ENVIRONMENTAL HEALTH AND SAFETY AND BIOCHEMICAL ENGINEERING WITH A CHEMICAL ENGINEERING FOUNDATION

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ABSTRACT: Chemical Engineering principles are utilized in a variety of industries such as semiconductor processing, environmental engineering and biotechnology. One main characteristic of these fields is their multidisciplinary nature. Thus, parts of the chemical engineering curriculum can be an integrated into the training of engineers desiring to work in these fields. We will describe an industry-driven engineering Environmental Health and Safety (EHS) degree program and a Biochemical Engineering emphasis that have been developed at San Jose State University (SJSU). The EHS program includes a strong foundation of Chemical Engineering courses even though it is housed in the General Engineering Department. The Biochemical Engineering emphasis is incorporated in the Chemical Engineering program. The development of the EHS program can be used as a model for the incorporation of Chemical Engineering courses as the foundation for other multidisciplinary degree programs. We will describe the assessment method which has been developed for the EHS program and the Biochemical Engineering emphasis and our first steps at implementing this assessment.

Introduction

The Chemical Engineering curriculum traditionally has been recognized for its breadth, partially due to the number of courses taken outside the discipline (e.g. chemistry, materials, circuits, etc.). More recently the multidisciplinary nature of the curriculum has increased due to the incorporation of examples of newer technologies such as semiconductor processing, biotechnology and environmental engineering into the majority of the required courses. Chemical engineering students are exposed to a variety of new technologies. However, some of those technologies are developing into official degree programs and concentrations in their own right. It is feasible that significant parts of the chemical engineering curriculum can form the foundation of these chemical-intensive fields as they develop into degree programs. In the rest of this paper, we will describe two programs at SJSU, one an EHS degree program outside of Chemical Engineering and one a biochemical engineering emphasis within Chemical Engineering, that were developed to include a solid foundation of traditional chemical engineering courses. We will describe how the curriculum for each program was proposed and accepted, the safeguards we included in the initiation process in order to assure a viable curriculum was proposed, and the utilization of our assessment process to monitor the continued success of the programs. We propose that the incorporation of Chemical Engineering courses into chemical-intensive fields such as EHS, semiconductor processing and biotechnology is a suitable and significant evolution of the Chemical Engineering discipline.

Development Process for the EHS Degree Program

We think that the motivation for the development of the EHS degree program at SJSU is similar to that which will result in the development of other multidisciplinary degree programs. Thus, we will describe the development in some detail as an example incorporating Chemical Engineering courses as the foundation of another curriculum.

Continued industrialization of the United States and the Global Community have increased the amount of process chemicals and waste products produced which pose a potential threat to the health and well-being of workers, surrounding community and sometimes, the entire planet. Over the past decade, chemical plant accidents in India (Bhopal), Great Britain (Flixborough) and the United States (Texas, etc.) have increased public and industrial attention on safety and loss prevention [1]. Nation-wide the demand has been made for industry to minimize process accidents, human injuries and environmental damage. Liability issues have also pressed industry to meet the regulatory and public demand for increased health and safety. On a national and local level, all major companies such as Xerox, IBM, Hewlett-Packard, DOW Chemical, Chevron, and Intel, have Environmental Departments. Smaller scale companies whose processing steps include the use of chemicals, typically have from one to five environmentally-focused employees.

However, at universities across the nation, academic programs at the baccalaureate degree-level have not adjusted curriculum to produce graduates with the expertise necessary to be hired by industries into many of the expanding number of EHS positions [2,3,4,5,6]. Thus, industry has experienced difficulty filling EHS positions with qualified personnel who are able to 1) design health and safety into processes and waste treatment, 2) determine appropriate means to meet compliance with existing regulations and, 3) improve processes to minimize waste production.

