Driving Continuous Program Improvement by Integration of Assessment into Strategic Planning

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Abstract

The College of Engineering at the University of Qatar is seeking to become among the first engineering programs in the Middle East to be evaluated by ABET using the EC2000 Criteria. The Chemical Engineering program's assessment and continuous improvement activities have evolved over the course of five years to move from emphasizing assessment measures to focusing on targeted areas of improvement and targeted assessment. The next step has been to integrate the curriculum assessment activities into the overall strategic planning and continuous improvement processes to insure that targeted areas of improvement are measured and acted upon to drive the program toward the realization of its ultimate vision. This provides more clarity and direction to the program, by having all activities being consciously driven from the mission and vision statements of the institution.

Introduction

The Chemical Engineering program was established at the University of Qatar in 1980 when it admitted its first class of students. The program was for male students but in 2004, was opened for female students as well. In keeping with the values of the culture, these programs are offered in the separate male and female campuses of the University.

The program has had over 125 graduates since its founding and recently has been graduating about 12 to 15 students annually. The program currently has an enrollment of nearly 100 male students and with the addition of the women's program will see the annual graduation numbers increase significantly. Ninety percent of the students are Qatari nationals.

The State of Qatar occupies a peninsula bordering Saudi Arabia with the island of Bahrain to the north and the United Arab Emirates to the south. The country has a land area approximately the size of the state of Connecticut and has a population of nearly 744,000 which includes about 200,000 Qatari nationals. The country was established in 1973.

Qatar is an oil producing country and a member of OPEC, but what truly sets Qatar apart is its reserves in natural gas. Qatar is ranked third in the world in natural gas reserves. The country possesses in a single field the largest unassociated gas reservoir. This resource has only recently begun to be exploited and 1996 marked the first shipment of liquefied natural gas (LNG) from the North Field. The rapid development of this national resource has resulted in Qatar becoming a leading exporter of LNG and will become the "capital" of gas to liquids (GTL) manufacture. Over fifty billion dollars of capital investment will be made in the oil, gas, and petrochemical

sectors of the economy in the next five years. The magnitude of the proposed projects is simply staggering.

With this rapid and significant development has come the challenge to make the Chemical Engineering program of the national university a national technical resource and asset. This challenge has forced the program to redefine its identity, refocus its mission, and develop a vision as ambitious as the developments taking place in the country.

One of the early conclusions of the College of Engineering and the Chemical Engineering program was to recognize the need to obtain ABET "substantial equivalency" recognition. During the early years of the College's founding, an advisory committee of distinguished engineering educators was brought from the United States annually. Their comments and criticism helped shape the initial curriculum and practices of the College.

In 1996, a major curriculum revision was implemented to bring the College into better alignment with the ABET Criteria[1]. In 2000, actions were begun to prepare the College for an ABET EC2000 visit. This has resulted in the College having its first ABET "substantial equivalency" visit on February 20-22, 2005. The results of this visit have confirmed the effectiveness of the actions taken by the College and program.

The program as a result of the constituent focus has oriented its curriculum to serve the oil, gas, and petrochemical industries. The program has a commitment to continue reviews by these industries to strengthen the level of preparation of the students in these areas. Currently, the faculty recruitment focuses on seeking those who will work in the areas Natural Gas Processing, Gas to Liquids Processing, Petroleum Engineering, and Environmental Processes and Policy.

Evaluation and Assessment Development

The College from its inception had always had an external international review committee. With each major change in curriculum, the proposed curriculum was sent to distinguished international educators for their review and input.

However, the College began to address the evaluation and assessment issues for the EC2000 Criteria[1] in 2000. Like many programs first attempting to develop assessment processes, surveys were relied upon heavily. The results of these surveys identified general concerns. However, the information obtained did not have sufficient detail to effectively pinpoint the problem areas and develop specific remedies.

Faculty were sent to ABET program evaluator training sessions, ABET international faculty workshops conducted in Istanbul and Singapore, the ABET annual meetings, and the "Best Assessment Processes Symposium" at Rose-Hulman Institute of Technology.

