, Dochy, & Janssens, 2005). Assessment as feedback should be focused more on practices to improve student learning. Many current assessment systems do not allow students to improve their own learning strategy because the assessment process is considered to be an endpoint process instead of performing the assessment process at the beginning of the module or as intermediate step, more details can be found in (C. W. McGlothlin, 2007). Currently, a little work has been published concerning the assessment methods of new-ABET programs learning outcomes. Most of recent work try to

discuss the new expressions included in the new text of the ABET outcomes (1-7); e.g. 'complex engineering problems', 'communicate effectively with a range of audiences', 'engineering judgment'. It is important to find out 'what do these expressions mean?' and 'how do we measure?' as the new ABET outcomes are now official. In the present paper, a new developed assessment plane is introduced in order to assess all of the seven new outcomes in the engineering education programs.

2. Improvement of current engineering programs according to (NTP2020)

The National Transformation Program 2020 (NTP2020) was launched at the beginning of the year 1437 AH with the participation of the Ministry of Education in KSA as one of the main programs for achieving the goals of the Vision 2030. The most important challenges facing education have been identified including weak students' personal and critical thinking skills, poor alignment of education and training outcomes with the market needs, low quality of the curricula, reliance on traditional teaching methods, and poor evaluation and assessment skills. For this issue, Taif University (TU), as one of the institutions of higher education, activated the national transformation program for academic programs. The main considered criteria for modifying the study plans of all programs were to address the main challenges facing education in addition to minimize the gap between higher education outcomes and market needs.

Civil Engineering Program (CEP) is one of such programs that had been modified under the NTP2020. The modified version was created fulfilling the international and national academic standards of both ABET and NCAAA. Not only that but also, it contributes to build its graduates' attributes compatible with the market needs, as well as with TU graduate attributes, which in turn targeted to achieve of the goals of the Kingdom's Vision 2030. Table 3 introduces the main added courses in the modified version of CEP study plan coupled with its importance.

Table 3 Main Added Courses in the Modified Study Plan of CEP and Their Importance

Added Courses	Importance
University Study Skills	Enhancement of students' skills of life-long learning through learning of different searching tools. In addition, students will be given many team-work activities that will contribute in enhancement of students' skills of such issue.
Engineering Ethics	Awareness of students of their professional responsibilities and applying whatever they will study through CEP study plan in their professional life after graduation.
Technical Reports	Enhancement of the students' presentation skills.
Two Additional Specific Courses of Technical English Language	Enhancement of the students' presentation skills.
Sustainable Infrastructures Projects	Awareness of students of the importance of sustainability concept and its applications in civil engineering. This is very important to achieve the KSA 2030 vision that which maximizes the concept of sustainability, which guarantees the economic and environmental considerations as well as the provision of natural resources.
Applications of Nanotechnology in Civil Engineering	Awareness of students of the new trends in material science and their uses in different civil engineering applications.
Railways engineering	KSA starts to expand its railways network during the ongoing decade to achieve the goals of the Vision 2030. It is important to have graduates supported with the knowledge and required skills that will build and operate the infrastructures of the railways' networks.

3. Proposed assessment plan for civil engineering program

To ensure that graduates of the CEP satisfy the students' outcomes (SOs), the curriculum must ensure achievement of each unique student outcome. Therefore, CEP uses a regularly appropriate, documented process for assessing and evaluating the extent to which the student outcomes are being attained. The results of these evaluations are

systematically utilized as input for the continuous improvement of the program. In this regard, a mapping was established relating the offered courses through the curriculum with different SOs. This mapping was conducted by looking at the syllabi of each course to find the most appropriate part to measure each outcome. In addition, the most suitable assessment tool is also considered during the choice of the supported outcomes by each course.

The assessment methods include direct methods of assessment which are based on the evaluation of demonstrated student performance (e.g., on an exam, project, etc.) relative to an outcome. In addition, indirect methods of assessment could be also employed which are based on self-assessment, opinions, recollection, etc.