Phase I of this project began in 1995 when Joint Venture Silicon Valley (JVSV), an alliance of industry, academia and government agencies located in the Silicon Valley area, recognized the negative impact the dearth of qualified graduates was having on the heavily industrialized Silicon Valley in Northern California. A JVSV Focus Group, whose membership includes EHS professionals and academics, was organized with the task of developing a means of providing qualified entry-level EHS personnel to Silicon Valley industry. The Focus Group developed a questionnaire which was sent out to 8 EHS organizations such as the Semiconductor Safety Association and American Association of Safety Engineering in order to determine what education and skills background were most desired in entry-level EHS employees. Input was received from EHS professionals employed by companies such as Apple, Intel, Applied Materials and Xerox. The questionnaire results indicated the necessity for a strong technical background in a broad number of subject areas such as regulations, toxicology, pollution control, ethics, chemical and radiation safety, communication skills, and project management skills. Respondents emphasized that they were not satisfied with the technical depth of many students from existing EHS-related programs who had been previously hired for EHS positions.

Based on the results from industry, the Focus Group decided that a 4 year accredited degree program rather than a certificate program was required. San Jose State University took the lead to be the home of the 4 year degree program. A sub-committee was then formed to develop a sample curriculum. Membership included 2 EHS professionals and 5 academics including a faculty member from Chemical Engineering. Mission and De Anza Community Colleges also were represented in this Focus Group as they had environmentally-related AA degree programs in existence. Environmental curriculum from SJSU, De Anza Community College and Mission Community College was collated and evaluated. Industrial representatives worked with SJSU and the participating Community Colleges in selecting appropriate courses, both existing and those which would require development, while maintaining university program requirements such as general education content. Once a month over a six month period the sub-committee met with the entire Focus Group to receive input on the curriculum as it was being developed. One of the results from this Focus Group was the development of an Engineering EHS track with the curriculum shown in Table 1. After acceptance of the developed curriculum by the Focus Group, it was again sent out for review to EHS professionals at Raychem, Dow Chemicals, HP and the Semiconductor Safety Association. Based on the positive response from the Industrial Review, Phase I was completed in May 1997. It then took about 2 years for the proposed curriculum to be evaluated and approved by the various college and university-level committees. The official engineering EHS program was initiated in the Fall 1999 semester.

The California State University (CSU) system has several curricular constraints not necessarily present in other university systems. Two major constraints are a heavy general education requirement in conjunction with a target cap on the total number of program units required for the degree. These two constraints put a limit on the number of units available in the major. In addition, upper division courses, which are the majority of the courses in the major, cannot be offered in the freshman and sophomore years since students would not be able to complete those courses at a community college.

These constraints are mentioned since they limit the number of courses in any particular focus that can be included in the degree. However, students can add depth through their choice of electives. Electives are segregated in the areas of chemistry, project management, safety, health, and environmental. Students can also target electives which will give them experience in a specific industry by taking classes related to that industry (e.g. biotechnology or semiconductor processing) as electives, and also by choosing an internship in the industry of their choice.

The Fund for Improvement of Postsecondary Education provided funding for the development of the engineering EHS degree program mainly due to the multidisciplinary nature of the program and the significant industrial involvement in all stages, curriculum, teaching and evaluation as elablorated in the discussion section of this paper.

Table 1. Engineering EHS Curriculum.

Freshman Year			
Fall Semester	Units	Spring Semester	Units
Math 30 Calculus I	3	Math 31 Calculus II	4
Chem 1A Gen. Chem.	5	Chem 1B Gen. Chem	5
Engl 1A Composition	3	Phys 70 Gen. Phys.	4
Biol 54 Human Under.	3	Engl 1B Composition	3
Engr 10 Eng. Proc. & Tools	3	Human Performance	1
Semester Total	17	Semester Total	17
Sophomore Year			
Fall Semester	Units	Spring Semester	Units
Math 32 Calculus III	3	Math 133A Dif. Eqn.	3
Chem 8 Organic Chem	3	CE 99 Statics	2
Phys 71 Gen Phys	4	GE (Oral Communication)	3
AMS 1A	6	AMS 1B	6
Writing Skills Test	0	Human Performance	1
		Chem 9 Organic Chem. Lab.	1
Semester Total	16	Semester Total	16
Junior Year			
Fall Semester	Units	Spring Semester	Units
ChE 115 Mat./Energy Bal.	3	ChE 151 Thermody.	4
ChE 190 Intro to Transport	3	ChE/CE 174 Hazardous Mat.	3
EnvS 170 Intro to EHS	3	CE 170 Prin. Envir Engr.	3
CE 192 Prob. Model.	2	CE 176 Biol. Proc.	3
MatE 25 Intro. Materials	3	Up.Div. GE	3
Engr 100W Engr. Reports	3		
Semester Total	17	Semester Total	16
Summer			
Engr 197 or ChE 180 Summer Internship		Semester Total	3
Senior Year			
Fall Semester	Units	Spring Semester	Units
ChE 161 Ethics/Safety	1	ChE 177 Air Poll. Comb.	3
ISE 112 Engr. Occup. Health	3	ISE 114 Safety Engr.	3
Biol. 137 Intro. Prin. Toxoc.	3	CE 134 Project Manage.	3
EnvS 124 Intro. Envir. Law	3	Up.Div. Tech. Elec.	2
MATE 198A Senior Design	2	Upper Division GE	3
Upper Division Tech. Elec.	3	MatE 198B Senior Design	3
Semester Total	15	Semester Total	17
		Total Units	**134**

