Response to EAC Draft Statement
Chemical Engineering

1. CRITERION 2: PROGRAM EDUCATIONAL OBJECTIVES (WEAKNESS)

The program evaluator identified three areas where clarification and/or remediation was required. 1) Several of the published objectives seemed to be oriented to attributes that students will have upon graduation, rather than after a period of time at the workplace. 2) The review of the PEOs seems to be excessively driven by the faculty rather than by the constituencies. 3) There are limited examples of the use of the information collected by the ongoing evaluation process towards the improvement of the attainment of the objectives.

As pointed out in our 14-day response, the reviewer indicated at the time of the exit interview that this criterion was a concern and not a weakness. The concern was later raised to a weakness for consistency with the evaluation of our Environmental Engineering program, which shares very similar PEOs and assessment process. Note that the environmental engineering reviewer did not find any weakness in our feedback loop towards improvement of the attainment of the objectives (point #3 above).

In the following sections, clarification and remedial action in each of the three areas of concern are presented. Note that our constituencies are CEE undergraduate students, departmental faculty and lecturers, program alumni, and their employers, and Advisory Board members.

1.1 Rewording of our PEOs

As described in Section 2 of our Self-Study, it has always been clear to us that the PEOs reflect broad career accomplishments that we would like our graduates to achieve within 3-5 years of graduation. These are clearly distinct from program outcomes. We acknowledge that the wording of the 2006 PEOs may have been confusing, blurring the line between accomplishments which are typically objectives, and preparation of graduate towards certain endeavors, which is typically an outcome. The ABET review provided an opportunity to review our PEOs.

After the ABET site visit, we sought input from all our constituencies and reworded our PEOs to ensure they meet ABET Criterion 2. More specifically the following was accomplished since the site visit:

1. The CEE faculty discussed the comments made by the ABET reviewer in several faculty meetings. The existing PEOs as well as the process by which we arrived at the PEOs were reviewed and discussed, and specific improvements to the process and to the PEOs were proposed.
2. Selected constituencies were then consulted to provide input of the PEOs and propose revisions.
3. A survey of our constituencies was conducted to determine the importance our constituents give to selected accomplishments.

4. The feedback served to draft revised PEOs.
5. Approval of the revised PEOs was voted by the CEE faculty.
6. The revised PEOs were presented and approved by the College of Engineering Executive Committee.
7. The revised PEOs were published on our web site (see http://www.engr.ucr.edu/chemenv/abet/chem.shtml). The new PEOs will be published in UCR's general catalog for the new academic year.

In crafting revised PEOs, we identified the fact that the revised PEOs needed to be faithful to core values and objectives for our graduates in their early careers that have spelled out, both in the past and through the most recent polling by CEE faculty and CEE program constituencies. Thus, the revised PEOs do not represent a totally new direction for the program, but rather a rewording of broad career objectives and career accomplishments for our graduates. They read as follows:

The program educational objectives are to produce graduates who demonstrate in their careers and professional pursuits, the following:

- An ability to apply mathematics, engineering principles, computer skills, and natural sciences to chemical engineering practice.
- Application of fundamental chemical engineering principles at an advanced level, and competence in synthesizing knowledge from multiple disciplines to develop and evaluate design solutions.
- Engagement in chemical engineering careers in diverse areas including bioengineering, nanotechnology, petrochemicals, alternative energy, and semiconductor manufacturing.
- Pursuit of graduate education and research in chemical engineering at major research universities.
- Exercise of professional responsibility and sensitivity to a broad range of societal concerns, such as ethical, environmental, economic, regulatory, and global issues.
- Effective performance in a team environment, outstanding communication, and involvement in personal and professional growth activities.

1.2 Process for Establishing and Reviewing the PEOs

The process for establishing the PEOs was described in Section B 2.3 of the Self-Study. In short, our program educational objectives evolved from those set at the inception of the CHE program and our first ABET visit in Fall 1994. Over the years, these educational objectives were modified, most importantly in 2000 and 2003 based on inputs from faculty, results of surveys, and input from selected constituencies. Since our program is relatively young, and since there is a significant lag between any change and measurable effects, changes to the PEOs have been relatively subtle after the 2003 changes.

Even so, as was stated in the Self-Study, a yearly review of PEOs is formally conducted by the faculty at the annual faculty retreat. Also, each year, the departmental Advisory Board provides input at the annual meeting. It is true, that although we conducted several surveys on the degree to which the PEOs were achieved, there was no formal mechanism for feedback on the PEOs themselves by undergraduate students, by program alumni, and their employers. These are important constituencies.

Thus, subsequent to the ABET visit, we modified our process to formally include all of our constituencies (CEE undergraduate students, departmental faculty and lecturers, program alumni, and their employers, and advisory board) in the review and development of our PEOs. The revised process conducted since the ABET visit was presented in the previous section and is not repeated here.

