Involving Constituencies in Curriculum Redesign

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The Problem

For several years, our program has been implementing a continuous improvement process that aligns with the requirements of the Engineering Criteria of ABET, Inc. Not only do we assess how well our students are learning in our program, but we also strive to improve the undergraduate program by keeping it fundamentally sound yet as contemporary as possible. The issue of modernizing chemical engineering curricula has been a newsworthy nation-wide concern over the past several years.

As many chemical engineering faculties across the country have doggedly observed, our curricula have not reflected the innovation and dynamics of the profession. Except for minor tweaking and title changes, most chemical engineering curricula have remained essentially stagnant over the past 40 years. Although starting salaries remain high, student enrollments have dropped and unemployment rates have increased (1). Many of the better students are attracted to other engineering disciplines or modern sciences. While reasons for these phenomena may be numerous and complex, it is clear that changes in the enabling sciences and the demands of the marketplace demand wholesale changes in undergraduate education in chemical engineering.

Superimposed upon the issues described above are recent trends in the out-sourcing of the U.S. engineering labor force, which adds some urgency to the need for thoughtful curricular revision. Although chemical engineering has not been as susceptible to this phenomenon as other engineering disciplines (2), one wonders if it is only a matter of time before U.S. chemical engineering jobs will be exported as well. Therefore, it is imperative that the chemical engineering community develops a curriculum to support a graduate who is well grounded, innovative, progressive, and adaptable.

Most well known among the impetus for change is the "*New Frontiers in Chemical Engineering Education*" workshops (hereafter referred to as "Frontiers") that have been conducted in Orlando, Cape Cod, Austin, and San Francisco (3). This paper describes a parallel and complementary effort in constituency-based curriculum redesign that is being conducted in our program. We describe the planning, implementation, and data analysis involved as well as both the obvious and subtle benefits that have come as a result of this ongoing effort.

The Plan

Early in 1999, immediately following our Fall, 1998 ABET accreditation visit, the chairperson of the Department of Chemical Engineering at Michigan State University (MSU) and its faculty

capitalized on the flexibility afforded by the new ABET Engineering Criteria and began to consider the question of curriculum redesign.

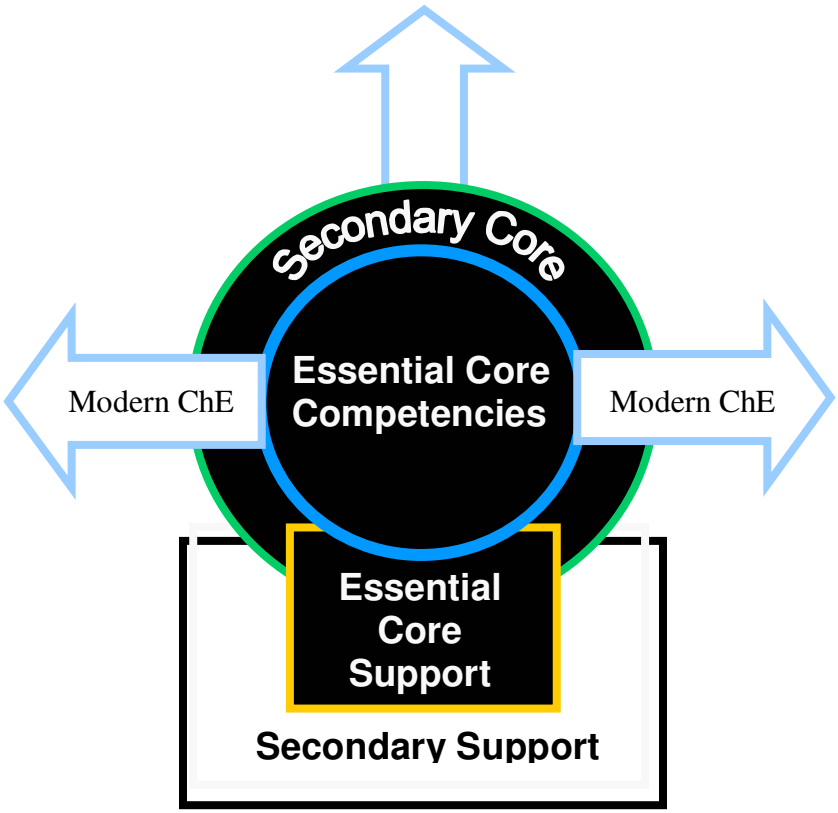
Our program educational objectives (4), which are condensed in the following paragraphs, emphasize both foundational education and the preparation for professional development and specialized study that will benefit our graduates.

