Discipline at a Cross Roads
Chemical Engineering Leadership Workshop

July 2002

Reporters: C. Zukoski, B. Armstrong and R. Rousseau

I. Introduction

A workshop to discuss the directions of the chemical engineering discipline was held July 8, 9, 10, 2002 at the Woodlands in Houston Texas. The workshop was hosted by Steve Miller, CEO of Shell North America, and organized as part of a Council for Chemical Research working group managed by B. Armstrong, R. Rousseau and C. Zukoski. Representatives from Bristol Myers Squibb, Shell, Kimberly Clark, Kraft Foods, the National Science Foundation, and Department Heads (or designees) from 24 Universities attended the meeting. The workshop had three goals:

1) Examine the case for change in the education and direction of the chemical engineering discipline.
2) Discuss the appropriateness of name changes for chemical engineering departments.
3) Develop a path forward.

The conference consisted of short presentations from Chip Zukoski (Ill) and Bob Armstrong (MIT) setting the background for the workshop, followed by discussions in break out groups that reported back for full group discussions on the following questions:

1) What is the vision for the discipline of Chemical Engineering, and how is this reflected in our approach to contemporary problems?
2) What role does biotechnology play in that vision?
3) How should undergraduate education be reflected in the vision?
4) How should graduate education be reflected in the vision?
5) How should the vision embrace education in biotechnology?
6) How is the ability to incorporate rapid changes in technology reflected in the vision?

A second set of breakout groups responded to the question of the need to change department names by developing and discussing possible names. This was followed by a plenary session in which the cumulative list was narrowed; the narrowing included establishing the pros and cons of different names. Three sessions finished the workshop: a panel discussion of the need for change and the role of biotechnology in the education of chemical engineers that was led by corporate and NSF friends; a review and discussion of the pros and cons of a name change; and, lastly, planning a path forward.

Below a summary of the discussions is presented, followed by the path forward established by this group.

II. Vision of Academic Chemical Engineering

Chemical engineering is the discipline that transforms materials into useful products through chemical and physical processes. Building on a foundation of mathematics physics and chemistry, the core engineering subjects defining the discipline are transport phenomena, reactor analysis, reaction kinetics, thermodynamics, separations, and the design, optimization and control of chemical processes. The combined approaches of taking a process approach to molecular scale transformations integrates across length scales reflected in the educational programs of chemical engineering departments across the country is enormously valuable to society. Education in this discipline produces individuals who are uniquely prepared to lead corporate and academic enterprises.

Chemical engineering education has long been built on the physical and chemical processes of chemical transformations. Chemical engineering students are required to take a substantial number of courses that are largely designed for chemistry majors and taught by chemists. The resulting skill set is developed from a fundamental understanding of engineering principles and processes built on a physical and chemical foundation that is recognized as valuable by a surprisingly large range of corporate sectors (chemical, energy, personal care, semiconductor, materials, fibers, pharmaceutical, biotechnology, and food).

In the past 20 years, understanding of biological systems has developed to the point that biological systems can now be engineered. The result has been a transformation in problems that can be addressed and products that can be made. The revolution in understanding biological systems has occurred at the molecular level, i.e., where key processes involve physical processes and coupled reaction pathways that are subject to feedback and control. These integrated networks can be engineered to transform materials into useful products. Understanding of biological processes is of importance not only to those sectors involved with human health (e.g., the pharmaceutical and biotechnology industries) but increasingly in the traditional employers of chemical engineers (i.e., corporate sectors including the materials, chemicals, food, personal care, energy, fuels, and semiconductor processing industries).

The chemical engineering profession cannot ignore this revolution. Indeed, application of core skills of chemical engineering is being increasingly recognized as valuable in further advancement of the understanding of biological systems and in the application of biological processes to solve societal problems. To be effective, chemical engineers now must have a working knowledge of biomolecular and cellular principles and processes. Reflecting this change, a number of departments are altering their curricula to emphasize biological processes.

Biological systems and reaction pathways are sufficiently different from the small-molecule and macromolecular chemistries taught in chemistry classes that formal education in biological processes and reactions is required for chemical engineering

graduates to be effective. Recognition of the need for formal education in biology represents a fundamental increase in the bandwidth of the education for students who will graduate to be leaders in industries using chemical and biological technologies.
A key conclusion of the workshop is that chemistry and biology are reaching equal standing as foundational sciences upon which the current discipline of chemical engineering is built.

Chemical engineering is a vibrant discipline with a venerable history, a vital intellectual core, strong demand for its graduates, and an exciting future in education, research, service and economic development. Despite this strong past history and exceptional potential for the future, the discipline finds itself in a unique competitive environment. Evidence of this competition can be found in three areas:

- *Enrollment*
  In the past 5 years there has been a significant decrease in the number of students enrolling in chemical engineering programs. Moreover, the industries hiring chemical engineering graduates have changed dramatically over the past 15 years, with a diminution in the fraction going to the chemical and energy sectors and a growth in hiring by the electronics, food, personal care, biotechnology and pharmaceutical industries. These factors make it difficult for several corporate sectors to hire chemical engineers of sufficient number and quality in order for their enterprises to flourish.

  There are several reasons for the enrollment decline. Primarily, there is a nationwide reduction in students majoring in engineering and the physical sciences. Secondly, students are not enrolling in chemical engineering curricula due to the reduced prestige and a poor public perception of the chemical industry. Thirdly, students are attracted in growing numbers to bioengineering and biomedical engineering programs and departments. Finally there is a poor understanding of high school (and younger) students of the excitement and career opportunities in chemical engineering.