Regarding the input of our constituencies, which is the main point made by the reviewer, a web-based survey was sent to all our constituencies (except for the CEE the faculty whose input was deliberately collected separately so as to separate its input from this of other constituencies). The results of the survey are presented in the table on the next page. They show a strong need for demonstrated application of math, engineering and computer skills at the workplace (Q1, Q2, Q4, Q5), and very strong needs to reach effective team work abilities and communication (Q7, Q8). The results highlighted that alumni found that the ability to apply natural sciences at the workplace was not a very important educational objective (Q3). Also surprising was that interdisciplinary career paths (Q11) scored low with the advisory board. The comments section where additional desirable accomplishments could be listed by respondents provided interesting views about the need for professional preparation of graduates in order for them to become successful professionals. These are captured in the CEE core values and in our PEOs, and together with upcoming feedback, they will continue to guide us in our continuous improvement process.

Overall, the survey was found to be an effective means to collect feedback from a diverse pool of constituencies. This kind of survey will be continued in the future. As mentioned earlier, the results of the surveys were used to formulate the revised PEOs, which have now been adopted.

The CEE faculty and CEE ABET Committee is convinced that the revised process now includes all constituencies is an improvement over the past practice and that it is in full compliance with ABET Criterion 2.

2006-2007 Program Educational Objectives (PEOs) Survey and Feedback

You have been invited to take this anonymous survey because you are a current undergraduate student, program alumnus, employers of one of our graduates, or a member of our Advisory Board. As part of our continuous improvement and accreditation process, we are consulting our constituencies for input to help us revise our PEOs. Thank you for your input.

Please indicate below the degree to which you think the following accomplishments are desirable/important for our graduates in their early careers.

Rating: 1=not important, 2=relevant but not essential, 3=desirable, 4=important, 5=very important

Question 1. An ability to apply mathematics and engineering principles at the workplace
Question 2. An ability to apply computer skills at the workplace
Question 3. An ability to apply natural sciences at the workplace
Question 4. Application of fundamental chemical or environmental engineering principles at an advanced level
Question 5. Competence in synthesizing knowledge from multiple disciplines to develop and evaluate design solutions
Question 6. Exercise of professional responsibility and sensitivity to a broad range of societal concerns, such as ethical, environmental, economic, regulatory, and global issues
Question 7. Effective performance in a team environment
Question 8. Outstanding communication skills
Question 9. Involvement in personal and professional growth and development activities
Question 10. Suitable preparation for entry into graduate programs and research at major research universities
Question 11. Engagement in an interdisciplinary careers path

Table 1. Results (±standard deviations) of the PEOs survey conducted early 2007. Note that because of the close connection between the chemical and environmental engineering programs, the survey does not distinguish between chemical and environmental engineering constituencies. (N=number of responses)

	Quest. 1	**Quest. 2**	**Quest. 3**	**Quest. 4**	**Quest. 5**	**Quest. 6**	**Quest. 7**	**Quest. 8**	**Quest. 9**	**Quest. 10**	**Quest. 11**
Current students (N=11)	4.5±0.5	4.4±0.6	4.1±0.6	4.8±0.4	4±0.7	4.3±0.5	4.6±0.5	4.5±0.6	4.1±0.6	4.6±0.6	3.8±1.1
Alumni (N=21)	4.3±0.7	4.7±0.5	3.3±1	3.4±1	4.2±0.9	3.8±1.2	4.6±0.6	4.5±0.7	4±0.8	3.8±1	3.9±1
Employers (N=9)	4.6±0.5	4.6±0.7	4±0.7	4.3±0.7	4.6±0.7	4.4±0.5	4.7±0.4	4.5±0.7	4.2±0.6	4.1±1.3	3.8±0.9
Advisory board (N=10)	4.6±0.5	4.4±0.9	4.2±0.6	4.6±0.5	4.1±0.7	3.9±0.8	4.5±0.7	4.2±0.7	3.6±0.8	3.2±0.9	3.2±1
All (N=51)	4.4±0.6	4.6±0.6	3.8±0.9	4.1±0.9	4.2±0.8	4±0.9	4.6±0.5	4.4±0.7	4±0.7	3.9±1	3.7±1

List other career and professional accomplishments you feel are important, or any comments you wish to add:
Results:

