Continuous Improvement

The process for continuous improvement of undergraduate engineering education at the University of Arizona consists of four major steps: (1) identify the direction and objective of the individual educational programs, (2) determine how we are attempting to meet those objectives, (3) assess if we are meeting the desired goals, and (4) provide feedback to determine where resources should be focused to improve the program. This section discusses the development of this process and provides details about these four steps.

This process was formulated with input from all College of Engineering (ENGR) departments through the College assessment team. It was implemented in the Department of Agricultural and Biosystems Engineering through the Biosystems Engineering Assessment Sub-Committee of the Department Academic Programs Assessment Committee.

A. Information used for Program Improvement
A variety of tools have been utilized to assess individual components of the Biosystems Engineering program as to their contribution to meet the program outcomes and objectives. These tools include, but are not limited to Senior Exit Surveys, Teacher-Course Evaluations, Alumni Surveys, Course Assessments, FE Exam results, and Academic Program Reviews. These tools are described in more detail in Criterion 3 above.

B. Actions to Improve the Program
Results of each of the assessment tools described in the previous section are analyzed and periodically reviewed by the ABE Assessment Committee. Where there are indications that modifications or improvements are required to be implemented, the department curriculum committee is charged with developing changes to the curriculum. For other changes, such as renaming the program, the entire faculty addresses the question either at a faculty retreat or a faculty meeting dedicated to the subject.

Analysis of the results of the assessment process described in the previous section identified several areas where change and/or improvement was recommended or required. This analysis has also identified strengths of the program and have indicated to what degree we are achieving both educational objectives and learning outcomes.

Based on analysis of the assessment results we have concluded that the level of achievement of Program Educational Objectives is High. Based on the analysis we can also conclude that the level of achievement of most of our Learning Outcomes is High. Based on the Academic Program Review of 2002, listed below are the areas identified for change or improvement:

1. Change the name of the undergraduate engineering program to Biological Systems or Biological Engineering.
2. Revise the undergraduate major to appeal to a wider range of prospective students.
3. Offer only two specializations in the major: water resources engineering and biological systems engineering.
4. Develop a set of core courses for the major and a list of technical electives for each specialization.
5. Develop additional specializations as the department evolves (biotechnology, biomedical, etc.)
6. Revise ABE 412 to include more concepts of basic machinery appropriate for all students in the major.
7. Drop ABE 423 from the curriculum and integrate computational methods in the remaining core courses.
8. Revise ABE 447 to cover more basic circuit theory or require an electrical engineering prerequisite.

We have implemented all of the above with the exception of #7, which will be explained below. Changes to our curriculum are most succinctly highlighted by a comparison of the curriculum from 2003-04 to 2009-10 (Appendix E and Appendix F).
1) Implementation of Program Improvements Based on Analysis of Assessment Data

ABE faculty continue to utilize the results of our assessment process in order to improve the student educational experience. The BE program has evolved with improvements in individual courses and alterations in curricular structure. The following specific actions have been taken to implement the changes/improvements recommended by the ABE continuous improvement process.

1. Replace the AME 230 (Thermodynamics) course with ABE 284 Biosystems Thermal Engineering with a greater emphasis on biological thermodynamics and heat transfer.
   
   **Reason for change:** Biosystems students were not receiving adequate training in biologically-oriented thermodynamics and heat / mass transfer. Of greatest importance was introduction of psychrometrics, chemical thermodynamics, and water-related thermodynamics. The previous AME (Aerospace and Mechanical Engineering) course did not address chemical thermodynamics.

   **Motivated by:** Academic Program Review (2002) and ABE Advisory Council.

   **Impact:** Student performance on the FE exam portion of thermodynamics has increased.

2. Remove ABE 412 (Agricultural Machinery) from the curriculum and replace with ABE 484 (Advanced biosystems transport phenomena).
   
   **Reason for change:** The machinery course for many years had received low ratings from students, poor feedback from alumni, and dissatisfaction from the faculty. Problems included a lack of appropriate equipment, lack of expertise and research by the faculty, and student perceptions of a lack of need for the topical material. At the same time, alumni discussed a need for a more advanced material on transport including fluid mechanics (both theoretical and applied) and heat and mass transfer.

   **Motivated by:** Student TCE scores, Alumni feedback, Academic Program Review (2002), and ABE Advisory Council.

   **Impact:** The number of students in the program increased shortly after making this change. Since “design machine systems” as an outcome of the program was removed, the impact on meeting our current outcomes was minimal. Few graduates in recent years had obtained jobs in the agricultural machinery area, both before and after changing this academic requirement and so impact on meeting our objectives was minimal.

