

4. CRITERION 4 - CONTINUOUS IMPROVEMENT

Required Content (as per E003 Self-Study Questionnaire 2009 6-11-09.doc)

A. Information Used for Program Improvement

Describe the available information, such as results from the Criteria 2 and 3 processes, commonly used in making decisions regarding program improvements

B. Actions to Improve the Program

Describe actions taken to improve the program since the last general review. Indicate why, i.e., the basis for taking action, and when each action was implemented and the results of the implementation.

4.1 Information Used for Program Improvement

The sum total of the assessment data obtained as described in Sections 2 and 3 serve as direct information on which program improvement is based and broad achievement is measured. Taken individually, each assessment tool described previously provides a variety of primary data that allows tracking of progress toward improvement on specific outcomes. Concrete examples include the 2AA0 and 3AA0 exams which are aimed at quantitative assessment on specific topical areas of the curriculum. Further, CEA's and DEQ's are in-course elements also designed at quantitative assessment of the achievement by the students on specific topical information or program outcomes. Tools such as these allow the department to make targeted improvements for specific areas in specific cases. These changes can be major or minor. For the purposes of this report, only major improvements are provided.

In addition to the primary data described above, other (less quantitative) information such as faculty opinions, informal student feedback, faculty discussion during review of course embedded assessments and departmental evaluation questions, discussion by the faculty at large during faculty meetings and retreats, general input by the alumni advisory committee and other external review persons are relied upon heavily when considering program changes. This type of information (collectively referred to as secondary data) is generally documented in meeting minutes, presentations, and other manners of documentation as appropriate.

To the extent at which the primary assessment data and/or secondary assessment data indicate an issue needs to be addressed, the CAPAC committee in conjunction with the faculty at large develop a plan for addressing the concern. Generally, the CAPAC committee will make a "first-pass" attempt at devising a strategy to address the issue. Subsequently, the faculty at large will discuss if major program changes are needed and/or suggest feedback to CAPAC, thereby creating an iteration loop in which possible corrective actions can be decided upon by the faculty.

4.2 Actions to Improve Program

The department has made numerous changes in response to the assessment data collected (described previously), faculty observations and trends in the discipline. These changes have occurred at various levels and have affected many different aspects of our program. The broader and more significant changes we have implemented, and the results thereof, are summarized in the sections that follow. They are organized roughly according to the hierarchical level at which the change was implemented.

4.2.1 CURRICULUM LEVEL CHANGES

4.2.1.1 Phase I Curriculum Changes

Just prior to the previous ABET on-site review, the department undertook a major curriculum revision. The main purpose of this revision was to provide new opportunities to perform assessment activities and to facilitate accountabilities and scheduling issues across the curriculum. Although not specifically a change made since the last visit, it is necessary to review this action to establish a baseline for the current curriculum.

Proposed in April 2003, the department established two non-credit courses to serve to measure proficiency and retention of science, math and engineering subject matter. Based on faculty concerns about subject matter deficiencies in the Faculty End of Course Surveys and also reflected in Senior Exit and Alumni Surveys, the department voted to employ "proficiency exams" similar in form to those already in use by the Auburn mechanical engineering program. In August 2003, the

Auburn University Curriculum Committee approved the proposal and allowed us to modify the chemical engineering curriculum to include CHEN 2@@0 (Progress Assessment I) and CHEN 3@@0 (Progress Assessment II). The designation of these courses changed to CHEN 2AA0 and CHEN 3AA0 when the university switched academic software.

The sequence of these two courses is prerequisite to students enrolling in the senior capstone design course CHEN 4470 Process Design Practice. In addition to serving as a gate to complete the program (assuring quality) the exams serve as a source of assessment data and help understand the perceived deficiencies cited by faculty. Specifically, the test questions are selected to verify the student's capabilities in important prerequisite topics. For example: use of the chain rule in differentiation, balancing redox equations, determination of limiting reactant, determination of reaction yields, etc.

The data from these exams can then be used to assess learning, retention, and ability to apply these topics. If deficiencies are noted, the CAPAC committee can investigate the matter and propose necessary changes. CHEN 2AA0 has been offered since 2004 and has provided a significant pool of examples of student work and skills. In the case of CHEN 3AA0, a considerable time was spend in developing, testing the exam materials and implementing the course.

A more comprehensive explanation of these actions is provided in Section 4.2.6.

4.2.1.2 Phase II Curriculum Changes

A second round of changes made to the curriculum involving a number of issues related to accreditation and EC2000 as well as to correct minor issues brought about by the universities conversion from a quarter based system to a semester-based system. The most significant of these were:

Addition of CHEN 3600 Computer-Aided Chemical Engineering: Assessment data collected during 2002 and 2003 pointed to a deficiency in the area of computer-applications and software proficiency in solving chemical engineering problems. This partly came about because two courses previously offered under the quarter format (CHE 213 Digital Computers in Chemical Engineering and CHE 515 Intermediate Computer Applications) were eliminated to decrease the number of hours in the program. The mandated College of Engineering course, COMP1200 Introduction to Programming, was perceived to provide insufficient exposure to the required computer language skills, important numerical methods and to software applications in the area of chemical engineering. During the several senior exit interviews as well as in comments made during the Senior Exit Survey and Alumni Survey it was strongly expressed that additional computer-related material was essential. To this end, the department added a new course entitled CHEN 3600 Computer-Aided Chemical Engineering to provide necessary instruction in programming specifically applied to the area of chemical engineering. This course will be taken in addition to the COMP 1200 Computer Science course. This course was first offered Fall 2004. It has since undergone considerable modification (as discussed in Section 4.2.3).

Standardization of Technical Electives: During the "quarter to semester" conversion, the department converted most of its existing technical elective openings to a two-credit hour format and similarly offered many of its technical elective courses as two-credit hour courses. This proved to be unsatisfactory for a number of reasons including difficulties in arranging for the department's program specialization plans as well as it being difficult to clearly demonstrate (for accreditation purposes) how these program specializations relate to the chemical engineering program. To remedy this problem, the department has converted all technical elective requirements to a three-hour format

and has changed all technical elective courses to a three-hour format as well. This uniformity will make course choices for the student much easier as well as allowing the department to demonstrate clearly that our program specializations are formed by appropriate selection of technical electives (rather than representing “new curriculums”).