- Flexibility in the working environment
- Computer programming, Foreign language skills and as broad as possible curriculum are in my opinion essential for early success in the workplace.
- A desire to continue learning new things. To be willing to except new task outside of the areas of their training. My example: I was educated as an Environment Engineer. As a design engineer I had to investigate cases of employees injured on the equipment. I also spend a year or more working on the redesign on cone crusher.
- A desire to solve the problem correctly. A passion for getting it right. This isn't something easily taught. It is usually passed on by example; from a professor that has true passion and desire to pass it on. If you have a professor like that on your staff, you must have that professor teach the class that is required by all students, such as a laboratory class where there is more interaction that just lecturing. Engineering is more than a job, it is a responsibility to society. The students coming out these days don't seem to hold that value. It needs to be reinforced.
- Ability to contribute to the profession, very broadly defined
- An unstoppable, career-long, desire to examine, explore and invent. A will to build and create.
- Communication is the most important aspect - both verbal and written. Breaking down technical information to pieces of information that relates to real world. Common sense evaluation of the problem presented is the most important skill most undergraduates these days are lacking, but is the most needed in the work place.
- Creativity
- I think the program prepared the students more for entering a graduate program versus entering the workforce. The few graduates who chose to enter the workforce were on their own to gain experience before graduating. More emphasis should be placed on preparing students for entering the workforce.
- How to go about creative and innovative problem solving, and how to lead others with integrity and inspiration. Becoming a balanced and dynamic engineer and person in the workplace is a necessity.
- I feel there needs to be a much stronger focus of professional and personal development. Particularly in a scientific field, where, say, personality is not a strong suit, we don't want our students to be taken advantage of by the strong social culture in the US. The program is intense for the students, and having gone through it years ago, we may forget how difficult and time consuming it was. I think there should be more effort to teaching the students how to network to develop their sales, communication, and presentation. More than just "lab presentation". Make industry night mandatory for example. It is far too easy to churn out followers, instead of leaders.

1.3 Examples of the Use of the Information Towards Improvement

The reviewer listed a concern that there were limited examples of the use of the information collected by the ongoing evaluation process towards the improvement of the attainment of the objectives.

This comment may be due to the fact that our program is relatively new and it is its first evaluation under the ABET 2000 criteria; hence, there is no long history of feedback loop to improve attainment of PEOs. While the reviewer stated that there are limited examples, it is undeniable that our program has markedly evolved in the past decade. A number of new course have been introduced, the curriculum was changed, and specific courses have been modified to better reach our objectives and improve the students learning experience. Many of the changes that have occurred can not be traced to a single cause. Frequently, changes are triggered by several factors such as surveys, informal or formal feedback by our constituencies, and faculty input. Further, we often try to accomplish several objectives with a single change. This all makes it more difficult to distinguish triggering factors and reaction.

Even so, the changes that were made are significant. Specific changes that have been made to improve attainment of the PEOs as a result of our continuous improvement process include but are not limited to:

CEE 10/11 was introduced to increase graduates' ability to perform at the highest level (PEOs 1-4). It was triggered by our evaluation of retention surveys, and feedback of alumni. We are currently evaluating whether our retention goals are reached and maximized with this course, and we have debated changing from the current one course with 2 units, to three courses in series (one unit each).

CEE 158 was introduced after review of surveys to better reach PEO #5 (exercise professional responsibility and sensitivity to a broad range of societal concerns, such as ethical, environmental, economic, regulatory, and global issues).

The establishment of the second computer room for undergraduates was triggered by student feedback and the need to increase their ability to use computers at high levels.

The recent discussions on possibly requiring ENGR 180 (Technical Communication; 3 unit course) is the result of employer feedback and feedback from the 2006 Advisory Board meeting. It is reinforced by some of the comments made in the 2007 survey discussed in the previous section.

As a result of alumni surveys which identified that being a successful professional within ~2 years after graduation was strongly limited by the lack of support in career placement, the College of Engineering created a new position (Career Development and Placement Officer) to assist graduating seniors with their transition into the workforce.

2. CRITERION 8: PROGRAM CRITERIA (WEAKNESS)

The program evaluator expressed the following weakness: "The chemical engineering program requires students have appropriate modern experimental techniques. Although many students demonstrate the ability to design experiments through the final design courses, elective courses, or participation in research projects, it is possible for students to complete the program without fulfilling this requirement.

The undergraduate committee, ABET committee, current lab course faculty, and the entire department discussed the outcome of the CHE program criterion 8 evaluation. The faculty were surprised by the evaluator's findings given the strength of our core main laboratory sequence CHE 160A, CHE 160B, CHE160C and the senior design course CHE 175A and CHE 175B, the modern undergraduate laboratory equipment available for the laboratory series, the breadth of the topics covered in the laboratory, and the experimental design included within the lab. This core series is also complemented with two technical elective laboratory courses CHE 124L and CEE 125. The evaluator notes that significant additional experimental design is acquired by the students in the electives, and/or extracurricular activities such as research; however, this is beyond the basic requirements.

Several documented actions have already been taken and implemented to improve upon the strengths of our existing program to further augment the experimental design component and the use of modern equipment in the core CHE curriculum. These include:

