

OUTCOMES ASSESSMENT IN CHEMICAL AND PETROLEUM ENGINEERING PROGRAMS

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Abstract: This paper describes the establishment, revision and assessment process for educational outcomes of chemical and petroleum engineering programs. This process is initiated by defining the Chemical and Petroleum programs outcomes to match the ABET (A-K) EC2000 criteria since program outcomes are the most important part of the educational process and must foster attainment of program educational objectives. Then a variety of direct and indirect assessment tools are proposed to determine how well graduates from both engineering programs are meeting the established outcomes. Three direct tools are implemented in the assessment process, namely; course / curriculum assessment, exit exam and capstone courses. The proposed indirect tools include internship advisor survey, course assessment by students, alumni survey, employer survey, students exit interview, and industrial advisory board. A schedule for collecting the assessment data to support the review of program objectives, outcomes, and curriculum is recommended. The overall assessment of achievement of program outcomes is performed by averaging the proposed assessment tools using a weighting factor designed to provide some judgment on the importance, quality, and number of feedbacks of each tool. Programs details and the results of the assessment process for one cycle are presented in this paper. Application of the outcome assessment results in the continuous improvement of both programs is also addressed.

Keywords; chemical engineering; petroleum engineering, outcomes assessment; assessment tools; curriculum evaluation; ABET accreditation

1. INTRODUCTION

The chemical and petroleum engineering department at the United Arab Emirates University was established in 1980. The mission of the Chemical and Petroleum Engineering programs is to meet the educational, research, and service needs of UAE society by providing programs and services of the highest quality. Also it contributes to the expansion of knowledge by conducting quality research and by developing and applying modern engineering tools and techniques that could play a significant role in the technical and economic development of the country.

The Accreditation Board for Engineering and Technology (ABET) is a professional accrediting organization in USA that accredits engineering, technology, computing and information science, and engineering related programs in the United States and internationally (Petrova et al., 2006).

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The objectives of ABET accreditation are to serve the public, industry, and the profession by stimulating the development of improved engineering education, encouraging new and innovative approaches to engineering education, and assuring that graduates of an accredited program are adequately prepared to enter and continue the practice of engineering. The new developed criteria of ABET for accrediting engineering programs EC 2000 (A-K) have changed the way that engineering programs prepare their graduates (Bai and Pigott, 2004). In order to survive in the future, each program has to develop a strategy to meet the new requirements specified in the EC2000 (A-K).

The Chemical (CHME) and Petroleum (PETE) Engineering programs at the United Arab Emirates University (UAEU) are designed to fulfill the ABET (A-K) EC2000 criteria. The Department of Chemical & Petroleum Engineering has established a well-defined process for outcomes assessment for the Chemical and Petroleum Engineering Programs in order to ensure that their graduates achieve the program educational objectives. Three direct tools are implemented in the assessment process, namely; course / curriculum assessment, exit exam, and capstone courses. The proposed indirect tools include internship advisor survey, course assessment by students, alumni survey, employer survey, students exit interview, and industrial advisory board (CHME Self Study Report, 2009; PETE Self Study Report, 2009).

This paper aims to describe the establishment, revision and assessment process for educational outcomes of chemical and petroleum engineering programs.

2. PROGRAM OUTCOMES

The College of Engineering at UAEU was inaugurated in September 1980 with two academic departments; the Civil Engineering Department and the Chemical & Petroleum Engineering Department. The Chemical & Petroleum Engineering department continued to offer a joint degree in Chemical & Petroleum Engineering until 1988, and since then separate degrees in Chemical Engineering and Petroleum Engineering have been offered. During that period, substantial equivalency to ABET accredited Chemical and Petroleum Engineering programs was granted twice. The programs are now under a new review by ABET and it is hoped that it will be granted full accreditation.