> *The undergraduate program in chemical engineering builds a strong foundation for the professional development of its students and prepares them to meet the technological challenges of the future . . . students are well equipped for a wide variety of positions as practicing chemical engineers or for graduate studies in competitive engineering and scientific disciplines. The intensive program promotes continued learning and professional development . . . The program draws on the scholarly accomplishments of its faculty to integrate traditional chemical engineering topics with specialized studies in . . . contemporary fields . . .*
>
> *[thus allowing graduates . . .]*
>
> - *to become successful in the practice of chemical engineering or in advanced studies in engineering, scientific or complementary disciplines;*
> - *to assume leadership roles in industry and/or their communities ;*
> - *to contribute to the economic environment of their communities; and*
> - *to maintain career skills through life-long learning.*

In the basic sense of truth in advertising, it occurred to us that we might be promising something that our traditional curriculum would not be able to sustain in the near future. In addition, the hiring of new faculty had enhanced our expertise in the burgeoning areas of chemical engineering, and these areas needed to be included in the learning experience of our undergraduates.

The Objectives of Curriculum Redesign

As has been the goal of the Frontiers workshops, our main objective before proceeding with curriculum redesign was to identify (a) the vital core elements of our curriculum and their support areas—i.e., that which makes chemical engineering unique and cannot be compromised, (b) the secondary and possibly expendable elements and their support areas, and (c) the emergent areas that needed to be incorporated into our curriculum in a solid, integrated way (see depiction below).



Essential to the redesign (as well as to ABET program improvement requirements, coincidentally) was the input of our major constituencies who are knowledgeable in the needs and trends of the advancement of the chemical engineering profession. It is in this aspect that our approach differed from that of the Frontiers efforts. The participants in the Frontiers workshops were largely academicians with specific research and other vested interests. In our approach, our alumni provided another source of input specific to their experiences in the practice and to our program educational objectives. This type of approach was also one of the "path forward" strategies identified by the Frontiers workshops.

The Process

With endorsement from our industrial advisory board, our tactic was to gather input from several of our key alumni and employers through focus group meetings. Our chemical engineering program has been blessed with an active advisory board that has been a major driver in constituency input. To obtain broader geographic and career representation, however, the decision was made to involve focus groups in several key areas of the country. While our advisory board is represented mainly by chemical engineers and material scientists in more traditional careers, the focus groups included alumni with more diverse career paths.

Focus groups are a powerful means of evaluating services or testing new ideas (5, 6)). A focus group session is intended to be an interview that capitalizes on group interaction. The key to the approach is to focus on a single main theme. We desired to both evaluate key elements of our

current curriculum and strategize for the future. In addition, because of the ongoing development efforts in our college and department, we viewed this as an opportunity for alumni outreach.

As part of the sabbatical leave responsibilities of one of the authors (DB), we took our focus group "show on the road" and traveled to regions of the country with large concentrations of our alumni. An initially overly ambitious and costly plan for five national focus group meetings was condensed to three national focus groups in regions that were key in employing both our graduate and undergraduate students—Houston, Texas, Chicago, Illinois, and Midland, Michigan.

Preparation. Our industrial advisory board members cautioned us that organizing effective focus group meetings is not to be taken lightly. Experts often recommend hiring a professional facilitator. This option was not economically feasible, so we were aided by a few board members who helped planning the meetings and in developing and focusing the questions.

The development office of the College of Engineering at MSU provided mailing addresses for our alumni. The data could be sorted by a variety of identifiers. We sorted by zip codes to identify large target populations of our alumni. Alumni were selected randomly; no restrictions were placed on degree level granted (B.S., M.S., or Ph.D.) or year of graduation.

For each of the three focus group regions, a key alumnus was identified who agreed to act as the local host. Having a friendly contact who was familiar with local eateries and meeting sites considerably simplified the planning. In two focus group meetings, the local hosts also subsidized the focus group expenses. All other focus group participants were guests of the department and incurred no expenses except their local travel to the meeting site.

Focus group candidates received an invitation letter with a follow-up phone call or e-mail reminder two to three weeks after the initial mailing. Since focus groups are limited to a small number of participants (typically eight to twelve individuals (5, 6)), we were very pleased with the thirty-one participants across all three locations.