1. Students following the Bioengineering Option of Chemical Engineering now are required to take CHE124L as part of their core requirements. Therefore, all CHE students will enroll in either CHE 124L (Bioengineering and Biochemical Engineering Options) or CEE 125 (Chemical Engineering Option). This catalog change has been enacted, i.e., it has been voted by the CEE faculty and approved by the College Executive Committee. This modification closes a potential loophole that the students following the Bioengineering Option could have avoided a fourth laboratory course and addresses the key concern from our reviewer. For information, no CHE student has ever graduated without the fourth laboratory course.
2. The laboratory manuals for CHE 160A, CHE 160B, and CHE 160C as well as CHE124L and CEE 125 have all been carefully reviewed and edited to emphasize experimental design by removing potential "cookie-cutter" descriptions of laboratory experiments. The students are expected to design the experiments by choosing key experimental parameters to vary in their efforts to obtain design information.
3. Additional data acquisition and statistical software tools have been added to the laboratory CHE 160 series to update the experiments and improve students learning in areas of concern noted by the reviewer. These tools include the purchase of a statistical software package (Minitab) for the laboratory to be used in the design of the experiment and analysis of data obtained. Eight dedicated Dell laptops were purchased and fitted with data-loggers for automated data acquisition for the CHE 160ABC lab series to continually monitor data from the various Armfield equipment. LabView 7i software has been installed on these computers to promote the use of programming. A LabView module has been added to CHE160A to instruct students on computer data

acquisition and measurement. The Dean has made a long term commitment totaling $90,000 towards further modernization of our teaching laboratories (see attached letter).

The above changes address the concerns raised by the ABET reviewer. The following sections detail the changes made and provide evidence of even stronger core laboratory component for all Chemical Engineering Undergraduates.

2.1 Major Degree Change:
At the time of the ABET review, all Chemical Engineering students were required to take the following laboratory courses: Bio 5LA (Cell Biology Laboratory), CHEM 1A-1B-1C (General Chemistry, each course includes major laboratory component), Phys 40A-40B-40C (General Physics, each course includes major laboratory component), Chem 112A-Chem112B-Chem 112C (Organic Chemistry, each course includes major laboratory component), and CHE 160A-160B-160C (Chemical Engineering Laboratory Course), and CHE 175A-CHE175B (Senior Design Course). Additionally, chemical engineers following the Chemical Engineering Option were required to take CEE 125 (Analytical Methods for Chemical and Environmental Engineers), those following the Biochemical Engineering Option were required to enroll in CHE 124L (Biochemical Engineering Laboratory) while students following the Bioengineering Option students could (and did) select CHE 124L as a *Technical Elective*. The general catalog has been changed to now include CHE 124 L as a required course for chemical engineers following the Bioengineering Option. The change from *technical elective* to *core* utilizes the "significant additional experimental design acquired by the students in the electives," noted by the ABET program reviewer, for enhancement of experimental design within the required program. These changes were proposed in an ABET committee meeting, agreed upon by the undergraduate committee, voted unanimously for approval by the Chemical and Environmental Engineering Department, and will take effect in the next general catalog year. No other changes were made to the existing Chemical Engineering curricula.

2.2 Changes to Existing Courses: CHE 160A-160B-160C
The existing course manuals have been modified to further emphasize experimental design within the coursework. The current/updated manuals for all 5 engineering laboratory courses have been included as an Appendix to this document (CHE 160A-160B-160C-124L and CEE 125). The ABET evaluator expressed some concern during our exit meeting over the "cookie-cutter" nature of some of the laboratory experiments. The concern was that too much information was supplied to the students in how the experiment should be conducted without sufficient emphasis on individual/team experimental design. After several discussions amongst the departmental faculty, each faculty member who had taught/was currently teaching a Chemical Engineering Laboratory course was tasked with review and modification where necessary of the course material to ensure ample experimental design was included within each laboratory course. Listed below are the changes to the course curricula for each of CHE 160 courses. A brief description of CEE 125/CHE 124L is also included as at least one of the two lab courses is required for all CHE students.

CHE 160A: Chemical and Environmental Engineering Laboratory

Catalog Description: Involves laboratory exercises in chemical and environmental engineering. Experiments cover physical measurements, fluid mechanics, and mass transfer. *Emphasizes experimental design*, analysis of results, and preparation of engineering reports.

Course objectives: Upon completion of this course, students should be able to:
1. Organize pre-lab write-ups prior to experimentation and review phenomena.
2. Understand and determine experimental errors.
3. Determine and explain phenomena from experimental data.
4. Summarize data analysis and present in concise format and make recommendations to experimental procedures.
5. Write technical reports in format of publication papers in journals.
6. Make effective oral presentation of experiments conducted and discussion of results.
7. Relate phenomena studied in course to industrial processes and orally present the processes researched.
8. Conduct laboratory experiments efficiently within time limit.
9. Utilize modeling software to predict process control outcomes.

Laboratories:
1. Pipe friction and fitting (headloss)
2. Gas diffusion
3. Liquid diffusion
4. Pump characteristics
5. Wetted wall column
6. K_La determination

Changes to CHE 160A:Chemical Engineering Laboratory
To enhance an ability to design a system, component, or chemical process, CHE/ENVR 160A was revised to meet this outcome. Two experiments (i.e. Exp. #1 Pipe friction and fittings (head loss) and Exp. #3 Liquid diffusion) were substantially revised to be open-ended experiment. Experimental procedure and guidelines for result and discussion for these experiments were eliminated from lab manual. Instead following paragraphs were following to statement the objectives of experiments.

