AC 2011-551: DESIGN OF A SUSTAINABLE PROCESS FOR UNDERGRADUATE CURRICULUM REFORM, DEVELOPMENT AND ASSESSMENT: A CHEMICAL ENGINEERING CASE STUDY

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Design of a Sustainable Process for Undergraduate Curriculum Reform, Development and Assessment: a Chemical Engineering Case Study

A chemical engineering program at a big research extensive university has undertaken a project to design and implement a sustainable and responsive process to renew its entire four-year undergraduate curriculum to address pressures of multi-disciplinary technological developments and the growing breadth of abilities and knowledge areas expected for competitive chemical engineering graduates. This paper discusses the process, the outcomes and experiences of the three-year, NSF-sponsored project to reform chemical engineering undergraduate curriculum. Additionally, it includes a discussion of the elements of a continuous improvement process, assessment methods and how assessment data were used to improve chemical engineering courses and curriculum.

In a time of rapid change, academic programs must experiment and evolve in order to keep pace with advances in knowledge, changes in professional practice, and shifting conditions in society. The need for responsive academic programs is particularly a concern in scientific and technological fields where the growth of knowledge is exponential (Rugarcia, et al.,[1]). A chemical engineering department at a big research extensive university developed and implemented several strategies to address these issues: (1) curriculum content reform and development; (2) faculty and students assessment activities; (3) integrated assessment plans and processes throughout the chemical engineering curriculum. The research points out that a major challenge is not initiating curricular reform but institutionalizing the reform for the majority of the students on the sustainable basis (Clark, et al., [2], Colbeck [3]). This paper discusses the strategies that were used to involve the entire department in contributing to and applying the ideas generated in the project. The strategies implemented ensure that the process is continuous, and responds to the demands by global changes in knowledge, skills, and society. Consistent conversations about learning outcomes, assessment, and continuous improvement engaged faculty members in a collective effort for sustained change. Some of these continuous strategies included (1) identifying and organizing curriculum development activities around four course strings to improve integration of learning outcomes and activities; (2) developing interlinked curriculum components (web-based teaching and learning modules) to organize and reinforce core ideas in chemical engineering curricular; (3) creating an integrated assessment plan that is being used to analyze the learning and development of chemical engineering students with respect to forward-looking set of learning outcomes, and (4) using service learning in required chemical engineering courses.

Course Strings

The first key strategy for curriculum reform and development involves organizing undergraduate chemical engineering courses into four course strings: thermodynamics and kinetics; emerging fundamentals and applications; transport phenomena; and systems design. Course string faculty committees were developed to address the following key issues: (1) what must undergraduate engineers learn/accomplish in the course string to be successful throughout their academic career and in the next generation professional settings; (2) what obstacles exist to providing the necessary educational experiences, and (3) how can we effect change and what changes (integration) need to be made to an existing curriculum. Course string faculty committees continue to hold regular meetings every semester to address these questions. Syllabi analysis provided invaluable information to enhance the alignment of the courses. As a result of course string faculty committees' working sessions, the department faculty had an opportunity to discuss undergraduate curriculum in depth and to affect the following changes:

1. **Integrated outcomes for all chemical engineering courses:** All undergraduate course syllabi were updated to include revised course outcomes. These outcomes were developed to insure continuity among the courses so as to deliver the overall curriculum outcomes.
2. **New assessment techniques:** The department implemented end-of-semester student and faculty course evaluations to assess students' achievement of course outcomes.
3. **Course portfolios:** One of the main curriculum management tools established as a result of course string committees' work is use of course portfolios. In addition to helping individual faculty members analyze achievement of student learning outcomes, course portfolios provide helpful reference documents for other faculty teaching the same course or related courses in a sequence by providing a detailed record of approaches and outcomes.

Interlinked Curriculum Components

Interlinked curriculum components (ICCs) are web-based learning sites for students that may address new technologies, non-traditional applications, and even common foundations that span all courses. ICCs can be used by students to review concepts and applications, to learn new applications, and to develop an appreciation and understanding of the common threads and methods of the various courses. Thus, the ICCs are envisioned as an integrating tool that will help students see the collection of courses in their program as a unified curriculum. The ICCs also allow faculty to see presentations of the topics and work towards better unification to their discussions. Currently, eleven faculty members from the three departments along with their students and associates are working on interlinked curriculum components implementation. An ICC coordination committee was formed to coordinate the progress reports from ICC coordinators. The ICCs that are being developed address the following topics: conservation principles; materials; system synthesis and integration; microchemical systems; molecular modeling; and environment and sustainability. ICC development may be viewed at the departmental website.

Assessment and Continuous Improvement Process

All above described strategies turned out to be very useful to the process of continuous improvement and assessment of a chemical engineering program outcomes and objectives and thus to the process of satisfying ABET engineering criteria. An ABET self-study report must include objectives and outcomes, as well as statements of where the outcomes are addressed in the program curriculum, how their level of attainment is to be assessed, and how the assessment results will be used to improve the program. The chemical engineering department has recently been successfully accredited by the Engineering Accreditation Commission of ABET, Inc.