Development Process of the Biochemical Engineering Emphasis

A formal biotechnology emphasis was developed for the *College of Science* by the SJSU Biotechnology Education and Research Institute (BERI) in 1998, although an informal emphasis had existed for a number of years previously. It is the purpose of the BERI to give direction to the development of biotechnology at SJSU on a multi-disciplinary basis; promote the sharing of biotechnological expertise and physical resources; serve as a clearinghouse for biotechnology-related matters; catalyze interaction between SJSU and concerned industry and governmental groups; and coordinate the seeking of intra- as well as extra- mural resources for biotechnologically related activities at SJSU. Several Chemical Engineering faculty members are active in BERI. The SJSU Chemical Engineering Department has had a Biochemical Engineering emphasis since 1994. At the time of its initiation Chemical Engineering students did not have adequate preparation to take many of biotechnology courses available in Biology, Biochemistry or Chemical Engineering. The emphasis developed over the next five years to remove this deficiency and the current emphasis is as shown in Table 2.

Table 2. Courses in Biochemical Engineering Emphasis.

Chem 135 Biochemistry (replaces second semester PChem)
ChE 192 Introduction to Biochemical Engineering
ChE 194 Biochemical Engineering Laboratory
*ChE 115 Materials and Energy Balances
*ChE 151 Chemical Engineering Thermodynamics
*ChE 158 Chemical Kinetics and Reactor Design
*ChE 160B Mass Transfer
*ChE 165 Senior Design

*These courses include specific biochemical engineering concepts and projects

Both ChE 192 and ChE 194 were developed with a multidisciplinary focus. Due to the commitment of the BERI members, we have had success advising engineering and science students to take cross-disciplinary courses. The BERI provides the support to advise students into the courses shown in the top part of Table 2. Cross-disciplinary teams work on selected project in each course.

A main objective of the laboratory course is to simulate industrial experience. Currently, it is the only biotechnology laboratory course that deals with scale-up procedures. Experiments are based on initial scale-up, however class discussion includes full scale-up production aspects. The laboratory course includes a capstone design project. This project is highlighted here because of its importance in demonstrating the final scale-up capability of the students and the fact it will give a significant demonstration on the evolved ability of the cross-disciplinary student teams to utilize their skills to produce their design.

The semester long assignment will be to produce a suitable industrial-level production plan for a product of interest to the team (such as insulin, human growth factor, etc.), as if it was to be presented to the Production Supervisor of a biotechnology company. Student teams include all steps such as selection of microorganisms with the DNA of interest, confirmation the microorganism is producing the desired product and determination of product viability after purification. A written and oral group presentation is required. Industry representatives evaluate the proposals and the interaction between the students during the final presentation.

Five traditional Chemical Engineering courses are highlighted for the Biochemical Engineering emphasis. This is due to the fact that many newer texts or newer editions of older texts have evolved to include discussions, examples and problem sets applied to newer technologies such as biotechnology, semiconductor processing and environmental engineering. This is true of the texts used in the courses listed in the bottom of Table 2. In these courses Biochemical Engineering concepts and projects are emphasized. This gives the Biochemical Engineering emphasis much more breadth and depth than if it had to rely solely on the three elective options for students.

Assessment

The programs have both been structured for Assessment, as per the requirements for accreditation under ABET. The Chemical Engineering program has been reconfigured to allow assessment, which includes the Biochemical Engineering emphasis. The EH&S Program was been designed for assessment as it was being developed.