Experiment #1: Pipe friction and fitting experiment

"Please design and conduct experiment to achieve following objectives

1) to determine the relationship between headloss (energy loss) and flow velocity for both laminar and turbulent flow through a pipe and to compare experimental results with the Moody diagram (figure 6.10 in Fluid Mechanics for Chemical Engineering, Third Edition).

2) to determine the relationship between headloss and flow velocity for turbulent flow through various common pipe fittings and to compare experimental results with data found in handbooks."

Experiment #3: Liquid diffusion

"The design and operation of process plants to achieve the desired changes in materials depends upon the properties of the materials (or contaminants) in a flowing medium (gas or liquid). One of the most important properties of materials in fluids under such circumstances is diffusivity. Fluid flow and mass transfer operations depend to some extent on this property and such data are always needed in plant design.

Please design and conduct the experiment to determine the diffusivity of a dissolved sodium chloride in water and compare the experimental data with published data from a handbook using one-dimensional diffusion cell."

Two experiments (i.e. Exp. #2 Gas diffusion and Exp. #5 Wetted wall column) were revised to be semi open-ended experiment. Experimental objectives and procedures are provided without guidelines for results and discussion. Result and discussion sections were eliminated from lab manuals.

CHE 160B: Chemical Engineering Laboratory

Catalog description: Consists of laboratory exercises in chemical engineering. Includes experiments in physical measurements, heat transfer, reactor analysis, and chemical kinetics. Emphasis is on *experimental design*, analysis of results, and preparation of engineering reports.

Course objectives: Upon completion of this course, students should be able to:

1. Organize pre-lab write-ups prior to experimentation and review phenomena.
2. Understand and determine experimental errors.
3. Determine and explain phenomena from experimental data.
4. Summarize data analysis and present in concise format and make recommendations to experimental procedures.
5. Write technical reports in format of publication papers in journals.
6. Present experiments conducted and discuss results.
7. Relate phenomena studied in the course to industrial processes and orally presenting processes researched.
8. Conduct laboratory experiments efficiently within time limit.

Laboratories:

1. Mixed-flow reactors in series
2. Reaction kinetics in a plug-flow reactor
3. Linear and radial heat conduction
4. Forced convection in a finned heat exchanger
5. Concentric tube heat exchanger
6. Thermal radiation
7. Widget lab (Added Fall 2007)

CHE 160B – Changes for Fall 2006 and Fall 2007

The main goals of the class remain the same:

1. Students will merge heat transfer/kinetics theory with laboratory scale experiments to ascertain critical design parameters used in chemical engineering practice.
2. Develop team skills
3. Develop communication skills (written and oral)

The following changes were made to the Fall quarter 2006 over previous classes. (This course was ongoing during ABET review, and changes were made as soon as the first comments made by the reviewer were received). An additional laboratory exercise was added to the final four weeks of the course where the students were given a bench scale cooling tower and a single engineering design question to answer with no further guidance. The students were asked to work within their laboratory teams to determine what the critical parameters for their design were, how they would be determined, and then used their experimentally derived parameters to answer the design question. Example questions include:

a. **Lab Group 1:** Find the area of each disk in the cooling tower (given the number of disks in the tower). Now, scale-up the tower to handle 1,000 lbs/hr of water cooled from 140 degrees Celsius to 70 degrees Fahrenheit.
b. **Lab Group 2:** Assume we are the manufacturer of this cooling tower and you just did your test runs. We are shipping this cooling tower to Houston, Texas, to be installed. The design wet bulb temperature in Houston, Texas (Kern, p. 597) is 81.0 F. This is the worst condition for your tower to operate at (hot and humid in July in Houston). We have to cool off a hot water stream from 110 F (temp hot water in) to 90 F (temp cooler water out). What L/G (liquid to gas mass flow rate) ratio will you recommend to run this cooling tower at?
c. **Lab Group 3:** Find the effectiveness of the cooling tower.
d. **Lab Group 4:** Find the humidity of the exiting air.
e. **Lab Group 5:** Find the exit temperature of water if hot water flow rate is 2000 lb/hr and inlet hot water temperature is 150 degree Fahrenheit.
f. **Lab Group 6:** Packing density of the tower is 110 m^{-1}. Suppose that the packing density was changed to 200 m^{-1}, find the makeup rate of water required to keep a constant water flowrate of 1000 lbs/hr.

The following additional changes have already been made and will affect the **Fall quarter 2007** class

1 The laboratory manuals have been updated to remove experimental details that are now left to the engineering laboratory team to identify.
2. More freedom is given to each engineering lab team to set key laboratory parameters for operating the bench-scale units as a direct result of 1) above.
3. Less guidance is provided on how to achieve desired results – each group must now determine how to approach laboratory apparatus to achieve desired end results. For example, the students must now select appropriate experimental temperatures, time intervals, flow rates, etc., to determine the necessary chemical engineering design

parameters for scaling the system up with the following laboratory objective: Using the Armfield tubular reactor apparatus to obtain key reactor parameters, design a system that will be capable of generating 100 m^3/d of ethanol based on this experiment. Provide appropriate design information such as raw material masses, flow rates, reactor size, operating temperature, etc. What will be the change in the required volume of the reactor if the operating temperature is reduced by 10 C? No details are provided to the students on what to collect, just how the apparatus works and what supplies are available.