Information. Those alumni who agreed to participate received a second mailing of a packet of information about the department. In an appropriately stylish packaging, the pre-reading materials included the program educational objectives, the latest departmental newsletter, a curriculum description, selected articles on curriculum reform (7-12), standard promotional materials, and a survey. Participants were asked to read the information and complete the survey before the focus group meeting. Focus groups are generally not a statistically representative body of the whole, so survey results may be skewed. Our main purpose in distributing the survey was not only to gather some basic data, but also to orient the comments and discussions that were to take place during the meetings. Surveys were returned by all but three participants.

Survey Construction. The main purpose of the survey was to gather information from alumni on their evaluation of the knowledge and skill areas that they saw (a) as having been important in their careers and (b) as being important for chemical engineering in the future. The survey was

tested by the faculty and by the industrial advisory board, resulting in several major changes to the survey questions and content.

Construction of the survey had several fringe benefits besides its obvious main purpose. All program faculty members were engaged in the survey construction because we identified the questions about knowledge and skill areas not simply by courses, but by very specific knowledge/skill content. Thus, each faculty member was asked to dissect his/her course into specific competencies, which was an enlightening and reflective experience for all faculty involved. This also helped the faculty identify competency threads throughout the curriculum, which would be useful later in the redesign process.

Focus Group Meetings. The focus group meetings were scheduled from 5:30 p.m. to 9:00 p.m. on a weeknight (Thursday or Friday). Focus group meetings should be no longer than 1½ hours (5), but since we were also interacting socially with our alumni, the proceedings began with a social hour and a formal dinner. Two faculty members served as facilitator and recorder at each focus group meeting; this was essential for stimulating effective discussion while maintaining a complete record of the commentary. The faculty facilitator reviewed the "state of the department" in a PowerPoint presentation. Subsequent discussion was based first on answers to questions provided in the survey, followed by the key issues of identifying what is core to chemical engineering, what is disposable, and what is essential to maintain currency.

Data Analysis

Demographics. Thirty-one alumni (9 women, 22 men) participated. Graduation years ranged from 1943 (participant who did not complete a survey) to 1999. Alumni careers were classified into three categories--industrial (19 participants), "non-traditional" (6 participants), and research and development (3 participants). The non-traditional category included alumni with careers in finance, stock and futures trading, patent law, and real estate.

Survey respondents were asked to use a five-point Likert scale to rate general knowledge and skill areas as to their usefulness in their careers to date and for the future of chemical engineering. A "Level 5" rating indicated extensive use of the knowledge or skill and a "Level 1" was used to indicate no use of a knowledge or skill. Results were analyzed as a composite of all participants, by region, and by career classification. Because of the small sample size, discrimination among numerical results was not as significant or enlightening as a comparison of relative responses.

Results. The survey results strongly reinforced the importance of good problem-solving skills and good communication skills, regardless of the career path. In contrast, the importance of understanding the global and societal context of engineering (one of the ABET designated outcomes) was ranked relatively low. The topical survey suggested that several subjects in the thermodynamics, separations, and reaction engineering courses be removed (power cycles, stage-wise contacting—particularly graphical methods, design of ideal reactors), and that traditional process control be either removed or completely refocused. Alumni recommended that our second physical chemistry course, which is the chemistry majors' quantum chemistry be eliminated. This was also the prevailing recommendation for a required a course in electrical

circuits theory. For this particular group of alumni, their need for knowledge in biological sciences was not highly ranked, which may have reflected the largely commodity orientation of the focus group participants.

The highlight of conducting focus group meetings is the face-to-face interactions and the ability to delve more deeply into critical questions. The records of the discussions at the three focus groups set a stronger tone and gave a definite "flavor" to the results of the focus group meetings. Recommendations to maintain rigor, excitement, and flexibility in the curriculum predominated. Alumni encouraged us to integrate mathematics into the chemical engineering courses as much as possible. Many of our alumni noted that, since new "pre-engineering" students at MSU take three semesters of required courses before entering a major, there is a significant discontinuity between the learning and application of the enabling sciences of math, physics and chemistry.

