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IMPROVING ENGINEERING EDUCATION AT KUWAIT UNIVERSITY THROUGH CONTINUOUS ASSESSMENT PART 1: ESTABLISHING THE PROCESS

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ABSTRACT

The initial stages of development and implementation of assessment plans for the engineering programs at Kuwait University are presented. The plans are based upon an integrated set of strategies aimed at: establishing and maintaining a structured process that translates educational objectives into measurable outcomes, and specifies feedback channels for corrective action; providing necessary assessment training; creating an assessment toolbox, and identifying and reviewing key institutional practices to ensure that they are aligned with the assessment process.

Keywords: *ABET, EC2000, outcomes assessment, curriculum development*

الملخص

يوضح هذا البحث المراحل الأولية لتطوير و تفعيل خطط التقييم لبرامج الهندسة في جامعة الكويت. لقد تأسست خطط التقييم هذه على مجموعة متكاملة من الإستراتيجيات التي هدفت إلى: تأسيس و إتباع آلية لترجمة الأهداف التعليمية إلى مخرجات قابلة للقياس و لاختيار القنوات الإنتقادية الازمة لتحسين الاداء, توفير التدريب الضروري للقيام بعملية التقييم, ابتكار الأدوات المطلوبة لعملية التقييم, وتحديد و مراجعة الممارسات المتبعة للتأكد من توافقها مع عملية التقييم.

1. INTRODUCTION

The College of Engineering and Petroleum at Kuwait University, in line with its efforts to improve and maintain the quality of engineering education offered by its programs, initiated external evaluations conducted by the Accreditation Board for Engineering and Technology (ABET). So far, there have been several ABET evaluations of engineering programs at the college. All evaluated programs were found to be substantially equivalent to accredited programs with similar titles in the United States. Recently, ABET introduced the new Engineering Criteria 2000 (EC2000) which address the effectiveness of engineering education programs by focusing on an assessment and evaluation process that assures the achievement of a set of educational objectives and outcomes. Though ABET has not yet started implementing EC2000 in the substantial equivalency evaluations [Phillips et al., 2000] the college viewed this paradigm shift as an opportunity to better structure its curriculum, instruction and assessment practices. Therefore, a process has been initiated to develop comprehensive assessment plans for each engineering program. The plans include a structured process that translates educational objectives into measurable outcomes at the program and course levels, development of required assessment instruments, and identification of relevant institutional practices, which may need to be aligned with the assessment process. Recently, Kuwait University Research Administration funded a three-year college project to help develop the process further. In the current paper the experience in developing and implementing assessment plans is presented. Improvements are already evident in the areas of teaching effectiveness, assessment of student learning, and involvement of all the constituents.

2. ABET ENGINEERING CRITERIA 2000

The conventional criteria were restrictive and focused on counting resources used to achieve an acceptable standard. The new ABET EC 2000 [ABET, 1996], on the other hand, address the effectiveness of engineering education programs by focusing on setting educational objectives and outcomes, and an evaluation process that assures their achievement. Eight basic level accreditation criteria comprise the EC 2000. Criteria 2 and 3 address educational objectives and outcomes assessment. Criterion 8 deals with program specific outcomes. The remaining criteria deal with the resources necessary for the program to be able to achieve its objectives.

Criteria 2 and 3 require two major feedback systems. One system focuses on educational objectives while the other focuses on the learning outcomes that the graduates need to demonstrate. The educational objectives system deals with long-term issues, and the interfaces with the program's constituencies (e.g., faculty, students, alumni and employers). The learning outcomes system deals mainly with daily issues that faculty and administrators must consider. The interaction of the two systems is the requirement to demonstrate success and improvement in the program. Therefore, both criteria call for an assessment and evaluation process that measures and demonstrates the achievement of these objectives, and uses the results to improve the program.

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3. ASSESSMENT PLAN DEVELOPMENT

The plan and methodology for establishing the asssesment process is built upon an integrated set of strategies [Rogers and Sando, 1996; McGourty, 1998; Besterfield-Sacre et al., 2000]. These strategies work together as a system to support the development, implementation and institutionalization of a comprehensive assessment and continuous improvement process for the programs of the college. Each strategy complements and supports the others. The explanation of the strategies and the associated tasks and accomplishments are given below:

Strategy 1. Refine and maintain a structured process

This strategy aims at building a foundation for strong assessment and continuous improvement, by providing all participants with a road map to follow. A structured process has already been initiated and is in progress. In the spirit of the cyclic nature of assessment and improvement, the process is being refined and maintained to ensure that:

- all the constituents (administrators, faculty, staff, students, alumni, employers etc.) are actively involved in defining educational objectives and learning outcomes, identifying appropriate assessment methods, and deciding how the assessment information is used for future decisions;
- clear guidelines are provided, to help establish expectations and common language to support communication and collaboration among participants; and
- assessment processes and methods measure what they are supposed to measure in a consistent and cost-effective manner, yielding useful information that leads to continuous improvement.