Assessment Methods of Students Outcomes (SOs) — (√•) Priority

Students' Outcomes			Assessment Methods									
ABET		NCAAA	Class Activities								Written Exams	
Code	Text	Code	Assignments	Quizzes	Reports	Presentations	Mini-Projects	Questionnaire	Oral/Group Discussions	Lab. Performance	Mid-Term	Final
1.	an ability to identify, formulate, and solve complex engineering problems by applying principles of engineering, science, and mathematics.	S1	√				√•				According to each instructor, the written Exams can measure any suitable outcome e. g., SOs (1, 2, 6 and 7) through the appropriate questions.	
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.	S2					√					
3.	an ability to communicate effectively with a range of audiences.	S4				√•			√			
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.	V2			√		√•	√•				
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.	V1					√•	√		√		
6.	an ability to develop and conduct appropriate experimentation, analyze and interpret data, and use engineering judgment to draw conclusions.	S3			√					√•		
7.	an ability to acquire and apply new knowledge as needed, using appropriate learning strategies.	K1	√	√	√•	√						

Learning Domains						
Knowledge and Understanding	Skills				Values, Autonomy & Responsibility	
K1	S1	S2	S3	S4	V1	V2
7	1	2	6	3	5	4

Figure 1 Guidelines for mapping between Different ABET/NCAAA SOs and all Used Assessment Methods

The specific outcomes of instructions (SOIs) of a specific course are the statements that describe what the students are expected to know and able to perform by the end of this course. The proposed assessment plan is mainly based upon the mapping between SOIs of each course to a set of SOs that were previously determined through the mapping of all program courses to the SOs. Each instructor determines which SOs relates to SOIs covered in that course. Moreover, he has to choose the most suitable assessment method for each topic and hence, he can assess each SO through one or more instrument.

Through direct assessment methods, the instructor related each instrument to the different SOIs of the course, the level of achievement of those SOIs is used as a measure of the student's achievement of the different SOs of the course. In this measurement process, all results of all students in a course had been used in the calculation of the achievement of SOs in that course. CEP has adopted two measures for the attainment levels of different SOs. At the course level, the percentage of students achieving a predefined set of attainment levels for the course level (SAEL) is the first measure. While, the average score of all students in a specific outcome is the second additional measure for attainment levels of different SOs. Both measures are helping the instructor to define the barriers faced him during the teaching of the course and also the improvement actions will be accurately specified.