The objectives of the assessment program are ultimately to confirm graduates are prepared to be successful in the workplace. Industry and our alumni have assisted in developing a group of target attributes as graduate outcomes and periodically provide survey data to assess graduate experience. The faculty has assembled a curriculum that will provide the content and student competence to support the graduate outcome targets. Comprehensive program learning objectives have been established to support student development towards the outcome objectives. Activities in individual classes are assessed to confirm they adequately support the program learning objectives.

Discussion

The development of some newer types of multidisciplinary degrees and emphases has been fueled in part because industry has not been satisfied with the training obtained by students graduating from traditional engineering disciplines. This fact highlights one of the most important aspects required to develop a successful multidisciplinary program. Significant industrial involvement must occur at every stage and must be at a level beyond periodic meetings with an industrial advisory board.

The proposed EHS curriculum is truly industry-driven as it was developed by the JVSV Focus Group in response to the need for entry-level EHS personnel who possessed sufficient technical depth to meet the demands of the job. Industrial representatives identified the problem, helped set the curriculum and are instrumental in the development and presentation of the curriculum. In order to ensure students from the EHS Program will meet the learning objectives which are required for them to be successful in employment in entry-level EHS positions, industrial representatives participate in the following ways:

- Industrial representatives are involved with faculty in course development/modification to help identify topics, course content, skills and proficiencies needed in order to result in qualified EHS graduates.

- At least two courses each semester in the Junior and Senior year are taught or team-taught by industry. Realizing that industrial representatives are skilled in real world problems, but might not be experienced or skilled in teaching, faculty and industrial lecturers are encouraged to participate with the SJSU Institute for Teaching and Learning to develop teaching skills and be sensitive to different learning styles of students.

- For courses which will be team taught, industrial representatives from industries such as Dow Chemicals, Consulting Firms such as EORM, and municipalities such as City of San Jose/Santa Clara Environmental Services Division, give lectures followed up by having students work on current industrial problems illustrating the lecture material.

- An EHS internship is required. Students will be hired in an industrial position during the summer between their Junior and Senior year to work on EHS-related problems presented to them by an industrial supervisor. Students will be fully involved at these sites and will participate in industrial EHS meetings during their internship.

This level of industrial participation throughout the Junior and Senior year allow faculty to get real-time analysis of the success of the EHS program in meeting learning objectives which will help students succeed in entry-level EHS positions. Industrial representatives interact with students at the start of the Junior year before students have focused on EHS courses, during their internship when they have completed at least half of their focused courses and at the end of the program when they are hired into industrial positions. This feedback loop at multiple stages allows deficiencies in skills or knowledge to be corrected on an immediate basis and allow successful practices to be emphasized.

The Biochemical Engineering emphasis was developed in a similar fashion. Several faculty members from the Chemical Engineering program are active in BERI and worked with BERI in order to develop the multidisciplinary biochemical engineering courses offered by the Chemical Engineering department. Industrial participation has been used in developing and implementing the experiments in the Biochemical Engineering Laboratory course to ensure students are exposed to experiments with appropriate content and skills and team-teaching or guest lecturing in the biochemical engineering courses required for the emphasis.

The formal ABET assessment procedure ensures that the curriculum for these programs are consistently and continually evaluated. Assessment provides an ongoing mechanism in which weaknesses can be identified and corrected while strengths can be emphasized.

Conclusions

As high tech industry gets more complex and specialized there will be an increased demand for students with multidisciplinary training not typically available in traditional degree programs. Some of this demand will result in the development of new degree programs and/or emphases. Many of the high tech industries requiring these multidisciplinary graduates are chemical-intensive. This provides an ideal incentive for Chemical Engineering faculty to be involved in the development of these new degree programs and for the Chemical Engineering curriculum to provide a foundation as appropriate. Chemical Engineering faculty will be required to be alert to demands from industry and to be participants during the development of these multidisciplinary programs which require a chemical-intensive education. The incorporation of Chemical Engineering courses into chemical-intensive fields such as EHS, semiconductor processing and biotechnology is a suitable and significant evolution of the Chemical Engineering discipline.

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