Curriculum Revisions for the (Bio)Chemical Engineer

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Abstract

Chemical engineering has traditionally used mathematics, physics, and chemistry as the foundation sciences. Recent advances have suggested that biology will play an ever increasing role in chemical engineering and should become one of the foundation sciences. Western Michigan University's (WMU) chemical engineering program is relatively new and was built on the traditional approach. As part of our ongoing educational objective review process, the need for the inclusion of biology was raised by our advisory board. Discussions of this issue occupied the advisory board for over a year and included, as well, the chair of WMU's biological sciences department. These deliberations included how much biology is sufficient, what topics were critical, how should these topics be addressed (new or existing course), the integration of these topics to the existing curriculum, and, critically, what material could be deleted to make room for the new material. The result was the inclusion of the Biosciences Department introductory biology class (BIOS 1500 – Molecular and Cellular Biology), the development / implementation of a bioprocess technology course (CHEG 3500 – Bioprocess Engineering), and the deletion of ME 2530 (Statics and Mechanics).

Introduction

Western Michigan University is one of five state-supported universities in Michigan offering a chemical engineering undergraduate program. (The others are the University of Michigan, Michigan State University, Michigan Technological University, and Wayne State University). Our program is relatively new, being approved in 1997, starting with a freshman class in fall 1998 and graduating our first class in April, 2002. With a graduating class in April, we scheduled our first ABET visit for the fall of 2002 and the 2002 class was retroactively accredited. (We were revisited in fall, 2005 to put our program on the same accreditation schedule as the remainder of the engineering and technology programs at WMU.)

Chemical engineering at WMU is an outgrowth of our long-standing Paper Engineering program. The Paper Engineering program was established in the middle 1950s at the request of the paper industry in Michigan (and the Kalamazoo area in particular). The Paper Engineering Program contained core chemical engineering courses such as material and energy balances, transport phenomena, heat transfer, and design. Courses in mass transfer and kinetics / reactor design were conspicuously absent. (Courses in pulping, bleaching, and coating covered portions of these two topics necessary for the pulp and paper industry.) The proposal to establish a BS in Engineering (Chemical) to be housed in the Department of Paper Science and Engineering was approved in late 1997. We elected to do a rolling implementation, with the first freshman class entering in Fall, 1998. The program is nominally a 4 year program, but, like most engineering programs at Western, students take 9 to 10 semesters to complete degree requirements.

The program is relatively small, numbering about 100 students across all year classes. The department houses programs in Imaging, Paper Engineering and Paper Science, and Chemical Engineering. The 14 faculty are split roughly evenly between the three programs, although many of us teach in both the paper and chemical engineering programs.

<u>ABET and Other Fun Stuff</u>

While not directly part of the program proposal, we knew that ABET accreditation was necessary for the success of our students (and the program). With our first graduating class expected in 2002, satisfying the "new" EC 2000 criteria would be critical for accreditation. One of our first tasks was to establish an Industrial Advisory Board (IAB) to help provide the external input and review that is clearly part of the ABET process. Unlike established programs, we did not have a set of chemical engineering alumni to draw upon for participation or recommendations. However we were fortunate to have the headquarters of several large manufacturing firms within a reasonable distance of Kalamazoo and we reached out to these firms for help. We were fortunate in obtaining IAB volunteers from several firms and our initial IAB consisted of engineers from:

Pharmacia (now Pfizer)
Whirlpool
EarthTech (a part of Tyco)
ABB

We also felt that a seasoned academic would be very helpful and were able to convince Jim Wilkes, emeritus professor at The University of Michigan, to join us.

The board was extremely helpful in developing a set of Educational Objectives as well as refining Program Outcomes. The IAB meets twice a year and a significant amount of time at each meeting is devoted to the future of chemical engineering and what should be appropriate Educational Objectives for a ChE program at Western Michigan University. Thus, while not only satisfying part of the ABET process, the IAB has also been extremely helpful in assisting the faculty in a continuous review of the program.