Rearrangements and Consolidations: Our departmental assessment process has revealed that several of the courses in the current curriculum would be more effectively taught if combined. The CHEN 2100 Principles of Chemical Engineering and CHEN 2101 Principles of Chemical Engineering Lab were combined into a single course CHEN 2100 Principles of Chemical Engineering to provide more uniform instruction. Similarly, the currently offered CHEN 4651 Process Safety Lab is being combined with CHEN 4450 Process Economics to form a more valuable CHEN 4450 Process Economics & Safety course. This corrects an accreditation issue that our seniors were involved in their senior process design practice project without having completed their safety course. The two-course process design sequence (CHEN 4460 and CHEN 4470) is being modified to shift an hour from the CHEN 4460 Process Simulation and Optimization course to the CHEN 4470 Process Design Practice course. This is consistent with the workload and time expectations in the CHEN 4470 course. Coverage in CHEN 4460 is reduced to accomplish this.

4.2.1.3 Phase III Curriculum Changes

In 2005, further changes to the curriculum were proposed and approved. These included:

Addition of BIOL 1020 Principles of Biology I and BIOL 1021 Principles of Biology Lab. The discipline of chemical engineering was and still is undergoing a nationwide revision. The traditional areas of chemical engineering are being augmented with emerging technologies including a biological engineering emphasis. In recognition of this trend and the department’s longstanding research expertise in bioengineering and biomedical engineering, the department seeks to revise the chemical engineering curriculum to provide coursework in appropriate biological topics.

Replacement of ELEC 3810 Fundamentals of Electrical Engineering with PHYS 1610 Engineering Physics II (4). The critical content relevant to chemical engineering is better presented in the Engineering Physics II course. Additional important topics are also discussed which will strengthen preparedness for upper-level courses. This course also provides exposure of topics found on the FE exam (Fundamentals of Engineering). Precedence for engineering programs without the traditional ELEC 3810 course is found in recent curriculum changes in Civil Engineering.

The Physical Science Elective (4) was replaced with an Advanced Chemistry Elective (3). Previously, the ABET accreditation criteria 9 (Program Specific Criteria for Chemical Engineering) required that the curriculum provide a “physical chemistry experience” and this was met with a required physical chemistry course. This requirement no longer exists for Chemical Engineering Programs, therefore, we have replaced the “physical science elective” with a broader-defined “advanced chemistry elective.” The new Advanced Chemistry Elective allows students to take either biochemistry or physical chemistry. The proposal was discussed with the Chemistry and Biochemistry Department and the net impact to that department was deemed negligible since the course being eliminated is replaced by a selection of courses from the same department.

4.2.1.4 Phase IV Curriculum Changes

Effective Fall 2010, a series of prerequisite changes will be taking place to properly sequence students through the progress assessment course sequence as well as assure that students

enrolling in CHEN 3AA0 have taken the appropriate coursework “before or while taking” the exam. This involved requesting that CHEN 3370, CHEN 3650, and CHEN 3700 are co-requisites (prerequisites with concurrency) for CHEN 3AA0.

In addition, the department has also proposed that CHEN 3600 serve as a co-requisite for CHEN 3620 and CHEN 3370 to assure that student possessed necessary computer and programming skills. All the above changes were because of assessment of preparedness by faculty during the end of course survey process.

4.2.1.5 Revision of All Course Outcomes

During Fall 2008, the CAPAC committee recognized the need for a curriculum-wide revision of the course outcomes. Small teams of faculty members selected from those who had most recently taught a given course were assigned to overhaul the course outcomes. The revised course outcomes were further adjusted for uniformity and comprehensiveness by CAPAC and returned to the faculty for adoption. The uniform set of course outcomes has enabled faculty and students to have clear expectations of course content, and allowed the focus to remain on the proper material throughout the semester.

4.2.1.6 Prerequisite Changes

Over the course the past three years, the department has undertaken a comprehensive review of prerequisite requirements and a series of changes were made. These changes are reflected in the current version of the curriculum model available in the university bulletin. It is noted that many of these prerequisite changes were driven directly from faculty input regarding student performance issues and analysis of student performance on the assessment exams. This information was gathered by CAPAC through the faculty course end surveys, exam results, and regular discussion of the faculty. For example, it was determined that it was necessary to make passing the CHEN 2AA0 Progress Assessment Exam a prerequisite to CHEN 3650 to ensure that all students in this important analysis based course had the rudimentary problem solving skills and basic math and science background to be ultimately successful in the course and the remaining curriculum.

Two other examples of prerequisite changes were cited in Section 4.2.1.4.

4.2.1.7 Ongoing and Proposed Curriculum Changes

In addition to the aforementioned changes, the department has approved two substantial changes to be implemented in the near future. One is the creation of a three course “Professional Practice of Chemical Engineering” course sequence that will consist of three, one credit hour courses designed to provide formal instruction on topics such as problems solving skills, communication skills, professional ethics, safety, environmental and societal responsibilities of engineers, professional workplace standards, interviewing skills, etc. These courses will be matched in content and level to the curriculum stage at which they are to be taken. As an example, the first of the three part sequence will consist of introductory material such as departmental standards, (Homework and report format), general expectations of professionalism, academic honesty, problem solving skills and the like.

The other substantial change approved for implementation involves the creation of a two-course Chemical Engineering Analysis sequence (CHEN 2650 and CHEN 3650). In the new CHEN 2650 course, important and relevant mathematical topics will be covered from a chemical engineering context. Such topics will include numerical methods, Laplace transforms, Differential equations and

boundary value problems as applied to the practice of chemical engineering. Thus, the existing course CHEN 3650 will then focus more on model development and solution strategies and model analysis, with re-visitation of the topics covered in detail in the proposed CHEN 2650. The information that motivated this proposed change stemmed from data (Course Embedded Assessments, Faculty Course End Surveys, quiz and exam performance) provided by the instructors of the CHEN 3650 and CHEN 3600 and CHEN 3370 and CHEN 3700 courses over the span of several semesters. CAPAC's analysis of this information led to a proposal that was presented to and approved by the faculty at the Fall 2009 faculty retreat. In essence, the faculty responded that there was a great need to improve the applied engineering math skills of our students. It was determined that the proper placement of this course material was to have it precede the CHEN 3600 course, thereby making the sequence of CHEN 2650, 3600, 3650, 4170 most effective. At this stage, Dr. Ashurst is charged with leading a subcommittee of faculty to develop this course for submission to the University for approval.