The assessment process is driven by a set of educational objectives, which are derived from the College mission and vision, and in accordance with the EC 2000. The educational objectives of the engineering programs are:

1. to impart in students a sound understanding of the fundamentals of mathematics, science and engineering science, and to develop the necessary analytical skills relevant to engineering practice;
2. to foster in students the skills for effective teamwork and communication;
3. to develop in students the skills pertinent to the engineering profession such as the identification, formulation, and solution of engineering problems and design through the use of appropriate analytical, computational and experimental tools;
4. to instill in students professional and ethical responsibility, and an understanding of the impact of engineering solutions on society; and,
5. to motivate students to engage in life-long learning and knowledge of contemporary issues.

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The mission statement and these objectives have been published in the "Undergraduate Bulletin" of the college and in the college web site [Kuwait Univ., 2002]. These objectives were first drafted by the faculty in 1998 and revised in December 2000 based on preliminary evaluations as well as feedback from most of our constituents (i.e., students, faculty, administrators, and the employers).

The process of academic decision-making involves all major constituencies and has been in place essentially since the establishment of the college, though various modifications have been made over time. Prior to 1998 the objectives of all Engineering programs were derived from the objectives of the college and the university with limited involvement of constituencies at the program level. A formal process involving all constituents has been in place only at the university and college levels. Recognizing the importance of involving the constituents at the program level, the departments initiated External Advisory Boards, and Student Advisory Councils.

Recently, the college has established the Office of Academic Assessment. The objectives of this office are:

- to help coordinate program assessment processes;
- to develop and implement regularly-scheduled and special-purpose faculty, student, alumni, and employer surveys;
- to assist academic, administrative, and student-support units with data from assessments, and to develop or evaluate their own assessment processes; and
- to facilitate assessment training and awareness programs.

It is proposed that the objectives are evaluated every five years based on the assessment process and other inputs from all constituencies. The decision-making and evaluation process regarding various issues at the program level involves the following bodies and committees:

The External Advisory Board consists of distinguished leaders in industry, government, and academia with experience in program activities. The board works with the administration of the department for review and critique to assure that the academic programs meet expected standards as well as the needs of the industry and the country at large. The board meets at least once a year on campus. They attend presentations on the state and challenges of the department and give their opinion at the meeting or later.

The Student Advisory Council consists of elected or nominated students, and a non-faculty departmental representative. The mission of the council is to improve the experience of students, to provide a voice for the students to the administration, and to act as an advisory capacity to the department chair. The council has monthly meetings.

The Undergraduate Program Committee is a standing committee of the faculty. Its composition is such that all program areas are represented. In addition, one member coordinates assessment activities with the office of academic assessment. The committee is responsible for curriculum development and review including setting academic policies, approval of new courses, reviewing assessment information, and periodic review of the curriculum.

Teaching Area Groups (TAG) are formed based on the current teaching interests of faculty. These groups advise the Undergraduate Program Committee on various matters related to the courses assigned to a particular group. The tasks include choice of textbooks, updating of course syllabi, and reviewing the assessment information.

A number of other committees are involved in improving the quality of academic environment such as student advising, faculty promotion, appointment and contract renewal, scholarship, laboratory, computing facilities, budget and planning. The advising committee is responsible for advising and counseling students to ensure a healthy progression towards graduation. Faculty promotion and retention are closely linked to satisfactory performance in teaching undergraduate courses. The college has a scholarship program to ensure the programs have sufficient Kuwaiti faculty in all curricular areas. Laboratories and computing facilities are constantly being upgraded to ensure that the students have access to state-of-the-art facilities. The budget and planning committee works closely with the whole department to ensure that adequate funds are allocated.