3. Replace the introductory computer course (either ENGR 170 or ABE 120) with ABE 205 (Engineering Analytic Computer Skills), an introductory computer course developed with applications using MS Excel with visual basic and Matlab.
   
   **Reason for change:** For many years, the Biosystems Engineering students were allowed to take either an introductory programming course (ENGR 170) or a fairly introductory course in MS Office (ABE 120). Neither course fully met students computational needs, especially as a means for solving differential equations and as an introduction to modeling.

   **Motivated by:** The ABE Advisory Council had for many years asked ABE to not teach programming skills but rather to focus on application-oriented skills such as using MS Excel and Matlab.

   **Impact:** The ABE Advisory Council stopped asking us to stop teaching programming. Student performance in ABE 423 (as gauged by class analysis and TCE scores) improved. Senior exit survey questions on “Can use techniques, skills, and modern engineering tools necessary for engineering practice” displayed no significant change.

4. Revise the ABE 447 (Sensors and Controls) course to incorporate foundational components of electronic circuits, advanced biological topics, and design of novel devices.
   
   **Reason for change:** Student skills in circuits entering this course were poor and led to lowered performance on device design and development. A new faculty member was hired in 2004 and took over this course. He utilized a few of the prior exercises and added numerous advanced topics and experiences.

   **Motivated by:** TCE scores, FE exam results, alumni feedback.

   **Impact:** Student scores on electricity and magnetism portion of FE exam has increased as have student ratings on TCE scores which increased substantially. No substantial change in senior exit surveys or alumni surveys.
5. Revise the set of core courses for the major including design-oriented electives and the required upper-division ABE courses. The technical elective sequence was changed from 16 units to 19 units organized in two categories: 9 units of design-oriented electives (typically ABE courses) and 10 units of science-based OR design-based electives. Six units were obtained by removing the requirement that students take ABE 455 (Soil and Water Resources Engineering) and ABE 481a (Engineering of Biological Processes). Three of these units are used for ENGL 308, described below.

**Reason for change:** The ABE 455 and 481a courses contain fundamentally applied topical material which is of most use for students entering career paths of water resources engineering or biotechnology oriented engineering, respectively. By changing this requirement, students now take more ABE courses and at the same time are better able to focus their interests on water or bio-based courses.

**Motivated by:** alumni feedback, ABE Advisory Council. Additionally, this meets the recommendation from the 2002 Academic Program Review to: revise the undergraduate major to appeal to a wider range of prospective students; and offer only two specializations in the major, water resources engineering and biological systems engineering; and develop a set of core courses for the major and a list of technical electives for each specialization. The result of these changes has been an increase in our student numbers from approximately 50 to 95.

**Impact:** This change has been a sizeable factor in altering our student composition with many more students interested in medical school and graduate engineering programs. Student numbers increased substantially shortly after this change which allowed students to better focus their interests. Performance on quantitative measures (FE scores, number and percentage of honors students) have increased due in part to this change – we are drawing from a stronger student population. Satisfaction of graduating seniors and alumni has remained consistent and strong. Since our program objectives include having graduates either obtain engineering positions or go directly to graduate programs, the impact on the percentage of our graduates meeting the objectives has not changed although the proportion of graduates meeting Objective 2 has increased.

6. Add the requirement of ENGL 308 (Technical Writing). This is a skills-based course which focuses on written, oral, and computer-based communications.

**Reason for change:** Students obtain a broad and extensive experience in conveying technical information to a variety of audiences.

**Motivated by:** alumni feedback, ABE Advisory Council. The ABE Advisory Council for many years has requested greater emphasis in technical communications.

**Impact:** Student writing skills have increased as gauged by feedback from faculty teaching Senior Design (ABE 498a,b). At the same time, a greater emphasis has been placed throughout the curriculum on communications and presentation skills, so improved student performance cannot be attributed solely to this course.

7. Revise the ABE 423 Biosystems Analysis and Design course to focus on applied computing (MS Excel, Matlab), biological modeling, and advanced biological topics.

**Reason for change:** This course on modeling had for many years been poorly connected to student skills, especially while the students took ABE 120 or ENGR 170 as their introductory computer skills course. This left the instructor with the task of providing skills in using more advanced computational methods (Matlab, Excel with visual basic, and other simulation tools requested by our advisory council) along with modeling methods and applications. ABE 423 has been revised significantly in topical material to better reach student current computational needs and their future activities. This course is now amongst the highest rated required courses (see Table 3-10 in our curriculum with a 4.0 out of 5 overall rating of the course.