4.2.1.8 Development of Instructional Materials for Students

In order to standardize elements of style and to help students improve their learning skills, the Undergraduate Program Chair undertook developing a set of online materials to be used as appropriate in all chemical engineering courses. The documents are introduced during CHEN 3600 Computer-Aided Chemical Engineering (aka Chemical Engineering Problem Solving and Communications) and faculty reinforce these principles as appropriate in subsequent courses. These documents have been approved by the faculty and represent an important element of developing our students' appreciation for adhering to expected formats and standards.

A short list of these materials and a brief description is provided below. The complete documents can be viewed online at the associated link.

1. Format for Equations: Detailed instructions for producing equations in technical memorandums and lab reports using Microsoft Word's Equation Editor. This summary also details the proper way to cite equations as well as how to represent equations in technical documents.
2. Citations and Reference Lists: Instructions about how outside resources used in writing memos and reports should be credited (cited) both "inline" (at the point of usage) and in the associated reference section.
3. Format for Figures, Graphs and Charts: Provides instructions about effective graphical representation including display of equations as well as experimental data. Discusses how appropriate, well-drawn graphical visual aids can substantially increase comprehension of text and convey trends, comparisons, and relationships more clearly than text alone.
4. Format for Tables in Reports: Provides instructions about making effective tables as well as pointing out the pitfalls of commonplace cutting and pasting between Microsoft Excel and Microsoft Word.
5. Short Memo Format: Engineers and scientists frequently use short memos to make requests, to give announcements, answer inquiries and as cover letters to transmit (accompany) technical reports. This document provides basic formatting and structural information about single-page memos.

6. **Specifications for Technical Memos:** Technical memos are used to communicate short reports where a formal report is not warranted. Typically they would be employed to communicate the solution to a posed question or assignment involving a technical analysis. Technical memos often include equations, figures and illustrations, tables, data and attached appendices. Because of its frequent use in the curriculum and the relationship to effective written communications, this form of memo is carefully explained and practiced.

Link 1: <http://eng.auburn.edu/cheweb/ABET/about-equations.docx>

Link 2: <http://eng.auburn.edu/cheweb/ABET/about-citations.docx>

Link 3: <http://eng.auburn.edu/cheweb/ABET/about-graphs-charts-figures.docx>

Link 4: <http://eng.auburn.edu/cheweb/ABET/about-tables.docx>

Link 5: <http://eng.auburn.edu/cheweb/ABET/short-memo-format.docx>

Link 6: <http://eng.auburn.edu/cheweb/ABET/technical-memo-format.docx>

4.2.2 PROGRAM LEVEL ADMINISTRATIVE CHANGES

4.2.2.1 Adoption of Required Homework Format

As previously discussed in Section 3.6.2.1.4, during 2007, the CHEN 2AA0 Process Assessment exam was changed to include “Show Work” problems where the students were evaluated on their problem solving methodology and approach rather than merely the selection of the correct answer. The performance of the students on these problems prompted the CAPAC committee to examine the issue of neatness and methodology for student work. As a result, in 2008, the department adopted a rigorous standard for the format and content of student homework. This standard is referred to generically as the “Required Homework Format” and is provided in Appendix M. This appendix also contains a document provided to the students called “Homework Myths and Realities.” This document provides student testimonials about the value of employing proper techniques in approaching problem solving.

Students are required to submit their homework in compliance with the standard format. The format is designed to promote a logical thought process for solution as well as to stress neatness and professionalism in written communications.

An initial version of the document cited that faculty or GTA should remove up to 20% of the problems credit if the format was not followed. Although many faculty employed this, two problems arose: (1) some faculty did not deduct for failing to follow the format (hence students felt it was “optional”) and (2) some faculty observed that students were willing to “sacrifice” 20% or less to avoid following the format.

In order to correct this situation, a faculty meeting was held to discuss the problem. It was decided that the homework turned in by students must follow ALL elements of the format. Further, this would apply to both undergraduate and graduate courses. Faculty were to meet with their graduate student graders to impress on her/him the importance of carefully grading the format of the homework. Most importantly, the deduction associated with not following the format is a credit deduction of from 20% to 100% of the assignment/problem value.

Since the inception of this policy, there has been a steady improvement in the appearance and organization of homework, quizzes and exams.

4.2.2.2 COE Annual Assessment Review

The College of Engineering implemented an activity called an Annual Assessment Review performed by selected members of each department's Alumni/Industry Advisory Council (or similar body). The Department of Chemical Engineering asked Tom Hendrick, Director of Supply Chain, Huntsman Corporation and Frank Magazine, Business Manager/President, Emerald Foam Control to serve as the department's reviewers. Although initially planned (in 2006) to be an annual activity, the review process has only been conducted once. Nevertheless, it provided a prototype for what may in the future be performed either annually or bi-annually.

The following briefly reports on our 2007 review:

Interview conducted on September 6, 2007

Participates: Dr. Chris Roberts, Department Chair
Dr. Timothy Placek, Undergraduate Program Chair
Dr. Nels Madsen, Associate Dean for Assessment

Objective and Scope: The objective was to evaluate the status of the ABET process in the Chemical Engineering Department and determine if adequate progress is being made to meet the ABET requirements. The scope included a complete review of the Department's programs and processes and a review of the facilities.

Information Source: Self Audit Report (2004), Report for Alumni Council Assessment Committee (July 2007 including attachments)

General Impression: The reviewers found that the department has put adequate controls in place to meet the current requirements of ABET. Details for critical elements are given below followed by an overall summary. Discuss here.

Summary Statement: We find that the department has established a solid foundation for its program objectives and outcomes that comply with ABET requirements. The challenge will be to maintain the momentum over time and follow up on the programs and processes that have been put in place to verify that the actions required for improvements are being taken.

4.2.2.3 Bloom's Taxonomy Based Teaching Philosophy

During the time since our last ABET on-site review, the department has been making significant improvements in acquainting students (and faculty) with the fundamental skills required to succeed in their academic pursuits and professional career. This effort was initially described with the phrase "How to Succeed in Chemical Engineering" but was officially re-titled "Proactive for Learning" which better describes the department and faculty's active role in helping students to learn, retain, and be able to apply the knowledge they are exposed to in the classroom and more broadly during their years at Auburn.