Additionally, consultants with ABET experience were engaged to help train the faculty, review the processes established, and review the materials prepared for a future ABET visit. An International Academic Advisory Committee was formed having the following membership:

Dr. Jerry Yeargan
Chairman
Distinguished Professor of Electrical Engineering
University of Arkansas

Dr. Robert Kersten
Civil Engineering
Dean of Engineering
University of Central Florida

Dr. Billy Crynes
Chemical Engineering
Dean of Engineering Emeritus
University of Oklahoma

Dr. Theodore Bickart
Electrical Engineering
President
Colorado School of Mines

Dr. Richard Williams
Mechanical Engineering
Dean of Engineering
United Arab Emirates University

This committee met specifically to advise the programs of the College on their ABET preparations and performed a mock visit prior to the ABET Consultative Visit which is required of international programs.

As a result of the experience gained from these activities, more varied and meaningful assessment tools were employed.

Current Curricular Evaluation and Assessment Plan

The current curricular evaluation and assessment plan[2] for Chemical Engineering has developed into the following.

Objective: In order to assure customer satisfaction with graduates and services from the Chemical Engineering program, processes of external evaluation and internal assessment will be performed. These processes must be regular, systematic, comprehensive, and accurate.

Definitions:
Constituents – The constituents of the Chemical Engineering program include:
1. Industrial employers
2. Alumni
3. Graduates

4. Students
5. Faculty

Evaluation – The processes to validate that the Chemical Engineering program mission and educational objectives are being achieved in the eyes of our constituents.

Assessment – The processes to validate that the Chemical Engineering program educational outcomes are achieved by all students graduating from the program.

Educational Objectives – These are the attributes (knowledge, skills, and qualities) that the student possesses as observed by his employer in the first few years after graduation. The employer will have had the opportunity to observe the strengths and weaknesses of the student's preparation and the degree of training required to make the student a productive employee.

Program Outcomes – These are the attributes (knowledge, skills, and qualities) that the student demonstrates competency in at the time of or prior to graduation from the Chemical Engineering program.

Evaluation Methodology

The following methods will be used to determine the level of satisfaction in the education received by graduates of the Chemical Engineering program in fulfillment of the program's mission and educational objectives.

1. Surveys – Industrial employers, alumni, graduates, and students will be periodically surveyed at the annual Engineering Open Day, at the biannual Chemical Engineering Majlis, and the annual Chemical Engineering Industrial Constituent meeting. These surveys will vary in format, but will focus on the accomplishment of the program mission and educational outcomes. These surveys will be conducted, reviewed, and reported to the Department Council by the Chemical Engineering Department ABET Committee. In academic years prior to 2003-2004, surveys were the only method used for objective evaluation.
2. External Examiners – Student projects in the Plant Design class and Graduation Projects will be evaluated by the industry sponsors of the work. The results of this evaluation will be submitted to the Chemical Engineering Department ABET Committee for review and reporting to the Department Council.
3. Performance Appraisals – the student performance appraisals from summer practical training will be received by the Chemical Engineering Department ABET committee, reviewed, and reported to the Department Council.

Evaluation Schedule:

The evaluation schedule is shown on Table 1. The Chemical Engineering Department ABET Committee prepares an interim report following each evaluation activity in order to inform the Chemical Engineering Department Council of the results. This allows the Department Council to make any immediate corrective action required. The Department Council summarizes the results of all evaluation activities in the Department ABET Committee's annual report for review and action. The Department Council reviews the findings of the Department ABET Committee,

recommend corrective actions, and propose improvements to the Chemical Engineering program. These actions will be documented in the regular minutes of the Department Council.