The program outcomes were established on the basis of the needs of the country, outcomes of other institutions, ABET A-K criteria, university and college strategic plans, feedback from industry through Open House activities, comments of students through interviews and other contacts, and better fulfillment of the outlined objectives and the constituencies' needs. After several revisions and input from the CHME Department Council and the College administration, the CHME and PETE program outcomes were consolidated to become identical to the required ABET A-K outcomes of Criterion 3 (i.e., outcome assessment) of Engineering Criteria 2000, which is required for continuous accreditation of the programs. Upon graduation every student in each program will have achieved all of the intended program educational outcomes and as shown in Table 1 (CHME Self Study Report, June 2009, PETE Self Study Report, June 2009).

These outcomes are self-explanatory; they relate to the skills, knowledge, and behaviors that students acquire in their matriculation through the CHME and PETE programs. They also describe what students are expected to know and be able to do by the time of graduation. The department reviews its outcomes every 3 years based on changes in ABET criteria and feedback received from constituents.

Table 1: Chemical and Petroleum Engineering Programs Outcomes

Outcome	Chemical Engineering Program	Petroleum Engineering Program
A	Thorough grounding in chemistry, physics, biology, math and engineering subjects such as fluid mechanics, thermodynamics, heat transfer, mass transfer, and reaction kinetics; and the ability to apply knowledge of these subjects in chemical engineering practice.	Competency in mathematics through differential equations, linear algebra, probability, and statistics; and engineering subjects including strength of materials, fluid mechanics, and thermodynamics; and ability to apply these courses to practical petroleum engineering problems.
B	An ability to design and conduct different chemical engineering experiments, as well as to analyze and interpret data.	Ability to design and conduct different petroleum laboratory experiments, as well as to analyze and interpret laboratory and field data.
C	An ability to analyze, design, and control a system, component and/or process dealing with fluids handling, separation, and chemical/biochemical reactions to meet desired needs	Competency in petroleum engineering including design and analysis of well systems, procedures for drilling and completing wells, characterization and evaluation of subsurface geological formations, design and analysis of systems for producing, injecting, lifting and handling fluids; application of reservoir engineering principles and practices for optimizing resource development and management; use of project economics and resource valuation methods for design and decision making under conditions of risk and uncertainty.
D	An ability to work and interact effectively in groups/teams which have diverse personalities, cultures, and backgrounds.	Ability to work and interact effectively in groups/teams which have diverse personalities, cultures, and backgrounds.
E	Ability to identify, formulate, and solve chemical engineering problems	Ability to identify, formulate, and solve practical petroleum engineering problems.
F	An understanding of professional and ethical responsibility	Understanding of professional and ethical responsibility.
G	Ability to develop effective oral, written, and interpersonal communication skills.	Ability to develop effective oral, written, and interpersonal communication skills.
H	Ability to evaluate the potential risks, i.e. consequences and probabilities of engineering solutions which may affect society and the environment.	Ability to evaluate potential risks, i.e. consequences and probabilities of engineering solutions which may affect the society and environment.
I	A recognition of the need for and an ability to engage in independent-learning and life-long learning	Recognition of the need for and an ability to engage in independent-learning and life-long learning.
J	A knowledge of contemporary issues	Knowledge of contemporary issues related to the petroleum industry.
K	An ability to use of computer software such as spreadsheets, mathematics packages, word processors, and design packages in solution of chemical engineering problems.	Ability to use computer software such as spreadsheets, mathematics packages, word processors, reservoir simulation models, and design packages in solution of petroleum engineering problems.

Currently, the CHME and PETE programs take a minimum of ten semesters to complete the 168 credit hours required for graduation. They include the University General Requirements (30 credits), General Culture and Free Electives (12 credits), College Requirements (38 credit hours), Specialization Requirements (73 credit hours), and Industrial Training (15 credit hours).

3. CHME & PETE PROGRAM OUTCOMES ASSESSMENT

3.1 Achievement of Program Outcomes

The Department of Chemical & Petroleum Engineering has established a well-defined process for outcomes assessment for the Chemical and Petroleum Engineering Programs in order to ensure that its graduates achieve the program educational objectives. Figure 1 presents the proposed framework for the establishment of the program objectives and outcomes assessment process. The significant feature of this proposal is indicated by the two loops making up the assessment process.