**Motivated by:** TCE scores, alumni feedback, ABE Advisory Council, ABET requirements for advanced biological topics. The course has been revised several times since 2004 and is now considered to be a good fit for the student skills and their computational needs.

**Impact:** Student ratings on TCE scores has increased in the years incorporating this approach (2006 and 2009).

8. Add the requirement of ENGR 211P (Engineering economics), a 1 credit, on-line course.
**Reason for change**: Students did not receive any substantial economics background prior to performing their senior design projects. Economics is deemed to be an important component of their professional preparation.

**Motivated by**: FE exam scores, ABE Advisory Council who have requested an increased background in economics and business practices.

**Impact**: Student performance on FE exam questions on engineering economics has declined. Initially, the average index for this area was 124 (albeit with few students taking the FE exam) whereas now performance on economics questions on the FE has an index of 87 (both compared to an “average” score of 100). It is not clear why student performance has declined on economics but we are addressing the problem within the senior design sequence. The question of whether this course should remain in the curriculum has been taken to the ABE curriculum committee for review. They will make a recommendation to the ABE faculty who will as a whole decide the course of action.

9. Revise the senior design sequence to increase student preparation in engineering economics.

**Reason for change**: Student performance on the FE exam economics section is less than ideal, and their knowledge base prior to performing their senior designs is not sufficient.

**Motivated by**: FE exam scores, ABE Advisory Council who have requested an increased background in economics and business practices.

**Impact**: Too early to fully assess the change as the change was implemented in full in the Fall of 2009. We have yet to obtain results from the 2010 FE examination.

10. Revise the ABE 296a / 496a sequence to incorporate ethics and a greater emphasis on professional development and contemporary issues.

**Reason for change**: Student performance on the FE exam ethics section is poor, and their knowledge base prior to performing their senior designs is not sufficient.

**Motivated by**: FE exam scores, ABE Advisory Council who have requested an increased background in economics and business practices, alumni surveys.

**Impact**: Student performance on the FE exam ethics section now has an index of 100 (after having been 112 in 2006 and 111 over 2001-2003). Apparently increased instruction on ethics has a negative impact on student performance and so these activities are being revised. Alumni ratings of these activities 3-5 years after graduation are lower than those of graduating seniors, although seniors claim a small increase in their understanding of contemporary issues.

11. Add a required professional internship to the curriculum (ABE 393) 1 credit, equivalent to 70 hours of volunteer experience. This one credit was obtained by a change in the number of technical elective units from 10 to 9.

**Reason for change**: Need for students to gain experience outside of the classroom. Most of our students normally were participating in internships, co-op experiences, or laboratory-based research. However, the students most in need of such experience often did not make such efforts. Adding this as a requirement extends the undergraduate experience beyond lectures and laboratories.

**Motivated by**: ABE Advisory Council who have requested an increased background in hands on experiences and business practices.

**Impact**: Too early to fully assess. Feedback from students has been positive as has support from the ABE Advisory Council.

12. Increase the student hands on experiences, especially interactions with the ABE Machine Shop prior to and during the early stages of the senior design experience.

**Reason for change**: Student performance in building prototypes for ABE 498b (Senior Design) has been inconsistent and based often on student experiences outside the classroom.

**Motivated by**: Faculty observations, review of student class performance in meeting outcome “k”.

**Impact**: Too early to fully assess, although the feedback so far has been positive. Students are connected directly with the ABE Machinist early in their undergraduate career and this has led to improved student performance and improved feedback on course outcome assessment. A longer time needs to pass for full assessment of impact of change in the sophomore year since much of the effect will be observed in the senior year.
13. Renumber ABE 320 to 221 (Introduction to Computer Aided Design)

   **Reason for change:** Lack of consistency with peer institutions on the academic level of an introductory computer aided design course.

   **Motivated by:** Comparison with peer departments and institutions.

   **Impact:** Should have no substantial impact on our students.

**Summary**
We have in place a set of comprehensive assessment tools which have been used continually to assess achievement of both outcomes and educational objectives. While results of these assessments indicate that we are meeting both our educational objectives and learning outcomes, several areas for improvement have been identified, changes have been made to the program, and the impact of these changes evaluated.

Assessments subsequent to programmatic changes indicate that in most cases the changes have had the desired effect while in others, particularly with engineering economics (ENGR 211p), the changes have resulted in minimal improvement in student performance or feedback. We have taken steps to improve the area of economics and will continue to monitor student performance in this area. Thus, as our process dictates, we continue to look for ways to improve the student academic experience to meet program objectives.