More effective use of the required humanities and social science courses was also encouraged, although this is a difficult coordination and management problem on a campus as large as MSU's (40,000+ students). In particular, the need for improved writing skills was frequently identified. Alumni further recommended the integration of laboratory experiences with the mainstream chemical engineering courses allowing students to exercise problem-solving skills in experiments with a clear purpose. The need to revise the process control course was again emphasized in the discussions of all three focus group meetings. Finally, alumni suggested a coordinated elective option in business to include the areas of strategic planning, finance, management, accounting, and marketing.

While the results were disperse and sometimes conflicting, the input of our alumni was of great value. Many of their recommendations reinforced our own perspective on how the curriculum should be redesigned. However, some of the comments pushed us out of our comfort zone and caused us to reconsider "traditional" courses with greater scrutiny. In at least three cases so far, some of the focus group alumni have participated in course redesign or have volunteered as guest lecturers. This connection with our alumni was the most valuable outcome of these meetings.

Other Inputs

This paper does not advocate *frequent* alumni focus group meetings as an efficient means of providing constituency input. It is clear that the cost and effort involved in gathering data to this extent cannot be sustained each year. Program improvement related to the evaluation of program educational objectives is a longer time-scale process and typically needs to be conducted on a three- to five-year plan. Of course, curriculum redesign should operate on an even longer scale (but probably not forty years). Focus groups are effective in gaining direct and specific feedback on focused issues. In addition, the renewing and establishment of productive relationships with alumni is a benefit that cannot be ignored.

Our program uses several tools as part of our regular continuous improvement processes. We are on a three-year cycle to evaluate achievement of our program educational objectives. The major sources of input into this process are

- The chemical engineering web-based alumni survey (conducted every three years)—**primary** source of input; specific questions are directly linked to the measurement of achievement of objectives;
- Senior Exit Interview (annual)—**secondary** evidence; although the comments from seniors are restricted to their on-campus experiences, they provide valuable information on perceived strengths and weaknesses of our program;
- Co-operative Education Student and Employer surveys (annual)—**secondary** evidence; since it is difficult to obtain information from a large number of employers, this tool provides preliminary and readily available evidence of how our students function as employees;
- Department Advisory Board Student Interviews (semi-annual)—**secondary** evidence; our advisory board interviews a select group of students. The input is anecdotal, but frequently useful;
- Collegiate Employment Research Institute Alumni Survey (alternate years)-- **secondary** evidence; this nationally known institute located on the MSU campus conducts biannual surveys of alumni two to three years post-graduation. Since the sample size is small for our program, the results are used only in a minor supportive role.

Benefits of the New ABET Engineering Criteria

Many engineering faculty have questioned whether ABET requirements for evaluation and assessment can ever provide an acceptable cost/benefit ratio for program improvement. In our experience, the role that outcomes assessment played in this process was surprising and positive. While curriculum redesign encompasses entire restructuring of courses, educational materials, and teaching methods, the information provided by yearly micro-scale evaluation of student performance provides important guidance, even to such macro-scale efforts as curriculum redesign. The assessment data are essential to decision-making on course content, placement of courses, and even restructuring of support courses. The value of outcomes assessment in program improvement has been clearly confirmed in our curriculum redesign process.

Early Implementation

The chemical engineering curriculum committee has begun developing a revised curriculum based on several inputs—the assessment of student outcomes in our own program (ABET Engineering Criteria, Criterion 3), input from the alumni focus groups, and response to some of the Frontiers proposals. Many of the elements identified by the Frontiers workshops have already been integrated into our curriculum over the past several years; these changes have been made based on the evidence gathered by our assessment and evaluation processes. The most important of these changes include

- an emphasis in the enabling sciences (a required advanced biology course, restructuring of the physical chemistry requirement, and a new chemical engineering applied math course);
- elimination of expendable electives (electrical circuits theory course and statistics);
- incorporation of applied statistics and experiment design into our laboratory courses;

- a new freshmen engineering course that emphasizes chemical engineering principles both on the micro and macro scales;
- the consistent use of teams throughout the curriculum (a long-standing practice);
- emphasis on writing skills in our junior seminar course;
- development of communication skills throughout the curriculum through a single, common set of learning tools (use of uniform nomenclature and handouts);
- inclusion of product design, entrepreneurship, and business finance as part of the design sequence;
- the complete redesign of the process control course into a process "systems" course with significant industrial input.

While we recognize that these changes are not yet the dramatic restructuring called for by the Frontiers workshops, we also recognize that the restructuring will have to be incremental. We believe that these changes represent a first step in the right direction that is responsive to our constituencies.

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