The ChE program requires that the student select an "option," which is a limited type of specialization. An option requires the completion of 17 credits of classes selected from a prescribed basket of classes. As initially formulated, the program had two options: one in pulp and paper and one in imaging and inks. Student input (an ABET process!) suggested that the list of options needed to be expanded. Likewise, we had industrial input along the same lines. After significant IAB discussions, we proposed, and the various curriculum committees approved, additional options in the life sciences, pollution prevention, and energy management. These options directly support local industrial needs. At present, roughly 40% of the students pursue the life sciences option, 30% the environmental option, and the remainder split across the other options. The importance of this is that the program has a history of students being interested in the life sciences.

Whither Chemical Engineering

In late November, 2003, one of the IAB members shared information from their corporate research advisory board on the future of chemical engineering. (This was basically information from the Frontiers in Chemical Engineering Education workshop series that is summarized by Armstrong {Armstrong, 2006) with details available at http://web.mit.edu/che-curriculum/discussion/index.html) This triggered a discussion of the future of chemical engineering and how / when WMU's chemical engineering program should respond. These discussions occupied the IAB for nearly a year, resulting in two main conclusions:

- Biology is truly a 4th foundational science of chemical engineering
- Nanotechnology is important, but is an application, not a foundation

The IAB continued to debate the level of biology appropriate for a chemical engineer; Dr. David Cowan, chair of WMU's Biological Sciences Department, was invited to join several of these discussions and his input was valuable in the final IAB recommendation. Additionally, student input was sought by the IAB chair through the student chapter of AIChE.

The ChE program at Western is a fairly rigid program comprising 132 semester hours of required and "elective" course work as shown in Figures I and II. (The elective courses are not "free" electives in that they must be chosen from a specified group of courses.) To complete the program in 4 calendar years (8 semesters), students must take 16 – 19 credits/semester. Most students take 9 or 10 semesters to complete the program. One IAB concern was that if biology courses were to be added to the curriculum what could be removed without significant deleterious effects, helping to keep residence time to a minimum. Courses considered for deletion were those in statics and mechanics, second semester physics (electricity and light), linear algebra and vector calculus, and second semester organic chemistry. The debate was generally constructive and the input from the two IAB members who are program graduates was especially valuable as they could comment in some detail on the actual content of the various courses being considered for deletion.

After roughly another 6 months of intense discussions, the IAB recommended that the faculty consider modifying the chemical engineering program by:

- Deleting the course in statics and mechanics (ME 2530 - 4 credits)
- Adding two biology courses (BIOS 1500 & 1510 - 8 credits)
- Incorporating examples of bioprocess engineering into current courses

The faculty curriculum committee carefully considered the IAB recommendation and agreed that the changes were appropriate. The only modification to the IAB recommendation was that rather than two required courses from the biosciences department, we would require the introductory biosciences course (BIOS 1500) and the department would develop a course in bioprocess engineering (CHEG 3550). (We are fortunate to have two faculty who have academic backgrounds and research interests in this area.)

The curriculum proposals have been approved by the faculty and are up for approval by the college curriculum committee. Assuming no hitches in the curriculum approval process, the biological sciences foundational leg will be added to the program effective with the Fall, 2007 semester. (It is our intent to offer CHEG 3550 next fall for those students in the life sciences option.) The modified curriculum is presented in Figures III and IV.

Conclusion / Lessons Learned

Of all the things we have done as part of the ABET accreditation process, the use of the Industrial Advisory Board to help guide the program has probably been the most beneficial. They raised the issue of changes in chemical engineering and spearheaded the effort to develop a recommendation for the faculty. It is clear that the "outer loop" portion of the ABET process can, and should, be used to drive change.

Feedback from students has also been positive. Many of our students already pursue the life sciences option and perceive the change as very positive. Others have had mixed responses, primarily due to both the increased credit hour load and the addition of another class with a lab. Still, they recognize the need and realize the positive impact on their curriculum.

We believe these modifications to our program will better position our graduates to respond to the changing nature of chemical engineering. They will be prepared to contribute in the "conventional" chemical processing industries as well as accept challenges in the emerging biotech sector.