To comply with the ABET engineering criteria, an ABET self-study report must include program objectives and outcomes, as well as statements of where the outcomes are addressed in the program curriculum, how their level of attainment is to be assessed, and how the assessment results will be used to improve the program. The exercise of constructing a clear program mission, objectives and outcomes requires the faculty to consider seriously what their program is and what they would like it to be. The main goal of designing an effective assessment and continuous improvement process was to create a unifying framework for course and curriculum development. Felder [4] points out that if faculty members then structure their course syllabi, learning objectives, and teaching and assessment methods to address the program outcomes, the results is a coherent curriculum in which all courses have well-defined and interconnected roles in achieving the program mission.

To guide and support the process of designing an assessment and continuous improvement process, an ABET committee members of an engineering department did an extensive research of other ABET accredited departments and research literature on ABET practices. A program decided to use two-tiered system with general outcomes statements defined by a manageable number of measurable performance criteria. An example of that system is described here:

Program Outcomes

1. Identify *Program Outcomes*.

Performance Criteria

2. Identify several *Performance Criteria* that are specific measurable program-outcome-related criteria.

Assessment Methods and Assessment Metrics

3. Identify several *"Strategies"*, *"Assessment Methods"* and *"Assessment Metrics"* to assess *"Performance Criteria"*.

The course learning outcomes (statements of what students in a course should be able to do by the end of the course) are very important to this process as they enable the program to demonstrate how specific program outcomes are addressed in the curriculum. Aligning performance criteria and thus program outcomes with educational practices (course learning outcomes) is a very important task of a departmental assessment plan. The process for determining the course outcomes and aligning them with performance criteria and program outcomes is handled in ABET Committee and faculty assessment committees program review process. This process allows to assess program outcomes continuously and the results are used to improve instruction in the courses that address them as well as a curriculum process overall.

The program outcomes assessment results are based on a number of assessment methods, including plant design project evaluations by an outside industrial panel, exit interviews with graduating seniors conducted by the outside industrial panel, course string faculty committee reports, CASEE surveys, FE exam results, faculty and student end-of-semester course evaluations, and co-op evaluations. Some recommendations and actions included the following items:

Recommendations:

Based on the analysis of the results for program outcomes, the ABET committee recommended reinforcing two important student learning outcomes in the curriculum: (1) to statistically analyze and interpret data, and (2) to demonstrate the ability to design experiments. It was recommended to offer a new course in statistics and experimental design.

Action Items for Continuous Improvement:

Beginning fall 2010, the chemical engineering curriculum includes a required course in statistics. A new performance criterion related to knowledge of experimental design methods was added and addressed in CHEN 320: Numerical Methods. Additionally, as part of addressing the students' ability to design experiments, course coordinators for CHEN 320 and CHEN 414/433: Unit Operations Lab I and II selected one of the lab experiments to use as a case study in CHEN 320. Students are required to demonstrate the ability to design the experiment in CHEN 320. This knowledge is strengthened in unit operations labs when the students perform the actual experiment as part of these classes.

Conclusions

Renewing an entire chemical engineering curriculum has proven to be a daunting undertaking for several reasons. First, the project team has found that there is a lack of applicable assessment tools and processes with which it can evaluate the abilities of chemical engineering undergraduates with respect to the learning outcomes. Although the project team has found some relevant assessment tools, there are many learning outcomes for which the project team, together with the entire department, has had to create assessment tools and processes, instead of using proven or promising alternatives. Second, engaging faculty members across the three chemical engineering departments has been more challenging than expected. Finding time and support to engage groups of faculty members in productive conversations about desirable learning outcomes, evaluating the extent to which students are achieving this outcomes, and constructing instructional materials, e.g., ICCs, to support instruction, especially in non-traditional subject areas, has taken longer than anticipated. Faculty members, in spite of their commitment to undergraduate education, are juggling multiple, competing responsibilities. In spite of these two challenges, the chemical engineering department has created an operational assessment plan that is being applied to analyze the learning and development of chemical engineering students with respect to a forward-looking set of learning outcomes. Further, the project has developed ICCs that will be useful in supporting the move to a renewed curriculum. These resources will be available to other chemical engineering departments.

References

1. Rugarcia, A., Felder, R. M., Woods, D. R., & Stice, J. E. (2000). The Future of Engineering Education I. A Vision for a New Century. *Chemical Engineering Education*, *34*(1), 16-25.
2. Clark, M., Froyd, J., Merton, P., & Richardson, J. (2004). The Evolution of Curricular Change Models within the Foundation Coalition. *Journal of Engineering Education, 93(1), 37-47*.
3. Colbeck, C.L. (2002). Assessing Institutionalization of Curricular and Pedagogical Reforms. *Research in Higher Education*, *43(4)*, *397-421*.
4. Felder, R. M. & Brent, R. (2003). Designing and Teaching Courses to Satisfy the ABET Engineering Criteria. *Journal of Engineering Education*, 92(1), 7-25.

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