4. Students will be required to compare their data to previous groups to establish confidence limits for each unit operation.

CHE 160C- Chemical Engineering Laboratory

Catalog description: Consists of laboratory exercises in chemical engineering. Includes experiments and simulations in separation processes and in process control. Emphasis is on experimental design, analysis of results, and preparation of engineering reports.

Course objectives: Upon completion of this course, students should be able to:

1. Organize pre-lab write-ups prior to experimentation and review phenomena.
2. Understand and determine experimental errors.
3. Determine and explain phenomena from experimental data.
4. Summarize data analysis and present in concise format and make recommendations to experimental procedures.
5. Write technical reports in format of publication papers in journals.
6. Present experiments conducted and discussion of results.
7. Relate phenomena studied in course to industrial processes and orally present processes researched.
8. Conduct laboratory experiments efficiently within time limit.
9. Utilize modeling software to predict process control outcomes.

Laboratories:

1. Tray drier
2. Distillation column
3. Liquid-liquid extraction
4. Gas absorption
5. Liquid level control/labview

CHE 160C – Changes for Winter 2007 (first time taught after ABET evaluation)

The main goals of the class remain the same:

1. Demonstration that students can practice separation theory and process control theory through laboratory exercises.
2. Communication skills, both written and oral.
3. Teamwork skills,

The following changes were made in winter quarter 2007 over the earlier classes.

1. Orientation shifted from simply carrying out prescribed laboratory plan to one where they are the engineer assigned to this unit and now responsible for describing the normal unit operations, limitations and opportunities for alternative use and improvements.
2. More freedom in setting the laboratory parameters for operating the bench-scale unit in order to comply with 1) above.
3. Simultaneous analysis of data from current and previous teams to establish confidence limits for processing units.
4. Demonstration of good laboratory practices.
5. Student reports are shifted from a format used in academics to a format used in business with emphasis on those communication elements articulated in Chemical Engineering Practice.
6. Students make an oral presentation applying an element of the Process Safety Manual for their unit.
7. Field trip to a large biodiesel plant and student assignment of separation problems occurring in that plant.

CHE 124L– Biochemical Engineering Laboratory
(formerly technical elective for Bioengineering Option of Chemical Engineering, now required course for Bioengineering Option of Chemical Engineering. Still required course for Biochemical Engineering Option of Chemical Engineering. Only Chemical Engineering Option not required to enroll in this class, Chemical Engineering Option required to enroll in CEE 125 listed after CHE 124L description.)

Catalog description: Laboratory practices in biochemical engineering. Determination of microbial kinetics and biologically mediated reactions, oxygen transfer coefficients. Batch and continuous culturing, air and media sterilization, bioseparations.

Course objectives: Upon completion of this course, students should be able to:
1. Design and conduct experiments and analyze and interpret experimental data for the determination of kinetic parameters of enzyme catalyzed reactions without and with inhibition.
2. Design and conduct experiments and analyze data for enumerating cell growth.
3. Design and conduct experiments and analyze and interpret experimental data for the determination of kinetic parameters of cell growth, substrate consumption and product formation kinetics.
4. Design and conduct experiments and analyze and interpret experimental data for expression, isolation and purification of a protein from genetically engineered microorganism.
5. Write technical reports in format of publication papers in journals.

Laboratories:

CEE 125 – Analytical Methods for Chemical and Environmental Engineers
(Required course for Chemical Engineering Option)

Catalog description: Topics include chromatographic separations, mass spectrometry, atomic absorption, and electrophoresis. Presents total carbon analysis as an introduction to analytical methods and their use in the chemical and environmental engineering fields

Course objectives: Upon completion of this course, students should be able to:
1. Design experiment to quantitatively analyze composition and/or concentrations of unknown solutions using advanced experimental techniques.
2. Calculate the precision and accuracy of a measurement technique.
3. Analyze chemical samples using: gas chromatography (GC), high-performance liquid chromatography (HPLC), mass spectrometry (MS), UV-VIS spectrometer, ion chromatography (IC), atomic absorption (AA), total carbon analysis (TCA).
4. Identify the abilities and short-comings of the following techniques: GC, HPLC, MS, AA, UV-VIS, TCA, electrophoresis. Describe each instrument's essential outputs.
5. Describe the principles of operation for GC, HPLC, IC, MS, AA, UV-VIS, TCA analysis.
6. Define chromatography. Describe chromatographic separation principles in terms of the Van Deemter curves. Identify the relative importance of each term for liquid, gas, and ion chromatography.
7. Define spectroscopy. Identify the regions of the spectrum. Describe the chemical property that each region analyzes for. Distinguish between absorption, fluorescence, phosphorescence.
8. Prepare effective laboratory reports on research team outputs including abstracts, background, experimental set-up, and discussion of results.