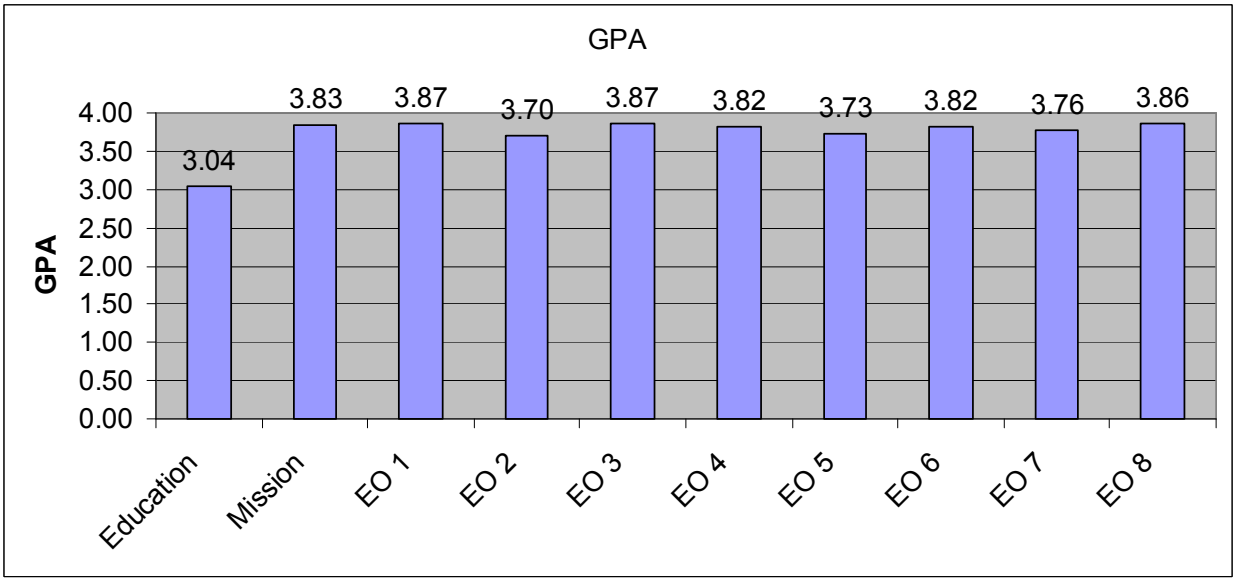
Table 1. Evaluation Schedule

Method	Constituent	Responsible Party	Evaluation Schedule	Review & Reporting
ChE Majlis Survey	Employers, Alumni & Students	ABET Committee Chairman	Biannually, Fall & Spring	ABET Committee Interim and annual Reports
Engineering Open Day Survey	Employers	ABET Committee Chairman	Annually, Spring	ABET Committee Interim and annual Reports
ChE Industrial Constituents Meeting Survey	Employers, Alumni	ABET Committee Chairman	Biannually, Fall & Spring	ABET Committee Interim and annual Reports
Summer Training Performance Appraisals	Industrial Supervisor	ChE Summer Training Advisor	Annually, Fall	ABET Committee Interim and annual Reports

Sample Evaluation Results

The combined results of the constituent "grading" of our revised educational objectives are shown in Figure 1.

Figure 1 – Constituent Acceptance of Mission and Educational Objectives



Where the educational objectives of the program are as follows:

1. **Be able to communicate effectively in English both orally and in writing in the professional setting.**

The student can prepare a quality technical report following established rules of format for informal and formal reports. The report should utilize good grammar and composition and be free of spelling or mechanical errors.

The student can make an oral technical presentation that includes the use of presentation software and following standard oral presentation criteria. The student can make a prepared speech and respond extemporaneously to questions resulting from the presentation.

2. **Be able to formulate, analyze and solve engineering problems both individually and in a team environment.**

The student can take a general problem statement and organize and compile the necessary information, develop a solution strategy or approach, understand the limitations, assumptions and uncertainties, and solve the problem.

This activity can be demonstrated by the student individually and in working with a group. The group environment should divide the labor fairly utilizing the particular strengths of the group members.

3. **Be able to apply the Chemical Engineering fundamentals in the professional environment.**

The student can apply the following fundamental areas of Chemical Engineering:
- Material and energy balances
- Fluid mechanics
- Thermodynamics
- Process control
- Heat and mass transfer
- Unit operations and separation processes
- Kinetics and reactor design
- Engineering economics

This would include knowing how to find data and information necessary to make use of these fundamentals.

The application of these fundamentals will include the following activities:
- Application of steady-state and unsteady-state mass and energy balances
- Design and operate processes that involve chemical reactions and/or separations.
- Determination of the optimum operating condition of a chemical engineering process.