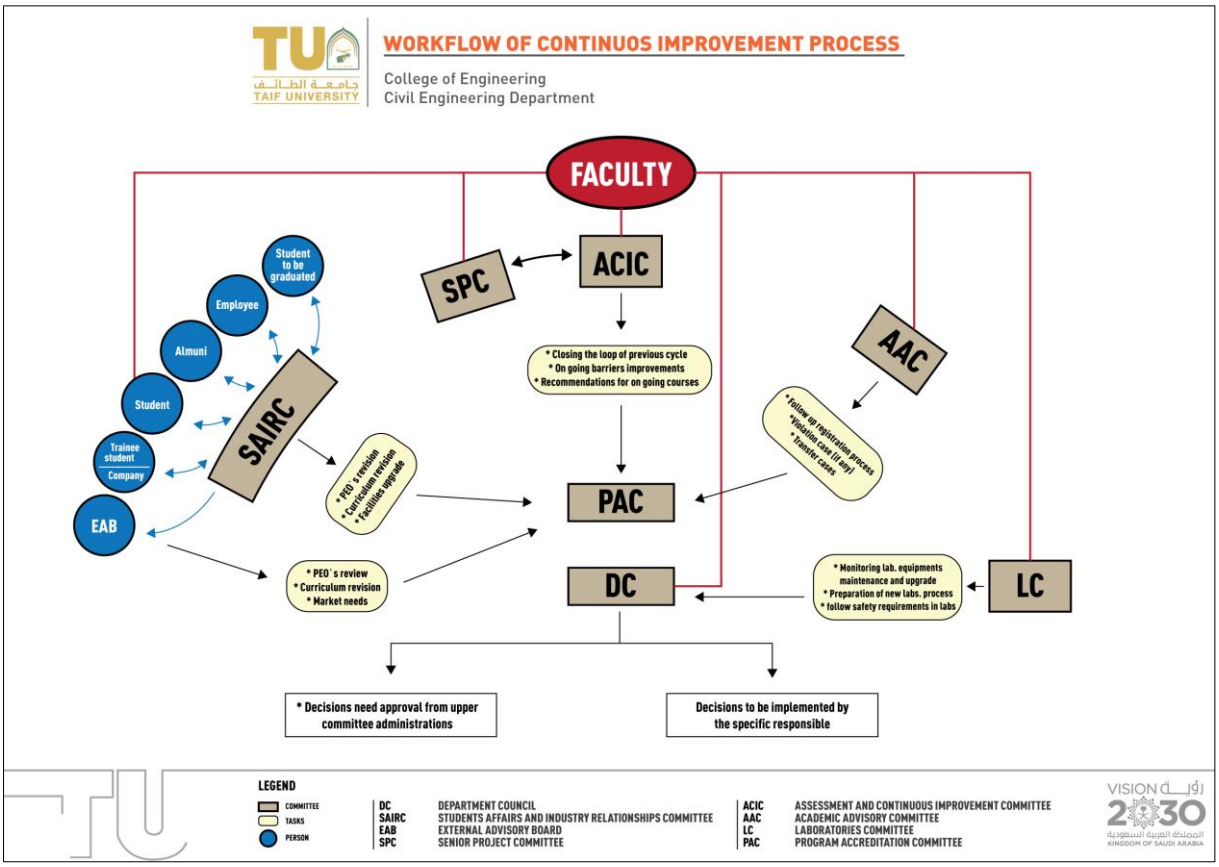

Figure 2 Workflow of the Continuous Improvement Process for CEP

On the other hand, the indirect assessment methods measure the attainment level of each SOI of the course through the viewpoint of the students of the course. Hence, each student is asked to complete a survey at the end of a semester indicating the level of satisfaction of his achievement of the different SOIs of the course. The scale provided for students ranges from 0 to 10 which will be counted as a percentage of satisfaction level varying from 0% to 100%. In this measurement process, all students were asked to participate and subsequently, their responses were used in the evaluation process for each course. The instructor has to specify a sperate SOI for each topic, this will help him to find out the satisfaction level of students of each topic and subsequently, he can touch the gaps in learning or understanding of each topic.

CEP has specified a simplified mapping between all supported SOs, either for ABET or NCAAA, and different assessment methods. It includes also the priority of assessment methods relevant to a specific SO especially for SOs that can be assessed by various instruments. Figure 1 shows this mapping incorporating the priority of assessment methods and also it shows the adopted mapping between ABET SOs and NCAAA under different domains of learning.

It should be pointed that; each course will provide assessment data in a spread excel sheet and the assessment coordinators will compile the data and present to the upper committees in the dept. for discussion and evaluation. The faculty was extremely supportive of this format for providing data. They expressed satisfaction at the clear visual guides (colors) and the fact that the pre-set mapping of the outcomes (that they had help set) provided the context and clarity on the reporting requirements. The use of spreadsheets with fixed contents allows the possibility of writing automated scripts to gather and compile the data, which is one of the on-going activities in the department.

CEP has established some procedures to check the closing of the continuous improvement loop. This process would ensure that there would be no gaps. These procedures have been implemented for both course level and program levels.

For the course level, a sheet is incorporated in the Course Assessment Report (CAR). This sheet included inquiries about closing the loop of the previous cycle. The main inquiries related to closing of the loop of the continuous improvement for a specific course include:

- Is there an improvement plan available for implementation for this course from the experience of previous year/semester?
- Who was responsible for improvement plan?
- Was the improvement plan implemented?
- Was the satisfaction criterion met?

For the program level, CEP has adopted a collective electronic sheet designated as Program Continuous Improvement Work Sheet (PCIW) which is prepared each semester. The sheet is collecting all the barriers and improvements pointed by the instructor of each course as well as the final recommendations by all the upper committees till the actions decided by the dept. council. Not only that but also the effect of the taken actions on the achievement levels of SOs after implementation during the next cycle of this course. Figure 2 is showing the workflow of the continuous improvement process for CEP.

4. Conclusion

Quality in engineering education programs is one of the essential issues in the process of developing and modernizing the education system within the vision of the Kingdom of Saudi Arabia 2030. This study offers a guide that helps the teaching staff to choose the most appropriate assessment methods with setting the priorities of the measurement methods for each educational outcome of the curriculum. The proposed a model for developing study plans and redesigning various engineering programs is to achieve a distinct level of the quality of engineering education.

Compliance with ethical standards

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Conflicts of Interest

The authors declare no conflict of interest.

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