Laboratories:

1. UV-Vis spectrophotomer
2. Gas chromatography – flame ionization detection
3. Gas chromatography – mass spectrometry
4. High performance liquid chromatography
5. Total organic carbon analysis
6. Atomic absorption spectroscopy
7. Ion chromatography

Each laboratory module is designed to provide the student/group with an experimental goal with the students needing to determine how to achieve this goal. Chemicals, glassware, modern equipment, etc., are made available with minimal guidance on how to achieve the final goal. Students must determine how to calibrate their instruments, what concentrations of calibrants to use, how they will effectively and efficiently approach the problem, etc.

2.3 Laboratory Equipment and Modern Experimental Techniques

Our teaching laboratories include a wide range of modern equipment, and well maintained teaching modules by Armfield. In the past few years, several Armfield modules had already been upgraded with modern analytical tools (e.g., NDIR CO_2 analyzer, computer for data acquisition). Below is a list of current laboratory equipment used in CHE undergraduate laboratories:

- Agilent 6890 Gas Chromatograph with Auto Liquid Sampler, Flame Ionization Detector and Electron Capture Detectors
- Agilent 6890 Gas Chromatograph/5973 Mass Spectral Detector with Auto Liquid Sampler and Programmable Temperature Vaporization Inlet
- Agilent 1100 Series High Performance Liquid Chromatograph. Includes Binary Pump, Degasser, Thermostatted column conditioner, Diode-array Detector, and Fluorescence Detector.
- Amersham Gels Gel Chromatograph
- Armfield "Pipe Flow and Fittings"
- Armfield "Test Rig for Pumps"
- Armfield "Gas Diffusion"
- Armfield "Liquid Diffusion"
- Armfield "Wetted Wall"
- Armfield "Mass Transfer"
- Armfield "Dynamic Behavior of Tanks"
- Armfield "Plug Flow Reactor"
- Armfield "Linear and Radial Heat Conduction"
- Armfield "Thermal Radiation"
- Armfield "Concentric Tube Heat Exchanger"
- Armfield "Forced Convection"
- Armfield "Drying"
- Armfield "Liquid-Liquid Extraction Column"
- Armfield "Distillation Tower"
- Armfield "Gas-Absorption Tower"
- Beckman UV-Visible Spectrometer
- Biorad Gel Electrophoresis
- Dionex (DX-120) Ion Chromatograph with auto liquid sampler
- Fisher Scientific Conductivity Meter
- HP Notebook Computer
- HP 5890 Gas Chromatograph Flame Ionization Detector
- New Brunswick Scientific Bioflo 2000
- Orion Dissolved Oxygen Meter
- Orion PH meters
- Shimadzu 5050 Total Organic Carbon Analyzer
- Shimadzu Atomic Emission Spectrometer
- Vernier Data Acquisition System (about 6 stations prior to purchases in January 2007)
- Labview 7i data acquisition software packages (Departmental license for instructional use)

- SuperPro Designer 6.0 Software (Departmental license for instructional use)

Laboratory Upgrades
While the equipment used in the Chemical Engineering Laboratories is of high quality and in good operating condition, it was determined by the Chemical and Environmental Engineering faculty that an upgrade into modern data acquisition techniques within the laboratory setting should be applied to the existing hardware. Therefore, eight new dedicated laptop computers and associated data acquisition equipment have been purchased for the CHE 160 series courses. These computers provide the foundation for measurement and data acquisition for the core sequence. The computers are equipped with two different data acquisition software (LoggerPro and Labview 7i) and Minitab, a professional statistical data analysis software package. The data acquisition systems impact all three CHE 160 courses by familiarizing the students with current data acquisition and logging systems. The new equipment purchased in January 2007 consists of:

- 8 Dell laptop computers dedicated to undergraduate laboratories (Dual Core, 2GB Ram)
- 9 Vernier Instruments data acquisition interfaces (5 multi channel, 4 single channel)
- Minitab statistical package (10 licenses)
- Assortment of electronic sensors/thermocouples to connect to data loggers (Vernier Instruments, 5 temperature probes, 3 conductivity, 7 dissolved oxygen, 1 pH, 3 voltage probes)

Lab Manager Hugo Galdamez with the newly purchased laptops which supplement the existing computers in the undergraduate laboratories for data acquisition and statistical analysis.

This equipment is currently being introduced in our laboratories. Further, the Dean committed a total of $90,000 (i.e., $30,000 per year) towards continued modernization of our instructional laboratories (see letter of commitment in Appendix). This will enable us to further improve the students learning experience in the areas criticized by the ABET site reviewer.

2.4 Other Experimental Design Considerations Already Present in the Curriculum

The core curriculum contains a number of opportunities to exercise experimental design. These were documented in our Self-Study. In addition, the curriculum includes advanced exercises in which students have to use their experimental design skills. It is our impression that these may have been overlooked during the site visit.