4. **Take an active role and participate in his professional development to insure professional competence.**

The student should have the knowledge of information sources and the ability to use them in situations where he has no prior experience. The qualities of curiosity, self initiative, perseverance, self confidence, and poise will be encouraged.

5. **Be able to make effective use of the available computer and communication recourses.**

The student should be able to make use of the following computational tools:
- Word processor
- Spreadsheet
- Presentation software
- Process Simulation software

- Mathematics software
- Engineering software
- Email and Internet resources.

6. Maintain and practice with the highest standards of ethics and integrity.

Students are encouraged to develop and maintain a reputation of integrity. Students will be made familiar with ethical issues within the engineering profession. Cheating and academic misconduct is not tolerated in the Chemical Engineering program.

7. Be familiar with and understand the use of professional codes and standards.

Students will be made familiar with the codes and standards that commonly apply to Chemical Engineering process design, construction, and operation. These include the standards of ASTM, API, ASME, and TEMA.

8. **Be able to work in multi-disciplinary industrial projects.**
Students will be made familiar with a multidisciplinary environment through summer practical training.

Assessment Goals

The goals of the outcome assessment process are as follows:

- The process will provide information of sufficient detail to indicate what shortcomings or areas of improvement exist in the curriculum and instruction so that corrective actions and changes may be made to improve the quality of the ChE program graduate.
- This process must be sustainable and not consume excessive time and energy from the program faculty.
- The process should have internal and external confirmation of results by multiple measures of the various outcomes.
- The process must insure that all students meet the outcome requirements with a satisfactory level of proficiency.
- This satisfactory level of preparation will be confirmed when the objectives of the program are evaluated by the program constituents.

Assessment Methodology: The following methods will be used to determine the level of satisfaction of the education received by graduates of the Chemical Engineering program in fulfillment of the program's mission and educational objectives.

1. Student Portfolios – Examples of student work will be collected from all students in the courses highlighted and in bold in Table 2. Table 2 represents the program requirements of the Chemical Engineering curriculum. No assessment activities of the program are tied to the University or College requirements of the curriculum. The student work from the highlighted courses will be compiled into outcome files at the end of each semester. The Department ABET Committee will review these files, observe the level of outcome proficiency of the students, and insure that all students passing each course met the minimum outcome proficiency. The Chemical Engineering Department ABET Committee will report the results of this review to the Department Council.
2. Fundamentals of Engineering (FE) Exam – Beginning the academic year 2004-2005, the Chemical Engineering program will require all graduates to take the FE Exam. The purpose of this exam is to use the results obtained from the NCEE to pinpoint specific

areas of weakness in the topical coverage of the curriculum and instruction. The results of this exam will be reviewed and documented by the Department ABET Committee and reported to the Department Council.

Table 2. ABET Outcome to Course Mapping

No.	Course name	Outcome
502211	Computer Methods	a
309285	Inorganic Chemistry	a
309286	Physical Chemistry	a
309383	Organic Chemistry	a
502201	**Introduction to Chemical Engineering I**	**a**, e, f
502202	Introduction to Chemical Engineering II	a, e, f, k
502212	**Chemical Engineering Thermodynamics I**	**a**, e, f
502213	Fluid Flow	a, c, e, f, g, k
502311	Heat Transfer	a, c, e, f, g, k
502312	**Chemical Engineering Thermodynamics II**	a, **e**, f, k
502313	Mass Transfer I	a, c, e, f, k
502314	**Chemical Reaction Engineering**	a, c, **e**, f, g, k
502315	Mass Transfer II	a, e, f, g, k
502323	**Process Control**	a, c, e, f, **k**
502324	Chemical Engineering Lab I	a, b, d, e, f, g, i, k
502325	Chemical Engineering Lab II	a, b, d, e, f, g, i, k
502326	Instrumental Analysis	a, b, f, g, k
502399	**Practical Training**	a, **d, e, f, g, h**, i, **j**, k
502421	**Plant Design I**	a, **c**, e, f, g, i, j, k
502422	**Plant Design II**	**a, c, d, e, f, g, h, i, j, k**
502426	**Chemical Engineering Lab III**	**a, b**, d, e, f, g, **i**, k
502427	Chemical Process Economics	a, h