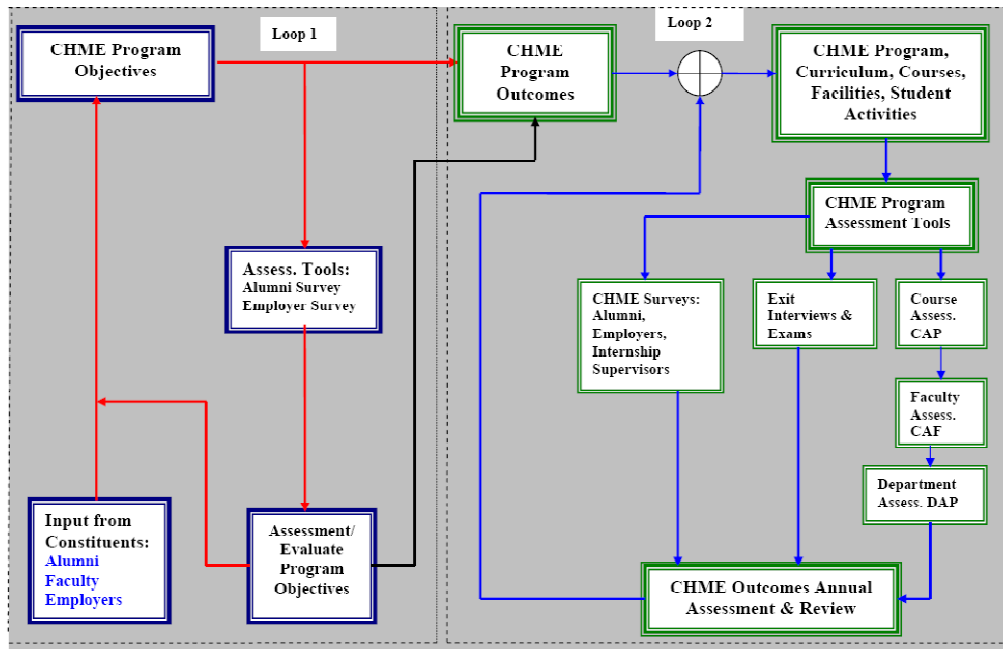


Figure 1: CHME Program Outcomes Assessment Framework

The first loop (Figure 1) encloses the cycle of program objectives assessment. The constituencies (alumni, employers and faculty) provide the input of the objectives in terms of surveys and direct contact in Open House meetings. The input data is gathered and analyzed before it can be used to evaluate and review the objectives. In addition, this information is incorporated into the determination and modification of the outcomes that are required to achieve these objectives, as illustrated in Figure 1. The second loop is composed of the assessment and evaluation of the achievement of the outcomes. Based on the outcomes, the program curriculum, courses, and student activities are designed. Data obtained from the assessment activities is central to both loops and it also drives the program toward improvement. Nine assessment tools are used annually to evaluate the program outcomes. The assessment tools are classified as direct tools (Course / Curriculum Assessment, Exit Exam, Capstone Course) and indirect tools (Internship Advisor Survey, Student Assessment of Course, Alumni Survey, Employer Survey, Students Exit Interview, Industrial Advisory Board).

3.2 Course and Curriculum Assessments

The curriculum assessment process accumulates individual contributions from selected courses in the CHME and PETE programs to the obtain program outcomes for the purpose of assessing the entire curriculum. By mapping the program outcomes to the program objectives, recommendations could be made at the end of the process to improve the program outcomes as well as the program educational objectives. The process then starts all over again.

3.2.1 Assessments of Course Outcomes

The process starts by developing the Course Syllabus. The course syllabus contains the course outcomes mapped to the program outcomes. The measure for assessment is the Course Assessment by Faculty (CAF), an in-house developed Excel program that includes three performance measures: Students, Faculty, and Quantitative. The CAF reports of the selected core