In CHE 117 (Separation Processes, required for all chemical engineering students) students are asked to perform virtual experiments on either a gas absorber, distillation or a stripping column using SuperPro Designer. Students have to decide what will be the operating conditions, and select two parameters to vary within a range determined by themselves to illustrate the effect of these two parameters either on the column diameter, column height, HTU, NTU, number of plates, etc., and comment on their observations. Students have picked gas/liquid ratio, design pressure drop, required absorption/stripping/distillation efficiency, packing size, compound inlet concentration, packing area, packing factor, temperature, reflux ratio, plate efficiency, etc.

Another example from CHE 117 is a typical exam question. This one was used in the final exam in Fall 2005, though variations on this topic are usually asked over the years. "*You have pilot-scale packed bed absorption tower in your laboratory. Describe how you will determine H_{OG} experimentally. (Explain concisely how the experiment will be conducted and what/how the data will be analyzed, use less than ½ page).*"

Through the use of various simulation software (SuperPro and PROII) exercises in CHE 175AB Senior Design, students obtain experience in designing and optimizing the parameters of equipment ranging from simple to complex systems such as flash drums, heat exchanger networks, pressurized systems and distillation trains. Students are given a range of conditions (temperatures and pressures, flowrates, tray locations) and are asked to determine and explain the results of changes imposed to these systems. This requires students to develop a systematic experimental design approach that leads to a better understanding of cause and effect relationships of the given unit operation. As for the exercises conducted in CHE 117, simulation softwares lend themselves very well to this activity as they allow each student to rapidly (and safely) find the outcome of their virtual experiment and test their experimental design.

Additional experience in designing and conducting experiments vary on a project-to-project basis in CHE 175AB. However, the requirement to analyze and interpret data and how data are collected are integral in all design projects. Data collection and analysis is prevalent in the modeling of the plant designs on simulation software such as SuperPro or PROII. Students build their processes using these simulators and must optimize the results by analyzing the material and energy data provided by the simulations. Some design projects require laboratory work to obtain data necessary for their design. When this happens, students determine the design variables, design the set of experiments including replicates, formulate the protocols, and conduct experiments. Other students in the class benefit form their peers experience through regular oral presentations in the class.

2.5 Summary

We believe that the already existing curriculum and well equipped laboratories coupled with the changes mentioned above to existing courses more than meets the requirements for "Modern Experimental Techniques" within Criterion 8 criticized by the on-site ABET reviewer. Key changes have been made effective which ensure that all students graduating from our program will have string training and demonstrated ability in modern experimental techniques.

3. CRITERION 3: PROGRAM OUTCOMES AND ASSESSMENT (CONCERN)

The concern of the reviewer is that the process in place for direct assessment of program outcomes seems not to be capable of distinguishing the performance of one program outcome from another. The program should modify the assessment process to establish a unique or nearly unique association between program outcomes and student work."

This is an issue which has stirred considerable debate both in the department and at the College level, since all programs use a very similar assessment method to evaluate the program outcomes. Although we strongly believe that the assessment method allows us to distinguish the success in individual outcomes without interferences from other outcomes, we are sensitive to the reviewer's concern.

Our assessment method has been elaborated over the past few years, and has been subject to many discussions, most of them at the College level, since the core principles of our assessment system are common to all programs. The system evolved over time. We were heavily inspired by a paper titled "Designing and Teaching Courses to Satisfy the ABET Engineering Criteria" by Felder and Brent. We use the same matrices that correlate course objectives to program outcomes, and use individual problems and student work (not course grades) to assess the degree to which each course objective was met, and therefore, by association, the degree to which each program outcome was reached. In devising our assessment method for continuous improvement, we were mostly guided by three main objectives. The assessment method should 1) allow us to determine if all program outcomes are covered adequately at a sufficient level, 2) allow us to determine if students demonstrate proficiency in these outcomes, and 3) guide us with our continuous improvement process.

We have demonstrated that our method does well in all three objectives. Over the past years, we have put the system to the test, and our data show that it works well. Two of our faculty in the College-wide ABET Committee are experts in data-mining, and they stated that what we do makes sense, and that the observations made are relevant. We also see a agreement between data collected from our direct assessment method, and our other assessments, for instance the exit survey.

However, it is also evident that the matrix method is quite complex, with several layers of calculations between inputs and outputs, which may have been a factor in the reviewer's concern. Thus, we believe that the best response to the concern is a very careful evaluation of our assessment method over the 06-07 academic year to demonstrate the unique association mentioned by the reviewer. This is an ongoing process which includes evaluation of data significance, and determination of the sensitivity of the output to the degree of orthogonality of the course assessment matrices. A correlation with an alternative assessment method will be attempted. This evaluation will be completed at the end of AY 06-07 and will be presented at the next scheduled ABET evaluation.

APPENDICES

Commitment letter from Dean Reza Abbaschian
Revised laboratory manuals for CHE 160A, 160B, 160C, 124L and CEE 125.