3. Graduate Exit Interviews – Graduates from the Chemical Engineering program will be interviewed by the Department Chairman to obtain their assessment of the education that they have received. The results of this assessment will be documented by the Department Chairman and submitted to the Chemical Engineering Department ABET Committee for review and reporting to the Department Council
4. Graduate Exit Survey – Graduates from the Chemical Engineering program are provided a survey related to the program outcomes and asked to rate their level of mastery. The results of this survey will be reviewed by the Department ABET Committee and reported to the Department Council
5. Performance Appraisals – The student performance appraisals from summer practical training by both the course instructor and industry supervisor will be received by the Chemical Engineering Department ABET committee, reviewed, and reported to the Department Council.

6. Student GPA Evaluation – This method was used in the academic years prior to 2003-2004 and has been discontinued. In this method, each course was broken down into the percentages of each outcome covered and the student grades were proportioned into an average GPA for each outcome. The course's contribution to the total curriculum was weighted. The contribution of all courses covering a specific outcome would then be computed as an overall outcome GPA. The method was discontinued, as it was only an inference of student mastery of a particular outcome and not a direct measure.
7. Surveys – This method was used in the academic years prior to 2003-2004 and has been discontinued as an outcome assessment. Students, graduates, and alumni were surveyed to determine outcome mastery. This method did not directly assess mastery but was a subjective estimate. This method was deemed more appropriate to be continued as a method of evaluation for Educational Objectives.

Assessment Schedule:
The assessment schedule is shown on Table 3. The Chemical Engineering Department ABET Committee prepares an interim report following each assessment activity in order to inform the Chemical Engineering Department Council of the results. This will allow the Department Council to take any immediate corrective action required. The Department Council will summarize the results of all assessment activities in the Department ABET Committees annual report for review and action. The Department Council will review the findings of the Department ABET Committee, recommend corrective actions, and propose improvements to the Chemical Engineering program. These actions will be documented in the regular minutes of the Department Council.
The results of the evaluation and assessment activities have been used to develop an action plan for curricular improvement that will be monitored by the Department ABET Committee and supervised by the Department Head. The first area targeted for improvement is to insure that the laboratory experience is industrially relevant and effective in its objectives.

Sample Assessment Results
The results of the graduate exit survey are shown in Figures 3, 4, and 5.

Figure 3 shows that the quality improvements imposed by the 2000 Curriculum, resulted in better prepared students entering the College of Engineering and higher student performance throughout the curriculum. The 2000 Curriculum is somewhat of a misnomer as it was first applied to students entering in the Fall Semester 1997.

Figure 4 shows that the students have actually become more "sophisticated," and are more demanding in their expectations of the program performance as noted by the general decline from 2003 to 2004.

Figure 5 shows that the students have a generally high level of satisfaction in the career choice they have made.

Table 3. Assessment Schedule

Method	Persons Being Assessed	Responsible Party	Evaluation Schedule	Review and Reporting
Students Portfolios	All Students	Course Instructor	End of Fall and Spring Semesters	ABET Committee Interim and annual Reports
Fundamentals of Engineering (FE) Exam	Graduating Students	ABET Committee Chairman	Annually, Spring	ABET Committee Interim and annual Reports
Graduate Exit Interview	Graduating Students	ChE Department Chairman	Biannually, Fall and Spring	ABET Committee Interim and annual Reports
Graduate Exit Survey	Graduating Students	ABET Committee Chairman	Biannually, Fall and Spring	ABET Committee Interim and annual Reports
Summer Training Performance Appraisals	Industrial Supervisor	ChE Summer Training Advisor	Annually, Fall	ABET Committee Interim and annual Reports