At diverse points in the curriculum, students are shown or reminded of materials developed to enhance their problem solving and learning capabilities. At any point in any course, the instructor can make use of these web-based resources.

The underpinning structure of these materials is to provide the students with an understanding of the Bloom's Taxonomy for Learning. This effort was preceded by faculty retreats and meetings where the concepts involved in the taxonomy were applied to developing course outcomes and explained in the context of developing appropriate examination questions.

The following documents represent the major topics available on the web; however, new materials are constantly being developed and added. The two “cornerstone” documents will be briefly described.

Bloom’s Taxonomy Applied to Engineering Education: This document describes the fundamental nature of the Bloom’s Taxonomy and how students can employ this in a progressive fashion in their courses. It explains the nature of each taxonomic level, the key responsibilities of the student and faculty, and how the student will know they have reached this level of learning.

Web Source: <http://eng.auburn.edu/cheweb/ABET/Bloom’s Taxonomy Applied to Engineering Education.pdf>

How To Succeed In Chemical Engineering: This document is a mindmap that represents the totality of issues and skills that contribute to a student being a successful engineer. This document was the initial effort in our efforts to promote student success and is a visual reminder of the breath of skills required to perform effectively in the chemical engineering profession.

Web Source: <http://eng.auburn.edu/cheweb/ABET/How To Succeed In Chemical Engineering.pdf>

The remaining documents have names that strongly reflect the content, so no further description is provided. Web links are provided should it be desired to read the actual documents.

- Homework Myths and Realities
- How Experts Overcome Barriers
- How Novices and Experts Solve Problems
- Problem Solving Steps
- Problem Solving Steps Summary
- Reasons for Failing to Solve Problems
- Successful Problem Solving Methodology Summary
- Types of Reactions Balancing Reactions
- Writing A Strategy for Success
- Damage Control For Exams

Web Source: <http://eng.auburn.edu/cheweb/ABET/Homework Myths and Realities.pdf>

Web Source: <http://eng.auburn.edu/cheweb/ABET/How Experts Overcome Barriers.pdf>

Web Source: <http://eng.auburn.edu/cheweb/ABET/How Novices and Experts Solve Problems.pdf>

Web Source: <http://eng.auburn.edu/cheweb/ABET/Problem Solving Steps.pdf>

Web Source: <http://eng.auburn.edu/cheweb/ABET/Problem Solving Steps Summary.pdf>

Web Source: <http://eng.auburn.edu/cheweb/ABET/Reasons for Failing to Solve Problems.pdf>

Web Source: <http://eng.auburn.edu/cheweb/ABET/Successful Problem Solving Methodology Summary.pdf>

Web Source: <http://eng.auburn.edu/cheweb/ABET/Types of Reactions Balancing Reactions.pdf>

Web Source: <http://eng.auburn.edu/cheweb/ABET/Writing A Strategy for Success.pdf>

Web Source: <http://eng.auburn.edu/cheweb/ABET/Damage Control For Exams.pdf>

We feel this is a unique and powerful improvement in our program. This action resulted from analyzing assessment feedback from students and faculty that pointed out fundamental learning issues in our students. Additionally, the previously mentioned three-course professional development sequence will build on these concepts and develop further resources.

4.2.2.4 Departmental Calculator Policy

During Fall 2006, student academic honesty was identified as an issue through our assessment process. Information was sought directly from students using a special survey to determine the extent of the problem as well as the affect on student attitudes (about the department and their fellow students). One of the mechanisms of cheating identified was passing information on calculators capable of storing and displaying text. As a result, the department has taken two corrective actions to address this issue. One corrective action was the adoption of a “Calculator Policy” whereby only departmentally approved calculators may be used on quizzes and exams. Departmentally approved calculators are generally those without programmable memory or external communication capabilities. Only models of calculators approved by NCEES (National Council of Examiners for Engineering and Surveying) are permitted to be employed during examinations and quizzes. This is consistent with the calculator policy employed in professional licensing (Fundamentals Exam “FE” and Professional Exam “PE”). The approved calculators are inexpensive and widely available. Students may continue to use any calculator or computer device they choose on homework and for other non-exam activities.

Similarly, there are restrictions on the use of cell phones, pagers, and other electronics devices during examinations.

This policy change is coupled to the inclusion of an “Honesty Statement” on exam papers and certain other student work material such as laboratory reports. Briefly, the Honesty Statement requires the student to affirm that he/she has adhered to the university guidelines for academic honesty and is aware of the consequences thereof. Because of these changes, improvement in the students’ comments during senior exit interviews and other related survey questions has been observed.

4.2.2.5 Student Mentoring/Advising

CAPAC has approved a student Mentoring/Advising program to become effective Fall 2010. This mentoring program is designed to assist students through the curriculum and into a professional career. A complete discussion can be found in Section 1.3.3.

4.2.3 COURSE LEVEL CHANGES

4.2.3.1 Revision of CHEN 2610 (Term Design Project and Updated Course Content)

Consistent with the department’s desire to distribute design content widely throughout the curriculum, an introductory design project has been made part of the CHEN 2610 Transport I course. Additionally, data from the 3AA0 assessment exam indicated that student retention in the area of fluid mechanics has been weak. It was thought that providing the students with an open-ended, independent project requiring the use of transport principles would reinforce these important concepts. As such, an open-ended design project culminating in a technical report and poster competition has been incorporated into CHEN 2610. For the first few years during this ABET review cycle, these projects centered on the design of a variety of fountains/pump systems. In an effort to also reinforce biological engineering aspects of the program, recent projects have focused on the design of an artificial heart/lung machine.

The current project has been updated to include an understanding shear stress and the derivation of velocity and shear stress profiles using the Navier-Stokes equations. In particular, the class project has been modified from the previous fountain design to a project involving the downsizing of an adult heart lung machine to a pediatric sized system. In addition to the core concepts historically reinforced through the project: choosing a pump, determining head loss through the system, calculating volumetric flow rates and pressure gradients, and comparing piping sizes and

materials, the new heart-lung machine project requires students to consider Reynolds numbers and shear stress of the fluid (blood) on the tubing wall in their system design.