Reference

Armstrong, R. C. 2006. "A Vision of the Curriculum of the Future," *Chemical Engineering Education*, 40 (2) pp 104-109, 2006

Figure 1
Chemical Engineering -- Freshman and Sophomore Years

	Freshman Year		Sophomore Year	
Area	Fall Semester	Winter Semester	Fall Semester	Winter Semester
Chemistry	CHEM 110 & 111 General Chem. I	CHEM 112 & 113 General Chem. II		CHEM 225 & 226 Quant. Anal.
Physics		PHYS 205 & 206 Mechanics & Heat + Lab	PHYS 207 & 208 Electricity & Light + Lab	
Mathematics	MATH 122 Calculus I	MATH 123 Calculus II	MATH 272 Vector Calculus	MATH 374 Differential Eq.
Chemical Engineering	CHEG 101 Intro. To Ch. Eng.	CHEG 181 Intro. to ChE Computations	CHEG 281 Data Acquisition	CHEG 296 Material & Energy Balances CHEG 261 Environ. Eng.
Chemical Engineering Option			Elective 1	Elective 2
Other Engineering	IME 102 Tech. Commun.		IME 261 Eng. Statistics	
General Ed.	Area I	Area III		
Total Credits	17	17	17	19

Figure II
Chemical Engineering -- Junior and Senior Years

	Junior Year		Senior Year	
Area	Fall Semester	Winter Semester	Fall Semester	Winter Semester
Chemistry	CHEM 430 Physical Chem.	CHEM 375/376 Organic Chem. I (+lab)	CHEM 377/378 Organic Chem. II (+lab)	.
Physics				
Mathematics				
Chemical Engineering	CHEG 311 Unit Ops. I CHEG 320 Thermodynamics CHEG 381 Comp. Model. I	CHEG 312 Unit Ops. II CHEG 330 Mass Transfer CHEG 382 Comp. Model. II	CHEG 410 Reaction Eng. CHEG 483 Process Control CHEG 450 Project Design	CHEG 487 Senior Design CHEG 420 Separations
Chemical Engineering Option			Elective 3	Electives 4 & 5
Other Engineering	ME 2530			
General Ed.	Area V	Area II Area VIII		Area IV
Total Credits	17	16	17	16

Figure III
Modified Program -- Freshman and Sophomore Years

	Freshman Year		Sophomore Year	
Area	Fall Semester	Spring Semester	Fall Semester	Spring Semester
Chemistry	CHEM 1100 & 1110 General Chem. I (4)	CHEM 1120 & 1130 General Chem. II (4)		**BIOS 1500** **Mol. & Cell. Biol. (4)**
Physics		PHYS 2050 & 2060 Mechanics & Heat + Lab (5)	PHYS 2070 & 2080 Electricity & Light + Lab (5)	
Mathematics	MATH 1220 Calculus I (4)	Math 1230 Calculus II (4)	MATH 2720 Vector Calculus (4)	MATH 3740 Differential Eq. (4)
Chemical Engineering	CHEG 1010 Intro. To Ch. Eng. (3)	CHEG 1810 Intro to ChE Computations (2)	CHEG 2810 Data Acquisition (1)	CHEG 2960 Mat'l & Energy Balances (4) CHEG 2610 Environ. Eng. (3)
Chemical Engineering Option			Elective 1 (4)	Elective 2 (4)
Other Engineering	IME 1020 Tech. Commun. (3)		IME 2610 (3) Eng. Statistics	
General Ed.	Area I (3)	Area III (3)		
Total Credits	17	18	17	19

Figure IV
Modified Curriculum – Junior and Senior Years

	Junior Year		Senior Year	
Area	Fall Semester	Spring Semester	Fall Semester	Spring Semester
Chemistry & Biology	CHEM 4300 Physical Chem. (3)	CHEM 3750/3760 Organic Chem. I (+lab) (4)	CHEM 3770/3780 Organic Chem. II (+lab) (4)	.
Physics				
Mathematics				
Chemical Engineering	CHEG 3110 Unit Ops. I (3) CHEG 3200 Thermodynamics (3) CHEG 3810 (1) Comp. Model. I CHEG 3550 Bioprocess Eng (3)	CHEG 3120 Unit Ops. II (3) CHEG 330 Mass Transfer (3)	CHEG 4100 Reaction Eng. (3) CHEG 4830 Process Control (4) CHEG 460 (3) Project Design	CHEG 4870 Senior Design (3) CHEG 4200 Separations (3)
Chemical Engineering Option			Elective 3 (3)	Elective 4 (3) Elective 5 (3)
Other Engineering				
General Ed.	Area V – Econ 2010 Microeconomics (3)	Area II (4) Area VIII (2)		Area IV (3)
Total Credits	17	16	17	15