Figure 3 – Average Graduate GPA

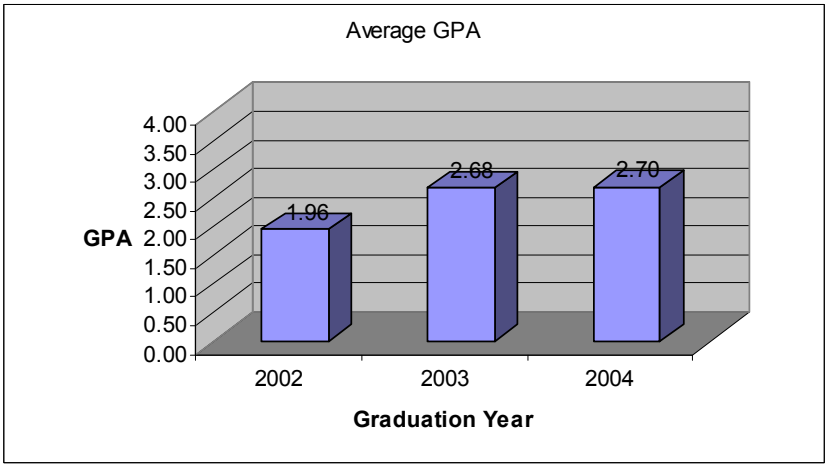


Figure 4 – Outcome a-k Survey Responses

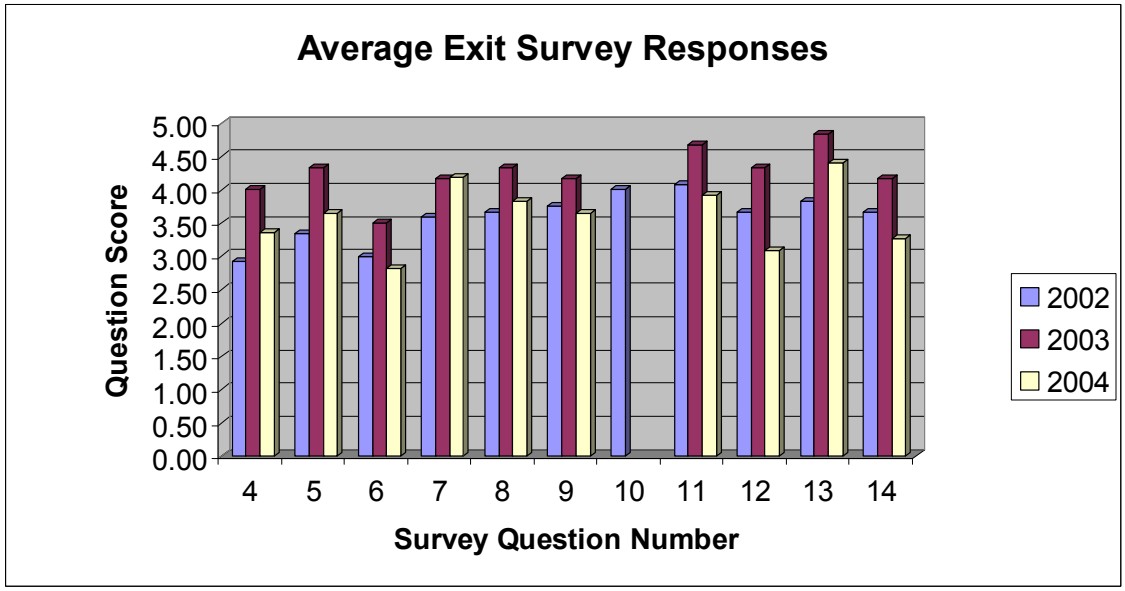
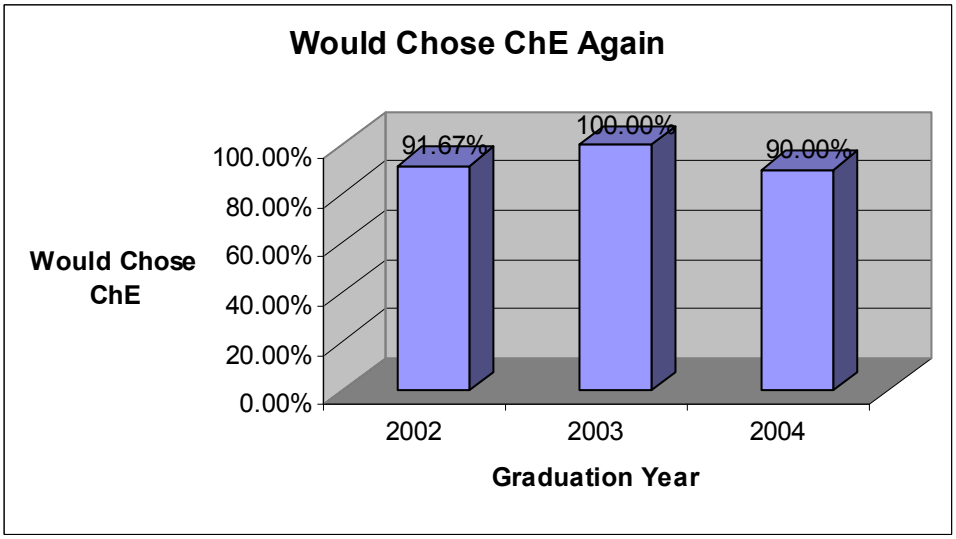