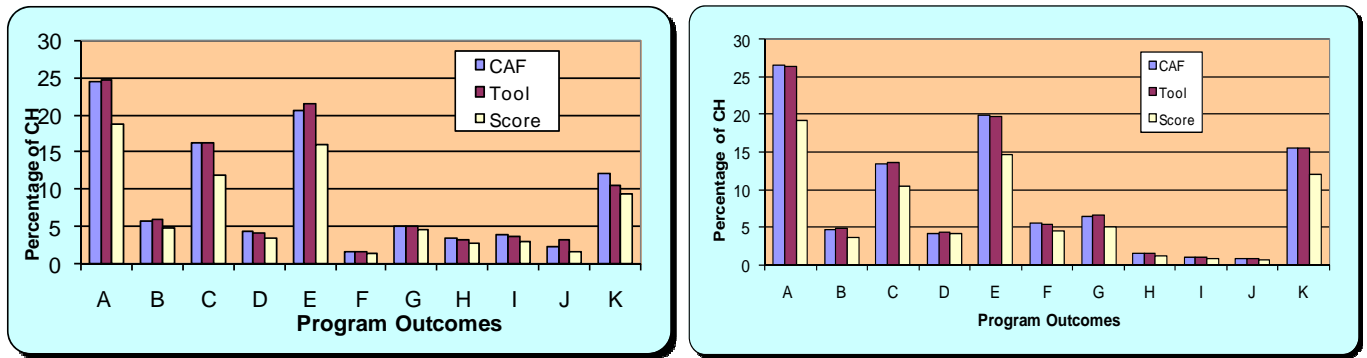
courses were compiled for each year and their corresponding outcomes were measured using the following indices.

1. Course Assessment by Students (CAS): At the end of each semester, students evaluate the course using the CAS Survey Forms. The survey lists the course outcomes as presented in the course syllabus. The survey asks students to evaluate each course outcome based on a 1-5 scale, where 1 is poor and 5 is excellent. The basis of evaluation should be on student's feeling of how the class has helped him/ her to achieve the abilities, attributes, and skills as described in the outcomes. The results of the survey were collected and analyzed as the CAS is considered one of components in the evaluation process.
2. Quantitative Assessment of the Course: Each course in the program contributes to some extent to the major intended outcomes of the Department. The relative weight for each related outcome is decided by the faculty member teaching the course (TARGET). Then these relative weights were fed into the CAP (Course Assessment by Program: another Excel program developed by the Department). This program breaks down each activity in terms of A-K criteria of the Department.

3.2.2 Assessments of Curriculum Outcomes

The results from CAP of some course selected every semester were fed into the Department Assessment Program (DAP) which refers to assessment of curriculum outcomes: an Excel program developed by the Department which adds up all outcomes measures in all the courses in the Department in terms of A-K contribution designated as CAF (intended outcome), TOOL (student assessment components) and SCORE (student performance relevant to TOOLS used). Thus, the overall picture of the Department is produced in terms of number of credit hours the department spends in each criterion. The Focus Groups study the relevance of courses to A-K and the student performance in the courses and come up with metric goals for each outcome that illustrate the level of quality of outcomes achievement felt necessary to produce graduates that ultimately achieve the Educational Objectives upon their graduation.

The distribution of A-K criteria in terms of credit hours for Chemical and Petroleum Engineering Programs at the end of December 2008 is illustrated in Figure 2. These were prepared from ten core courses in chemical program and from eleven selected core and elective courses in petroleum engineering program. In Figure 2, CAF is the distribution of the weights of A-K criteria by the faculty member as per the subjects covered. TOOL is the extent of student assessment for each activity according to the A-K criteria. SCORE is actually what the student has achieved in the course activities. It can be observed from Figure 2 that the CHME and PETE curriculums focus mostly on the ABET criteria A (knowledge), E (Engineering Problems), and to a lesser extent on C (Design) and K (Techniques, Skills and Tools) as the most important outcomes to be achieved. In the second rank, it focuses on criteria B (Experiments and Data Interpretation), D (Functioning in Teams), F (An understanding of professional and ethical responsibility), and G (Ability to communicate). Based on the Course Assessment by Faculty (CAF) reports, the results of *score to tool ratio* versus the individual A-K outcomes for the selected courses for year 2008 are listed in Table 2. It can be observed that in all criteria this ratio is well balanced (over 3.5 out 5) except outcome J in CHME program, which is slightly below the target, and thus it could be claimed that the instructors have been successful in setting their tool elements for the selected courses. More emphasis should be placed on criterion B in PETE program to improve the score/tool ratio.