Strategy 2. Provide assessment awareness/training for faculty and students

In order to instil a structured process in the academic culture, professional related activities, including seminars and workshops, have been organised and delivered to all concerned in the assessment process. Firstly, the activities help administrators, faculty and students to get involved in the process through constructive debate and understanding of the assessment language, implementation issues and concerns. Secondly, the activities provide training skills required in the assessment operations, ranging from developing valid assessment methods to interpersonal feedback skills, with the students receiving timely and consistent feedback on their performance. Thirdly, the activities provide faculty with the necessary support as they adopt new instructional models and take a closer look at their teaching methods.To date, the following training and awareness activities have been conducted:

- Meetings with various units within and outside college to coordinate relevant assessment activities.
- A series of meetings with the assessment coordinators (Undergraduate Program Committees) to plan program assessment.
- Departmental briefings to introduce the basic framework of assessment and to instill the required culture of assessment.

- Faculty training workshops and seminars.
- Seminars and open meetings with employers from both private and public sectors.

Strategy 3. Create an assessment toolbox

Assessment tools are required to evaluate the stated outcomes and provide quantitative meaurements. The main concern here is to avoid the tendency of designing too many assessment tools that might prove redundent or unnecessary. For this reason, the objectives and outcomes of all programs were studied and a number of unified instruments or what is called a common "assessment toolbox" was created. The toolbox contains a number of templates that the faculty and students can utilize to support the assessment of learning outcomes. Some of the instruments are made available on-line for automation of data collection and analysis.

Strategy 4. Align key institutional practices with assessment process

This strategy is very important to institutionalise a comprehensive assessment process college-wide and eventually university-wide. There are many institutional practices that must be aligned with the objectives of the assessment process. Such practices include but not limited to: admissions, current teaching evaluations, new course approval mechanisms, faculty orientation, rewards system, course load, promotion practices, tenure and contract system, cross-departmental and college linkages, and industrial advisory board. These practices are currently been reviewed to identify which ones will enable or hinder an effective assessment process. It should be emphasized here that, the administration and faculty must work together to modify miss-aligned practices in order for the assessment and continuous improvement to become successful and embedded into the educational environment.

4. PROGRAM OUTCOMES AND IMPLEMENTATION OF ASSESSMENT

The curricula for the engineering programs are thoroughly based on mathematics, science, engineering science, and design to fully ensure achievement of program educational objectives. Program educational objectives are used to establish both the program outcomes and specific objectives for individual courses in the program. Measurable outcomes for each course objective and the assessment methods used are given in the course syllabi for all courses offered by the programs.

An assessment process is in place to ensure the achievement of the program educational objectives. The curricula and the processes that are used to ensure the achievement of program educational objectives are continuously reviewed and modified according to inputs from various constituents. Recommendations from periodic external evaluations such as ABET visits are also considered.

Program outcomes are derived from program educational objectives and satisfy the outcome requirements of ABET EC2000 Criterion 3 as well as applicable Program Criteria (ABET Criterion 8) [Rogers and Sando, 1996; Christoforou et al., 1999]. As an example, the Mechanical Engineering Program outcomes are given below:

1.1 Students will have the ability to develop proper mathematical models for engineering systems and to solve the mathematics analytically or numerically.

1.2 Students will be able to recognize the involvement of physics and chemistry in modeling an engineering system and to apply successfully the appropriate concepts to obtain reasonable predictive models or verify noted systems behaviors.

1.3 Students will be able to integrate concepts from mathematics and science with other knowledge to obtain reasonable predictive models or explain behaviors.

2.1 Students will be familiar with the requirements for effective leadership and will perform effectively as members of teams.

2.2 Students will communicate effectively in oral and written form.

3.1 Students will have the ability to identify, formulate, and solve engineering problems

3.2 Students will have the ability to design and conduct laboratory experiments and critically analyze and interpret experimental data.

3.3 Students will be familiar with current technology and be able to utilize state-of-the-art hardware and software in problem solving and design.

3.4 Students will be able to design, and realize both thermal and mechanical systems, components, or processes, to meet desired needs.

4.1 Students will have the ability to identify, and critically analyze ethical issues, which arise in real engineering situations.

4.2 Students will be prepared to perform under professional obligations of the codes of ethics and to adhere to the highest principles of ethical conduct during the course of employment after graduation.

4.3 Students will have the broad education necessary to be aware of their responsibilities in safety, health, welfare, and well-being of the society and the environment during the performance of their professional duties.