Figure 5 – General Satisfaction Level of Graduates



A sample student portfolio review is shown below. This is typical of what was performed for each a through k outcome and for each of the highlighted courses. This provides specific course improvements to strengthen the outcome being considered. At least two course are used to assess each outcome. This philosophy assures that "all students" and "all outcomes" are satisfied by the program.

a. Ability to apply knowledge of mathematics, science, and engineering

Chemical Engineering students possess basic science and mathematics background in the areas of: Calculus, Differential Equations, Probability and Statistics, Numerical Methods, General Chemistry, Physical Chemistry, Organic Chemistry, and General Physics. They possess background in engineering subject areas of: Engineering Graphics, Electric Circuits, Engineering Economics, Fluid Mechanics, Heat Transfer, Thermodynamics, Mass and Energy Balances, Mass Transfer, Reaction Kinetics, and Process Control.

Applying this knowledge will be demonstrated by solving engineering problems that use the concepts from these subjects either in total or in part.

Assessment results:

1. Evidence of Student Work – One assignment for all students collected in the following:

502201 – Introduction to Chemical Engineering I

- Are assignments present for all students?: **Yes** / No
- Type of assignment: **Exam** / Project / Report / Homework / Other _____
- Subject areas demonstrated in assignment:

  Calculus, Differential Equations, Probability and Statistics, Numerical Methods, General Chemistry, Physical Chemistry, Organic Chemistry, General Physics, Engineering Graphics, Electric Circuits, Engineering Economics, Fluid Mechanics, Heat Transfer, Thermodynamics, **Mass and Energy Balances**, Mass Transfer, Reaction Kinetics, Process Control.

- Did all students passing the course demonstrate proficiency? Yes / **No**

  Student X failed this exam yet passed the course

  Student Y failed this exam yet passed the course

- Comments concerning observed areas that may be improved:

  a. Students need to learn to organize there answer sheet

  b. Units must be stressed.

- Reviewer: Dr. Z
- Instructor comments:

The assessment provided was the most demonstrative of the outcome studied. The two students who failed this exam, did demonstrate this outcome was fulfilled. Additional materials for these students will be provided.

Strategic Plan Development

The College began its strategic planning activities in January 2002 and produced its first strategic plan in March 2002. The University engaged the Texas International Educational Consortium (TIEC) as a consultant to assist in the development of a University strategic plan. The first version of this plan[3] was issued in February 2003. The College strategic plan[4] was revised and reissued in June 2003. The College is currently reviewing its strategic plan and developing its third version. Additionally, departments are being asked to prepare strategic plans that coordinate with the University and College plans.

The Chemical Engineering program in the development of its strategic plan was confronted with the unique and unparalleled opportunities that the current industrial and economic development provides. Initial discussions with the local industry indicated a need for the Chemical Engineering program to aggressively and ambitiously revise its understanding of its identity, mission, and vision.