In addition, students have the opportunity to practice scaling a system and to think through the important design parameters. The students must also minimize changes in the surface area to volume ratios since contact with the tubing wall damages the process fluid that will in turn lead to adverse outcomes. Finally, approximately half of one lecture is spent teaching the students to search the primary literature for papers on a particular topic and use related tools (primarily Web of Knowledge). Overall, the open-ended nature of this project along with the need to gather information independently and read research papers is designed to help the students learn and think independently in the fashion of lifelong learning.

Examples of the student's posters are provided in Appendix O.

4.2.3.2 Revision of CHEN 3600 (Problem Solving and Emphasis of Written Communications)

Based on concerns about the problem solving skills of our undergraduates from Faculty End of Course surveys as well as Senior Exit Surveys, the department has revised the curriculum in CHEN 3600 Computer-Aided Chemical Engineering to formally include instruction in "systematic problem solving" and "critical thinking." Consistent with this change (and another change to be discussed below), a new name was proposed for the course (Chemical Engineering Problem Solving and Communications). This change will be submitted to the University Curriculum Committee to be effective during the 2010-11 academic year.

Much of the related instructional material was developed over the past few years. The nature of programming leads to a systematic approach to problem solving thus making these topics highly relevant. It is anticipated that students will be given additional opportunities in subsequent courses to employ and further develop their problem-solving skills.

Instructional materials developed to date include:

- Stages of Critical Thinking
- An Introduction to Problem Solving
- Engineering Reasoning Objectives

A second action has been implemented in CHEN 3600 concerning formal instruction in written technical communications. Faculty have noted in End of Course Survey comments that students have had very poor writing skills, especially in expressing engineering concepts as well when reporting their results of laboratory experiments. Prior to 2000, the department had as part of the curriculum a "technical writing course." This course was removed when the university implemented an increased core curriculum but maintained a cap on total credit hours.

Depending on the term, a number of different lectures and assignments help the students improve their ability to express technical content in a written communication format. Since computer solutions of chemical engineering problems frequently leads to graphical, tabular, and textual results it was felt that a "good home" for this material was the Computer-Aided Chemical Engineering course. The term-to-term variation in approach and assignments keeps the course "fresh" and avoids problems in students employing materials from previous terms.

Comments from faculty who teach subsequent courses have indicated a significant improvement in the effectiveness of students' written communications. The capstone-design project reports show markedly better communications skills.

4.2.3.3 Revision of CHEN 3650 (Restructuring of Content)

CHEN 3650 Chemical Engineering Analysis was changed significantly in content during the 2006 academic year. Based on feedback from the students and faculty depending on the material covered in CHEN 3650, it was determined that the content of the course needed revision in order to better meet the needs of the curriculum. The course was restructured to build upon ideas covered prior to CHEN 3650 in CHEN 3600 Computer Aided Chemical Engineering and to set the stage (by introductory treatment) for topics that are thoroughly treated in CHEN 4170 Digital Process Control. These elements guide the topics covered in CHEN 3650 and flavor the examples and assignments made therein.

The CHEN 3650 course now focuses on numerical methods and the computer solution of pertinent equations using these numerical methods to solve chemical engineering problems. Examples include Euler and Runge-Kutta integration techniques, Newton-Raphson iteration, Method-of-Lines Finite Element approaches, Levenberg-Marquardt nonlinear regression and eigenvalue analysis, all implemented from within Excel and/or VBA. CHEN 3650 also builds on and focuses problem formulation as applied to process modeling. Examples include use of modeling algorithms, classification of models by type and solution method, single input single output models, multiple input multiple output models, vector/matrix (state space) representations, transfer function (frequency space) representations, and model constituency.

In addition to these topical changes, since the spring of 2008, the CHEN 3650 course has contained a "make-it-real" experiment (see Section 4.2.3.9) designed to involve a simple (individual) experiment design and modeling project culminating in a comprehensive written report that details the experiment, model results and conclusions. The engineering concept that the experiment focuses on is always selected from prerequisite course material with the point being to reinforce the concept and deepen the student's understanding of the relation of that concept to other engineering processes.

4.2.3.4 Revision of CHEN 3820 (Strengthening of Error Analysis Concepts)

In 2007, an internal review of the students' laboratory reports indicated that the use of standard error analysis techniques among students taking CHEN 3820 and CHEN 4860 was often inconsistent or totally lacking. The students did not routinely take into account the uncertainties associated with their experimentally gathered data and, as a result, did not consistently calculate or report the uncertainties for their quantitative results.

Discussions between the reviewer and the faculty teaching CHEN 3820 resulted in a determination that a change in the sequence in which error analysis techniques were taught to the students was necessary. In the previous course configuration, the error analysis techniques were taught over the course of the semester concurrent with the running of certain experiments. For example, a technique suitable for analysis of a particular set of data might be taught weeks after the data had been gathered, analyzed and reported on.

In response to this deficiency the schedule and nature of CHEN 3820 experiments was modified. Currently all the students in CHEN 3820 perform an "introductory" experiment where the data for this experiment is gathered by the class as a whole and the students are instructed in the

application of the “standard deviation of mean” method to gauge uncertainties. This occurs well before the theoretical underpinnings of the method are formally established. The data scatter typically observed in this experiment helps to ensure the students are appreciative of the fact that data in subsequent experiments has uncertainties and needs to be properly analyzed.

4.2.3.5 Revision of CHEN 4170 (Restructuring of Content)

During the early 2000's, our CHEN 4170 Digital Process Control course focused strongly on one type of controllers (i.e., programmable logic controllers (PLC)). PLC has wide applications in industries, but its application is usually associated with the automation of electromechanical processes, such as control of machinery on factory assembly lines, lighting fixtures, etc. The most significant difference between electromechanical processes and chemical processes is that chemical processes usually have strong dynamics while electromechanical processes usually are static processes. Therefore, in chemical and petrochemical industries, the most commonly used control system is distributed control system (DCS), which implements proportional, integral and derivative controllers as well as advanced control methods such as model predictive control and robust control algorithms. In addition, most chemical engineering departments including those at leading universities, such as UW-Madison, UIUC, UT-Austin, all focus their undergraduate control course on classical control theories where transfer function is the basic tool used to analyze a process and design an optimal control system.