5.1 Students will be committed and motivated to life-long learning as a necessity for survival in the profession and will be confident in their capabilities to acquire new knowledge independently.

5.2 Students will be aware of emerging technologies and of their impact in a local and global context and get involved in analyses and discussions of contemporary issues related to society, environment, safety, and public health.

These outcomes are related to the outcome requirements of Criterion 3(a-k), and Criterion 8(l-o) as shown in Table 1. As mentioned above these outcomes are directly derived from the program educational objectives. The numbering system used clearly indicates the relationship between the program outcomes and educational objectives (e.g., Outcome 1.1 means the first outcome derived from Educational Objective 1).

All program outcomes are embedded into the curriculum through the course objectives and outcomes. The faculty describe how course objectives are related to the program outcomes, and the requirements of Criterion 3 and 8. In addition, the faculty indicate to what extent the specific outcome is relevant to the course taught, as shown in Table 2 for the Mechanical Engineering curriculum. Additional information can be found in the course syllabi [Kuwait Univ., 2001].

Table 1: The relationship between program outcomes and ABET requirements

Program Outcomes	**ABET Outcomes**														
	Criterion 3											**Criterion 8**			
	a	**b**	**c**	**d**	**e**	**f**	**g**	**h**	**i**	**j**	**k**	**l**	**m**	**n**	**o**
1.1	X											X		X	
1.2	X												X		
1.3	X											X	X	X	
2.1				X											
2.2				X			X								
3.1					X						X				
3.2		X													
3.3											X				
3.4			X												X
4.1						X									
4.2						X									
4.3								X							
5.1									X						
5.2										X					

The assessment process involves both course level and program level assessment practices. As indicated in Table 2, each course in the curriculum addresses some of the ABET specified outcomes. The level at which these outcomes are addressed is specified as High (H), Medium (M) and Low (L).

Table 2: The relationship between the courses in the curriculum and ABET requirements

Courses	ABET Outcomes														
	Criterion 3											Criterion 8			
Requirements	**a**	**b**	**c**	**d**	**e**	**f**	**g**	**h**	**i**	**j**	**k**	**l**	**m**	**n**	**o**
Humanities and Social Science electives (12 credits)								H		H					
English language courses (6 credits)							H								
Math and science courses and labs (27 credits)	H											H	H	H	
Basic Engineering Requirements	**a**	**b**	**c**	**d**	**e**	**f**	**g**	**h**	**i**	**j**	**k**	**l**	**m**	**n**	**o**
Engineering Workshop	L					H		M			H				
Engineering Graphics	L						H				H				H
Computer Programming For Engineers					L						H				
Statics	H				H						L				
Dynamics	H				H						L	H	H		
Strength of Materials	H		M		H										
Electrical Engineering Fundamentals	H				H						M	H	H		
Electrical Engineering Fundamentals Laboratory	M	H			M	L	M				M				
Engineering Thermodynamics	H				H	M		M			M	L			
Engineering Economy	M		M		M			H	M	H	M				
Engineering Probability And Statistics	H				H			M	M	M	M			H	
Numerical Methods In Engineering	H				M						H				
Mechanical Engineering Requirements	**a**	**b**	**c**	**d**	**e**	**f**	**g**	**h**	**i**	**j**	**k**	**l**	**m**	**n**	**o**
Materials Science And Metallurgy I	H	M	L	L	M		L	L	L	M	L				M
Introduction To Design	M		H	H	H	H	H	H	M	M	H				M
Theory Of Machines	H		M	L	H	L	M	M	M	L	M	L		M	M
System Dynamics	H		L	L	H	M	M	L	L	L	H	H	H	M	M
Engineering Thermodynamics II	H		H		H		M	M	M			L		L	
Fluid Mechanics	H		L	L	H	L	M	M	L	L	M	M	M		H
Mechanical Design I	M		M	M	H	L	H	M	M	M	H				M
Manufacturing Processes	L		H	H	H	M	H	H	M	M	H	L			M
Engineering Fundamentals Laboratory	M	H	M	H	M		H				M			H	H
Mechanical Vibrations	H		M		H	M	M	M	M	M	H	H	H	H	M
Control Of Mechanical Systems	H		H	M	H	M	M		M	L	H	H	H	M	M
Heat Transfer	H		M	H	H	M	H	M	L	L	H	M	H	L	
Refrigeration And Air Conditioning	M		H	M					M	L	M	M			M
Mechanical Design II	H		H	M	H	H	M	M	M	M	M	M		L	M
Computer Aided Design	H		H	H	H	H	H	M	M	M	H				H
Engineering Design	H	M	H	H	H	H	H	H	H	H	H	M	H	H	M
Thermal Science Laboratory I	H	H	M	M	M		M				M			M	M
Dynamics Of Machines And Mechanical Vibration Lab.	M	H	M	M	M	M	H	M	M	M	H			M	M
Thermal Science Laboratory II	H	H	M	M	M		M				M			M	M
Control Of Mechanical Systems Laboratory	H	H	L	L	M	H	H	L	L	L	H	H	M	H	M
Mechanical Engineering Electives	**a**	**b**	**c**	**d**	**e**	**f**	**g**	**h**	**i**	**j**	**k**	**l**	**m**	**n**	**o**
Technical electives (15 credits)	H	L	H	L	H	H	M	M	M	M	H	H	H	M	M