In order to assist the program with its reformulation of identity, mission, and vision, an international panel of Chemical Engineering professionals was formed to become the Chemical Engineering Advisory Committee. The membership of this committee included:

Dr. Gintaras (Rex) V. Reklaitis
Chairman
Edward W. Comings Professor of Chemical Engineering (and former Head)
School of Chemical Engineering
Purdue University, West Lafayette, Indiana

Dr. Mahmoud El-Halwagi
McFerrin Professor and Associate Head for the Graduate Program
Texas A&M University, College Station, Texas

Dr. Subhas K. Sikdar
Acting Associate Director for Health (and former Director EPA's Sustainable Technology Division)
National Risk Management Research Laboratory
U. S. Environmental Protection Agency, Cincinnati, Ohio

Dr. H. Dennis Spriggs
President (and former Professor at West Virginia University and University of Wyoming)
Matrix Process Integration, Woodlands, Texas

This advisory committee spent four days in Qatar. They met with the Minister of Energy and Environment, the Secretary Generals of the Supreme Council for Planning and of the Supreme Council for the Environment and Natural Resources, and the managing directors of LNG and GTL companies, as well as meeting with University administration and faculty. The committee report will address the Chemical Engineering mission and vision, the target state, the current state, gap analysis, development of strategies (that would include solution fragments, candidate strategies, and evaluation and selection), and an implementation plan. This report is in preparation at the time of writing.

It has become clear that the curricular evaluation and assessment simply becomes one piece of the overall continuous improvement activities of the department and needs integration into the overall strategic plan activities.

Vision 25 Strategic Plan

The Chemical Engineering program will celebrate its twenty-fifth anniversary in the next academic year. This plan, currently being developed, is designed to launch the program into its next twenty-five years. The overall framework of the plan has been adopted from the College of Engineering plan framework and addresses the following elements.

- Department Organization and Management
- Student Affairs
- Academic Programs
- Research and Community Service
- Human Resources
- Finances
- Facilities and Supporting Services
- New Initiatives
- Continuous Improvement

The plan is organized to state the overall strategic objective with sub-objectives. The accomplishment of these objectives is the necessary and sufficient condition to achieve the program mission and vision. These objective statements have success measures imbedded within each statement. These statements, with the results of evaluation and assessment findings, drive the development of specific action plans to move the program toward the realization of these objectives.

The early information obtained from the advisory committee and interactions with the industry and government entities leads to the conclusion that the Chemical Engineering program needs to become a national technical resource and asset. The magnitude of the development occurring within the chemical process industries demands that the program move itself to a world class stature. A major cultural change is required of the program and the advisory committee has outlined five immediate focal areas:

- Student recruiting
- Review, revise curriculum with industry
- Faculty realignment
- Develop Center plans
- Recruiting strategic partners

In subsequent years, the program will need to address the next priority areas:

- Faculty growth
- Implement Center plan
- Plan MS
- Plan leadership

Longer term (3 to 5 years), with the successful completion of the previous activities, the program will have the following agenda:

- Start courses for MS curriculum
- Implement MS
- Plan for 10-yr horizon
- Thesis MS
- New Center?
- PhD Program?

Industry and government have already encouraged and welcomed this shift in program culture. It will be with their support that this will be financially possible.

Conclusions

Continuous program improvement is not limited simply to the curricular aspects. The ABET EC2000 Criteria requirements for evaluation and assessment lead a program to develop evaluation strategies for the total program. Effective strategic planning incorporates evaluation processes to drive improvement to the ultimate realization of the mission and vision.

Acknowledgments

The authors would like to acknowledge the support of the University President, Dr. Sheikha bint Abdulla Al-Misnad, for her support of the Chemical Engineering program initiatives; the vision of the past and present Deans of the College of Engineering, Dr. Ismail Tag, Dr. Nabeel Al-Salam, and Dr. Adnan Nayfeh; and the members of the International Academic Advisory Committee and the Chemical Engineering Advisory Committee for their generous gift of time and expertise.

1. *Criteria for Accrediting Engineering Programs*, ABET Engineering Accreditation Commission; ABET Inc., Baltimore, Maryland, November 1, 2003.
2. *Self-Study Report for Chemical Engineering*, University of Qatar, Doha, Qatar, November 21, 2004.
3. *University Qatar Strategic Plan 2003-2008*, Texas International Educational Consortium, Austin, Texas, February 10, 2003.
4. *College of Engineering Strategic Plan*, University of Qatar, Doha, Qatar, June 2003.

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