When Dr. Jin Wang joined the department, she undertook several important changes in the CHEN 4170 course to the students prepare for their future industrial jobs and/or graduate studies. These changes included:

- Selection of a new textbook (one commonly used at the leading chemical engineering departments)
- Implementation of MATLAB Simulink to allow students to learn how to simulate a process and visualize process dynamics. The MATLAB software is a commonly used computation language both in academia and industry
- Assignment of a term project related to controller design that requires the use of computer simulation
- Including a field trip to a facility where the students can see how a DCS is implemented in an industrial environment and what a human-control-interface looks like. In this way, students will have a better idea of what to expect if they become a control engineer. Similarly, they will be better prepared if they go to graduate school since this content is similar to the content at other leading universities.

At the time these changes were first implemented students did not have the necessary math background, especially Laplace transforms. In order to correct this problem, changes in the content of CHEN 3650 Chemical Engineering Analysis was revised in order to provide more exposure to the topic of Laplace transforms, as well as how to develop mathematical models for dynamic processes (see the discussion in Section 4.2.3.4). As a result, students who entered CHEN 4170 during the last year have significantly better preparation and are performing better.

4.2.3.6 Revision of CHEN 4450 (AIChE Safety Certification)

Based on feedback obtained during the evaluation of the senior design projects by the external industrial evaluators, as well as the results of the EBI survey during that time-frame, it was determined that increased emphasis on safety was needed in the program, particularly related to industrial process safety. To address this concern, the Process Economics and Safety course (CHEN 4450) adopted the Safety and Chemical Engineering Education (SaChE) program's Student Safety Certificate Program as a required part of the coursework starting in the Fall of 2008.

Web Link: http://sache.org/student_certificate_program.asp

The initial offering of this SaChE safety certificate program was very well received by our students and was deemed highly successful, such that the instructor for the course has made this a permanent element of the course. In addition, the instructor attended a workshop put on by SaChE to gain a full appreciation of the full scope of materials that are available through SaChE to academic programs and has added several new elements to the course each year. As a result of this change, the 2009 and 2010 external industrial evaluators cited marked improvement in the students' awareness of relevant health and safety considerations.

4.2.3.7 Revision of CHEN 4470 (Increased Coverage of Safety)

The senior design sequence has been significantly restructured to include increased coverage of equipment design, environmental impact and sustainability. A much stronger emphasis on process safety and sustainability has been included in CHEN4470, and this was subsequently enhanced with the additional changes in CHEN 4450 involving the SaChE certification program described above.

These changes were implemented largely as a result of assessment by external industrial evaluators (using the Design Rubrics) in the CHEN4470 course. The external industrial evaluators observed and noted distinct improvements in these areas already by Spring 2007 as described in a letter by Mr. Robert D'Alessandro, Director of Process Engineering at Evonik Degussa (full letter is available upon request): "I must say there has been a definite improvement since I participated in 2005.... I was especially pleased to see how many of the teams considered process safety as an integral part of their designs as opposed to simply considering safety as a matter of toxicology. We discussed this aspect during my 2005 participation and you have obviously taken our previous discussion seriously....."

4.2.3.8 Introduction of "Make it Real" Experiments

During Fall 2008 the so-called "Make it Real" experiments were devised in order to give our students opportunities to experience, in the real-world, engineering concepts and to demonstrate by example these concepts to themselves. The particulars of the "make it real" experiments vary by course, and are generally designed to highlight key aspects of the course in which they are offered. The general approach was to devise a series of experiments aimed at utilizing everyday objects in view of



slightly more technically advanced metrology. The goal of these experiments is to have the students design, carry out and analyze the results of a simple experiment that demonstrates a basic concept of chemical engineering. As an example, one of the “Make It Real” experiments developed in CHEN 3650 involved the process of adding ice cubes to a glass of water in order to cool it. The object of the experiment was to model the process and measure the temperature of the water during the cooling and subsequent warming period. This experiment was aimed at demonstrating the latent heat of fusion and natural convection concepts.

4.2.3.9 Adoption of Standard Software

The department recognizes the need to apply uniform instruction in software products throughout the curriculum. This matter was frequently cited by exiting seniors and through end of course survey comments. However, the use of varied software is unavoidable, as products such as ASPEN, MATLAB, Simulink and Excel all have significant use in the chemical process industry into which most of our students become employed. To the extent possible, we strive to reduce the number of software products employed by the courses within the curriculum. As an example, the CHEN 3650 course recently adopted VBA as the designated software for the course, in order to build on and reinforce the development from CHEN 3600 Computer-Aided Chemical Engineering. It is anticipated that VBA and Excel will increase in use throughout other courses over the next few years.

4.2.4 PROGRAM OUTCOME AND EDUCATIONAL OBJECTIVES CHANGES

4.2.4.1 Revision of Departmental Educational Objectives

Beginning in 2006 with the publication of “measureable achievement” requirements for program educational objectives, the department undertook a comprehensive evaluation and revision of existing program objectives. This important action has been extensively presented at the beginning of Section 2.5.

4.2.4.2 Revision of Departmental Outcomes (AUCHEN (1-11) to AUCHEN (A-K))

During 2006, the CAPAC committee began consideration of the approaching 2010 ABET on-site review and program inspection. It had been previously considered advantageous to employ unique program outcomes that could be related to the ABET (A-K) requirement of Criteria 3. At this time, having distinct and independent outcomes was seen as a disadvantage to clearly demonstrate compliance with ABET requirements. After discussion and approval of the faculty, it was decided to employ program outcomes derived from the general ABET (A-K) using specific wording changes to specify the unique elements of our program. One additional change was the splitting of ABET (G) into AUCHEN (G1) and (G2) which effectively separated the written communications capabilities from the oral communications capabilities. This was felt to be useful in that very different criteria are employed for each of these areas.

A future action which is still under consideration is the inclusion of a related AUCHEN (G0) outcome which would be directed at measuring the student’s capability to effectively read technical materials. The sequence G0, G1, and G2 would assure complete communications proficiency.