A designation of H for an outcome in a course indicates that demonstrating this knowledge or skill is critical for the student to perform successfully in the course, and it is one of the most important outcomes of the course. If demonstrating this knowledge or skill has considerable impact on the overall performance of the student a designation of M is assigned.

A designation of L indicates that demonstrating this knowledge or skill has only minor impact on the overall performance of the student. These designations are assigned by the TAGs.

At the course level, the individual instructors perform the initial assessment. The main assessment tool used is the Instructor Class Evaluation Form. This form reports the grade distribution as well as the assessment of program outcomes served by the course. Depending on the nature of the course, in addition to sample student works submitted as evidences, instructors use specific tools, such as team evaluation form, written report evaluation form, etc. to document their assessment. The teaching area groups perform the second assessment at the course level. Each group evaluates the assessment results for the courses in their area to ensure the achievement of course objectives. In addition, they provide feedback to the undergraduate program committee for program level assessment. The committee evaluates the assessment results and recommendations of the teaching area groups as well as other assessment results (e.g., exit, alumni, employer surveys) to ensure that the graduates are achieving the program outcomes.

The assessment process established in the departments and the college works in a continuous improvement cycle. The undergraduate program committee in cooperation with the department chair reviews the results of the assessment and compares them to the established criteria. Based on the analysis one of the following actions are taken [Clemson Univ., 1999]:

- The existing criterion is met: In this case, the criterion is reviewed and the results reported to the faculty and the college through the Office of Academic Assessment.

- The existing criterion is not met: In this case an investigation is carried out to determine the causes. In some cases, an assessment tool or method used to measure an outcome may need improvement. If this is the case, the undergraduate program committee recommends the appropriate changes to address the shortcomings. In certain cases, the criterion itself may not be appropriate and needs revision. In other cases, there may be deficiencies or shortcomings in the curriculum, practices or policies. For these cases, the undergraduate program committee studies the problem, and recommends possible corrective actions, which may include curriculum revision, policy changes, and communication to appropriate committees within the department or to the Office of Academic Assessment for further action.

5. SUMMARY AND CONCLUSIONS

The initial stages of the outcome assessment process development have been presented. A structured process that includes development of measurable outcomes, assessment tools, and feedback mechanisms has been established for all engineering programs. The process has been in place for about an academic year. Faculty are participating in course and program level assessments. The students are being informed about the outcomes. They are also part of the process through course evaluations/surveys and exit surveys. Student advisory councils

are also being established at the department levels. Employers and alumni have also been involved through specially designed surveys. Preliminary results show that the process is working, though some adjustments need to be made on the course objectives and outcomes, as well as some assessment instruments. Plans are currently underway to review and evaluate the available assessment results. It is anticipated that the curriculum and assessment plans will be revised accordingly. Existing assessment tools are currently being unified for ease of data management and correlation.

It is clear that assessment is multilevel, multidirectional and with many interfaces, and thus very challenging [McGourty, 1998]. Therefore, maintaining and improving cooperation and participation of all concerned parties is of paramount importance at this stage. The willingness to make and apply decisions, adapt and change the curriculum for continuous improvement is the guiding principle. In doing so, care is taken not to overwhelm the faculty and the students. Finally, institutional practices beyond the college level (e.g., admissions, teaching evaluations, new course approval mechanisms, faculty orientation, rewards system, course load, promotion practices, tenure and contract system, cross- college linkages, etc.) must be reviewed for miss-alignments that may hinder an effective assessment program [McGourty, 1998].

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