(a)

(b)

Figure 2: The percentage distribution of credit hours in 2008 (a) Chemical (b) Petroleum

Table 2: Curriculum Assessment of 2008

Program	Outcomes											Average
	A	B	C	D	E	F	G	H	I	J	K	
CHME	3.9	4.1	3.8	4.4	3.8	4.7	4.7	4.5	4.5	3.4	4.5	4.2
PETE	3.7	3.5	3.8	4.2	3.7	4.4	3.7	4.6	5.0	3.9	3.8	4.0

3.3 Exit Exam

An exit exam encompassing all the core courses in the Chemical and Petroleum Engineering Programs with 50 questions was designed in order to assess the students in their final semester. This exam is conducted during the last portion of Graduation Project II course. Exit exam questions were also mapped to ABET criteria and assessment of the exam is included in the overall assessment.

3.4 Capstone Course

The capstone design course is spread over two semesters as Graduation Project I and Graduation Project II. The CHME and PETE programs use the results of the GP II (bulk of design work) only in the assessment process. It was found that students performed quite well in achieving the program intended outcomes.

3.5 Internship Advisor Survey

All CHME and PETE students are required to join the industrial training program after they complete at least 114 credit hours. Each trainee spends a full semester (about four months) in an industrial setting. The industrial supervisor is asked to complete a survey to assess the trainee's abilities, attitudes and skills relevant to the educational outcomes of the CHME and PETE programs.

3.6 Alumni Survey

The alumni survey was designed to provide the information needed by the CPE Department to measure the intended outcomes for the CHME and PETE programs. For this purpose two types of alumni surveys were conducted: (1) For fresh graduates with less than 3 years experience, and (2) For senior graduates with three years experience or more. The fresh graduates' survey has 11 stated items that match the A-K outcomes of the CHME and PETE programs. Each item was quantitatively evaluated from the standpoints of strength, career-wise, and the preparation that

the program has offered. The senior alumni survey was designed to encompass two parts; the first part considers the attributes addressed by the program objectives and the second part considers the abilities, attributes, and skills addressed by the A-K outcomes of the programs. The survey was analyzed to determine the "strength" level for each of the stated items. The Alumni were asked to evaluate all items as "Very Weak", "Weak", "Average", "Strong", or "Very Strong".

3.7 Employer Survey

The survey was conducted to assess how well CHME / PETE graduates meet the program outcome criteria as judged by their employers. This survey is considered to be one of the important feedback tools from the program constituencies. The Employer Survey contains two sets of questions; the first set includes 5 questions that conform to the program educational objectives and the second set includes 11 questions that conform to the program outcomes. The results of employers' assessment of the CHME and PETE programs outcomes through the performance of its graduates are achieved by computing the weighted average of the survey to every program A-K outcome.

3.8 Exit Interview

The Exit Interview was designed to get some comments directly from graduating students. In the interview, graduating seniors were asked questions that focus on their opinions regarding their experience at UAEU and their perception of achieving the CHME and PETE programs outcomes (as reflected by the ABET outcomes). The results of this interview are qualitative and thus do not have a weight in the overall assessment of the program. However, students' comments were considered in the continuous improvement cycle of the program.

3.9 Overall Assessment of Achievement of Program Outcomes

The following section summarizes the results of the assessment for quantitative data gathered on a regular basis that were used to assess the quality of achievement of the outcomes and analysis of those assessment results. The assessment tools weight distribution was selected in accordance to the level of strength of the tool as follows: Curriculum (30%), Employer Survey (25%), Internship (5%), Capstone Courses (10%), Alumni Survey (20%), Exit Exam (5%) and Student Assessment of Course (5%). The data were aggregated to evaluate individual program outcomes separately. The following success criteria for each outcome were suggested: 1. **Suggested Improvement:** The program outcome has been met, but recommendations for some improvement may be suggested. The score is between 3.5 and 5.0 for any of the surveys except Exit Exam and Course Assessment by Students (CAS). The score for the Exit exam and CAS should be above 60%. 2. **Needs Improvement:** The program outcome has been marginally met. Improvement should be suggested and implemented. The score is between 3.0 and 3.49 for any of the surveys except Exit Exam and (CAS). The score for Exit exam and CAS is between 50%-60%. 3. **Major Improvement:** The program outcome has not been met. Major improvement should be suggested and implemented. The score is less than 3.0 for any of the surveys except Exit Exam and (CAS). The score for Exit exam and CAS is less than 50%.