4.2.5 CHANGES TO THE DEPARTMENTAL ASSESSMENT PROCESS

4.2.5.1 Course Embedded Assessment (CEAs) of Program Outcomes

As has been previously discussed in Section 3.6.2.1.5, Course Embedded Assessments (CEAs) are a unique tool to “probe” the developing capabilities of the students and to be able to make important changes to the curriculum before the students arrive at the senior year. The files associated with the CEAs collected and acted on thus far will be available for inspection during the visit.

4.2.5.2 Departmental Examination Questions (DEQs)

Related to the implementation of the Concept Inventory Exam in CHEN 3AA0, we noticed a markedly poor performance on the section of the exam in which the students provides “explanations” or “descriptions” of various engineering concepts. As a result, the department has undertaken having faculty add “explain questions” to their standard exams so that students will have more exposure and practice with this type of question. This action has been previously discussed in Section 3.6.2.1.6.

4.2.5.3 Course Notebooks

During the Fall 2008, the CAPAC committee and Department Chair approved a requirement for faculty teaching undergraduate courses to compile a “Course Notebook”. The purpose of the notebook is to provide the department with accurate and consistent information about classroom activities. This activity is a continuing requirement (independent of the collection of student work exhibits). Notebooks are required for all standard undergraduate courses including pre-CHEN courses such as ENGR1110, core courses (required chemical engineering courses), elective courses, and special topics courses (formal courses in development). It is not required for undergraduate research, directed reading or similar courses. These notebooks will be submitted to the department at the end of the term and serve as a “snapshot” to be used in course and curriculum improvement as well as peer review, accreditation and other purposes.

It is suggested that the faculty prepare the notebooks (collect the necessary materials) “as the term progresses” rather than being assembled at the end of the term.

Course notebooks contain the following information:

- A cover sheet (course information sheet) is provided to document the course notebook (made available separately).
- Course syllabus or course outline
- Copies of all course handouts directly related to the instructional mission of the course. Copies of handouts of a non-essential nature do not need to be provided.
- Copies of all exams and final (include the solution of these exams).
- Copies of all quizzes (optionally include the solution of these quizzes).
- List or schedule reflecting the homework assignments made (if taken from the course text) or copies of the assignments themselves if not taken from the course text) (solutions do not need to be provided).
- Copies of all major assignments, (special projects, term projects, reports, etc.)
- Designate on the cover sheet those assignments or tasks which reflect computing activities.
- Designate on the cover sheet those assignments or tasks which reflect written or oral communications activities.

- Beginning Spring 2010, the course notebooks will contain the required Departmental Evaluation Questions (DEQs) that were employed during the term. Each course should provide a minimum of 2 (3 is preferable) DEAs. There is a separate reporting form to be included with DEQs. Examples of student work are required.

During the ABET on-site review, course notebooks will be available in the CAPAC office for inspection.

4.2.5.4 Restructuring of CAPAC Committee

At the point of the last ABET on-site review, the CAPAC committee was composed of the Undergraduate Program Chair, the Department Chair and one or two select faculty. With time and experience, we found that the CAPAC committee's effectiveness depended much on the size of the committee and the time availabilities of each of the members. Previously, only more "established" faculty were used on the committee, however, we have switched to a somewhat larger format (5 individuals) composed of "new blood" to generate "energy and vitality" in the committee's work. As a matter of sustainability, the CAPAC committee meets once weekly for one and one-half or two hours with an optional second meeting if there is a lot of unfinished business. This has worked out very well and will be continued in the future.

4.2.5.5 Changes in Departmental Constituency

Alumni/Industrial Advisory Council Membership

In order to ensure that the department is receiving feedback from all appropriate industrial and professional sectors, the department's primary advisory group undertook a significant restructuring and growth of its membership as described in Section 2.4.4. As such, the name of this council was changed to Alumni/Industrial Advisory Council. In short, the membership was increased significantly with emphasis on greater diversity of area of specialization and expertise.

Recent Alumni Group

As previously discussed in Section 2.4.5, recent graduates of the program were asked to provide unique feedback on a variety of issues including assisting in the development of the Alumni Survey, feedback on computer programming language use, and others. The addition of this group as a formal constituency has proved invaluable.

4.2.6 ACTIONS INVOLVING ASSESSMENT TOOLS

4.2.6.1 Changes in Survey Tools

At the time of the last ABET on-site review, the department was employing the Perseus Survey Software. Due to changes in licensing and based on suggestions by our Alumni/Industry Advisory Council, we selected to employ the web based "Survey Monkey" product. Since converting to this system, we have found the new software to be easier to use to deploy new surveys as well as perform the analysis of the results. We have learned that one small change in an item (such as the wording of a program outcome) can require adjustment of many related documents and web-based information. Ease of use and maintainability are therefore important considerations in choosing survey and database software.

4.2.6.2 Changes in Assessment Exam Tools

The major changes to assessment tools are seven-fold. Each of these topics has been previously discussed and the reader is directed to the earlier discussion.

- Inclusion of Show Work problems on CHEN2AA0 Exam (see Section 3.6.2.1.4)
- Inclusion of Explain Questions on CHEN3AA0 Exam (see Section 3.6.2.1.4)
- Development of Course Embedded Assessments (CEAs) (see Section 3.6.2.1.5)
- Development of Departmental Evaluation Questions (DEQs) (see Section 3.6.2.1.6)
- Development of the Laboratory Assessment Rubric (see Section 4.2.6.3)
- Development of a Junior Survey (see Section 3.6.2.2.2)
- Revision of Alumni Survey (see Section 2.5.1)

4.2.6.3 Revised Laboratory Assessment Process and Rubric

In 2006, it was determined that the process being employed to assess the outcomes derived from the capstone laboratory course (CHEN 4860) were not sustainable. As such, the department streamlined this process by assigning one faculty member each year to independently review that year's student laboratory reports using a modified laboratory assessment rubric (see Section 3.6.2.1.3). This refined process has proved to be much more sustainable and has yielded quantitative and qualitative assessment information that can be acted upon. For instance, the 2007 review indicated an issue related to proper error analysis techniques. This information was then used to modify the course offerings of CHEN 3820 and CHEN 4860 and improvements were observed in the following terms.

4.2.6.4 Video Recording of Oral Presentations

For the past several years, the oral presentations given by the students in the laboratory courses (CHEN3820 and CHEN4860) as well as the capstone design class (CHEN4470) have been recorded on DVD's. Initially the recordings were done primarily for documentation purposes so that a record of the students' performances existed beyond the Powerpoint slides. Furthermore, the video record allows concrete feedback to be given to the students on their performance to assist them in improving further.

The presentations in the design class are often attended by students from the freshman ENGR1110 class as part of their professional development activities and also by students from the junior separations class (CHEN3660). Due to class schedule conflicts etc. it may not be possible for all interested students to attend these presentations in person, so we are considering using the DVD's for other purposes as well. With the strong emphasis in the department on effective communication skills, these recordings serve as a valuable resource to provide examples of how to deliver a professional presentation. Furthermore, for design projects where the separation tasks were particularly challenging, the relevant parts of the student presentations could be used as case studies in the CHEN3660 class as well.

4.2.7 ACTIONS INVOLVING THE FACULTY

4.2.7.1 Development of Accreditation and Instructional Related Materials for Faculty

In order to improve the nature and importance of the assessment process, the Undergraduate Program Chair developed a series of materials highlighting various accreditation issues. These were promulgated to the faculty via regular meeting, retreats, and email.

A short list of these materials and a brief description is provided below. The complete documents can be viewed online at the associated link.

1. **ABET Outcomes (A) vs (E) Explained:** One of the early discoveries of the CAPAC committee was the general misunderstanding of the difference between ABET (A) and ABET (E). Many faculty considered that testing on course lecture material was demonstrating problem solving skills. This document provides a “Bloom’s Taxonomy” based description of the key elements of “knowledge” versus “problem solving”.
2. **Bloom's Taxonomy – It's Not About Stuffing Armadillos:** During 2007, it was observed that many of the faculty were unaware of the well established model for “learning” (i.e., Bloom’s Taxonomy). This presentation was made to acquaint the faculty with the general nature of the classifications and to encourage their conveying this approach to learning to their students. At the present, Bloom’s Taxonomy is a lecture topic in the CHEN 3600 Computer Aided Chemical Engineering course as an element of “problem solving”.
3. **ABET Outcomes Explained Using Bloom's Taxonomy:** This is a follow-up to item (1) where all ABET required program outcomes were discussed from the standpoint of Bloom’s Taxonomy. This was a precursor discussion to the next item where faculty were asked to prepare revised course outcomes reflecting the keywords available in Bloom’s Taxonomy.
4. **Developing Course Outcomes:** During the complete revision of all course outcomes, a meeting was held to provide faculty orientation with regard to the specific objectives of reviewing existing program outcomes. As stated in the document, “Program outcomes are not achieved “by chance or accident” but rather are achieved by carefully coordinating (designing) the curriculum’s content and delivery to develop student knowledge, skills and abilities as described by course outcome statements. Therefore, course outcomes provide the means by which program outcomes are achieved. This linking needs to be specific and demonstrable (during the accreditation process).”
5. **Employing Bloom's Taxonomy When Developing Course Outcomes:** This document was developed to assist faculty in preparing effective course outcomes using an approach based on Bloom’s Taxonomy. In particular, the faculty were instructed to consider:
 - a. What are the specific student behaviors, skills, and abilities that would tell them your course goals were being achieved?
 - b. Ideally and briefly, what would a skeptic need (what evidence needs to be present) in order to see that the students were achieving the major goals you have set out for them?
 - c. What evidence tells you when students have met these outcomes?
6. **Seeing the Forest for the Trees:** This document was prepared to provide faculty with a clear understanding of the function of the CAPAC committee and the importance of the accreditation process in the Chemical Engineering Program.
7. **Student Study Habits CHEN3600 (2008):** During the Fall 2008 term, the students in CHEN 3600 were asked (as a written communications project) to discuss their individual study and learning habits. This material is shared with both students at various points in the curriculum as well as allowing faculty a unique glimpse into the “life of our students”. The following is an excerpt from one student’s submission:

Chemical Engineering is a demanding curriculum, therefore more studying and other various academic activities are required from its students. Every subject introduces unique challenges to overcome, which necessitates unique study habits. However, they all demand time. A popular

belief for engineering is that a student must spend two hours studying for every hour spent in lecture. While this is a good starting point, many subjects may require less (unlikely), while others may require much more depending on the student's skill in that particular subject.

Every class I take requires me attending lecture every day. Missing class is inexcusable if it can be avoided. Taking thorough notes is a requirement because many of the subjects discussed in lecture, which also appears on exams, are not necessarily contained in the textbook. Also, the notes presented by the instructor are more like the format found on exams than instructions explained in the books. Lecture gives me the opportunity to have the instructor clarify any confusion about the subject material, and if that is not sufficient, I am able to ask the instructor after class if I am able to receive additional help.

Link 1: [http://eng.auburn.edu/cheweb/ABET/ABET Outcomes \(A\) vs \(E\) Explained.docx](http://eng.auburn.edu/cheweb/ABET/ABET Outcomes (A) vs (E) Explained.docx)

Link 2: <http://eng.auburn.edu/cheweb/ABET/Bloom's Taxonomy - Not About Stuffing Armadillos.pptx>

Link 3: <http://eng.auburn.edu/cheweb/ABET/ABET Outcomes Explained Using Bloom's Taxonomy.docx>

Link 4: <http://eng.auburn.edu/cheweb/ABET/Developing Course Outcomes.docx>

Link 5: <http://eng.auburn.edu/cheweb/ABET/Employing Bloom's Taxonomy When Developing Course Outcomes.docx>

Link 6: <http://eng.auburn.edu/cheweb/ABET/Seeing the Forest for the Trees.docx>

Link 7: <http://eng.auburn.edu/cheweb/ABET/Student Study Habits CHEN3600 2008.docx>

4.2.8 ACTIONS INVOLVING FACILITIES RENOVATION, IMPROVEMENT AND REPLACEMENT

As described in Section 7, the department has benefited from a significant improvement of its facilities (including multimedia classrooms and conference rooms, computer labs, unit operations labs, research labs, faculty and graduate student offices, student study lounge, etc.). This has resulted in a tremendous improvement in faculty and student interaction and student sense of community as well as professional pride in their program. In particular, the improvement of the computer laboratory facilities has addressed a longstanding deficit as noted by the students in previous senior exit interviews and student surveys.