Table 3 summarizes the results of all assessment tools that were conducted to evaluate the CHME and PETE program outcomes in year 2008.

4. CONTINUOUS IMPROVEMENT

Further improvement in the curriculum outcomes assessment can be achieved by some combination of the following; (a) implementation of focus groups recommendations, (b) upgrading of course materials, (c) introducing new software packages to solve engineering problems, (d) emphasizing team work, (e) shifting to industry-oriented design problems in capstone courses, and (f) introducing new courses if necessary. The results of the overall outcome assessment for year 2008 shown in Table 3 indicate that all A-K program outcomes have been met. However, more work seems to be needed to improve outcome J in chemical engineering program and outcomes B and C in petroleum engineering program. Recommendations made by focus groups for CHME and PETE courses were partially deduced from the results of the various assessment tools used in the proposed process of program outcomes assessment. These recommendations are to be implemented in the specified courses during the subsequent semesters.

Table 3: Summary CHME and PETE Programs Outcome Assessment Data, year 2008

Outcomes	Assessment Tools CHME Program								Assessment Tools PETE Program							
	Curriculum	Capstone	Exit Exam	Internship	CAS	Alumni S.	Employer S.	Total	Curriculum	Capstone	Exit Exam	Internship	CAS	Alumni S.	Employer S.	Total
Wt%	30%	10%	5%	5%	5%	20%	25%		30%	10%	5%	5%	5%	20%	25%	
A	3.9	4.2	3.2	3.7	4.3	3.8	4.0	3.9	3.7	4.3	3.2	2.9	4.4	4.2	3.7	3.8
B	4.1	3.9	2.9	3.4	4.1	3.6	3.9	3.8	3.5	4.2	2.4	2.5	3.6	4.3	3.4	3.6
C	3.9	3.9	3.2	3.1	4.0	3.5	3.6	3.7	3.8	4.2	3.3	1.0	4.0	4.1	3.4	3.6
D	4.4	4.4	NA	4.0	4.3	4.0	4.4	4.3	4.2	4.3	2.2	3.3	4.1	4.4	4.4	4.3
E	3.9	3.9	3.1	3.5	4.2	3.8	4.0	3.9	3.7	4.2	2.9	1.8	4.1	4.4	3.7	3.8
F	4.6	4.4	5.0	4.0	4.3	3.9	4.1	4.3	4.0	4.5	2.7	3.3	3.1	4.1	4.3	4.0
G	4.5	4.2	3.7	4.0	4.1	3.8	3.9	4.1	3.7	4.3	2.6	3.3	3.3	4.2	3.9	3.8
H	4.3	3.9	2.3	3.8	4.0	3.6	3.8	3.9	3.9	4.2	3.0	2.4	3.6	4.0	3.7	3.8
I	4.4	4.4	2.1	3.8	3.8	3.8	4.0	4.0	3.8	4.5	4.2	2.9	3.6	4.1	3.7	3.9
J	3.4	3.9	2.2	3.5	3.6	3.4	3.9	3.5	3.8	4.2	3.2	2.8	3.4	4.1	3.7	3.8
K	4.5	4.4	3.4	3.7	4.1	3.9	3.8	4.1	3.8	4.5	2.9	2.9	3.9	4.3	3.9	3.9

5. CONCLUSION

A systematic approach is proposed in this study for the assessment of CHME and PETE programs' educational outcomes. Direct and indirect assessment tools were recommended and implemented to achieve this purpose. The results of the proposed outcomes assessment process can lead to identification of points of weaknesses and strengths in the program which could then be translated into actions for the improvement of the CHME and PETE programs. The evaluation process developed in this work for the CHME and PETE programs at UAEU is recommended for implantation in other engineering disciplines and subdisciplines. .

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