- *National Policy Making and Funding Sources for Research*
  The United States is focusing enormous effort in human health and biotechnology. The result has been changes in national policy regarding health care, biotechnology and the funding of research. NIH recently established the Institute for Biomedical Imaging and Bioengineering. This Institute reflects the national priorities of developing a better engineering underpinning for human health and offers academic engineers opportunities to tap into large research funding streams focused on engineering problems associated with human health. As a result of the general perception that chemical engineers focus on the petroleum and chemical process industries chemical engineering faculty can find themselves at a disadvantage in competing for these funds.

- *Establishment of Bioengineering and Biomedical Engineering Programs*
  Competition for students and resources arises on many university campuses from the successes of the Whitaker Foundation in driving engineering colleges to build

bioengineering programs oriented towards medicine and biomedical engineering departments. These programs and departments are establishing research and teaching agendas that are increasingly congruent with established programs in chemical engineering departments.

- *Campus Perception of Role Played by Chemical Engineers*
  Chemical engineering has long been associated with the chemical process industries. This perception stereotypes the types of problems where chemical engineers are likely to have an impact. The breadth of the discipline is often overlooked by campus administrations with the result that chemical engineers are routinely not at the table in developing campus-wide strategic initiatives. The fact that chemical engineers may not be at asked to participate in discussions where chemical engineers are making substantial contributions is a special concern given the investments currently being made in the biotechnology at universities around the country.

In response to the competition for the best students, external funding, and local resources, there is a growing trend for chemical engineering departments to alter their names to either Chemical and Biological Engineering or Chemical and Biomolecular Engineering. These name changes enhance the visibility of the educational and research programs that already contain strong elements of molecular and cellular biology, and establish that these departments embrace biology as a core fundamental science. Associated with the name changes are alterations in curricula and degree names. The result is a divergence of evolutionary paths between units that have changed their names from those who have not. A consequence of this state of affairs is that the discipline of chemical engineering faces the possibility of fragmentation.

Workshop participants concluded that pressures acting on particular departments to change their names are felt broadly across the discipline and fragmentation will accelerate if, as a group, departments of chemical engineering do not develop a coordinated response to these pressures.

III. Transforming the Curriculum

Recognizing the broadening of the foundational sciences of the chemical engineering discipline offers the opportunity to alter the way chemical engineers are educated. Advantage should be taken of this opportunity to develop better strategies for teaching chemical engineering principles. **Workshop participants concluded that altering the curriculum should be done to include molecular and cellular biology as underlying fundamental science and also to include expanded examples of applications of core chemical engineering concepts drawn from corporate sectors reflecting where our students go upon graduation (i.e., examples drawn from areas like product development, materials processing, food processing, energy, fiber processing as well as biotechnology and pharmaceuticals manufacture).** The revitalized curriculum should also develop methods for capturing the attention of students earlier in their university years through courses that motivate the students in their freshman and sophomore years. These changes should be made with the goal of developing more effective methods to attract more students into the discipline. If done correctly, this process can further expand the diversity in our profession.

Changes to the curriculum require addressing the number and substance of biomolecular and cellular courses, while also working with the relevant core scientific disciplines to ensure that the courses satisfy the needs of our students. Incorporating biological chemistry and processes in core chemical engineering courses is also seen as a key element in curriculum reform.

Greater discussion will be needed to reach a conclusion on the most effective methods for building a new curriculum. Models proposed include a different degree and an option or minor route for providing more advanced material to undergraduates. **Despite differences of opinion on structural details, workshop participants concluded that all chemical engineering majors should receive a minimum level of exposure to biological and cellular reactions and processes.**

At the graduate level, there was a sense that the research enterprise is strong and will continue to thrive. On the other hand, developing methods for attracting students into graduate school is an issue. As the bandwidth of the chemical engineering discipline expands, developing methods for encouraging students from non-traditional programs to earn PhDs with faculty members in chemical engineering departments will be of growing importance. Sentiment at the workshop was expressed that a focus be placed on the outcome of a graduate education as opposed to what is required as an input (or the preparation level of the students). Professional MS degrees were discussed as a method to provide additional educational and professional development opportunities, while exposing students to advanced degree programs.

IV. Name Changes

Several departments have already responded to changes sweeping the chemical engineering profession by changing their name. **A broad consensus developed that, while details are subject to local pressures, a cohesive response by a majority of departments would build strength while a fragmented approach would damage the discipline.**

Below are highlighted arguments pro and con for any name change and for particular names.

Reasons not to change departmental names

- The discipline is not in a crisis so the name change is not needed.
- A compound name such as Chemical and Biomolecular Engineering or Chemical and Biological Engineering is unnecessary because departments are already changing curricula and the chemical engineering research enterprise without a name change.

- Expansion of the core scientific underpinning of the profession can be accomplished through minors and options with no need for changing department names. These options and minors can be advertised and used to establish the intellectual domain of chemical engineering. Indeed changing the name before the details of new curricula have been worked out is premature.
- A compound name does not fully reflect the broad nature of chemical engineering and stands the risk of alienating both faculty who do not have biology as a base of their research as well as alienating materials, personal care, chemical, energy and semiconductor processing companies that currently hire many chemical engineering majors.

Reasons to change departmental names

- The chief intellectual reason for changing the name of departments is to recognize and communicate the expanded scientific base of the profession.
- Having a compound name is important to establish identity and to enable an expansion of self-identification within the profession. The compound name change serves as a statement of an expanded intellectual basis for the future of chemical engineering.
- Chemical engineering is recognized as incorporating those molecular transformations and processes that are important to a wide range of corporate sectors and research sub-disciplines that rely heavily on chemistry as their primary science. Including a bio-name recognizes the expanded scientific basis of the discipline without in any way diminishing the commitment of the discipline to those industries that are not reliant on biotechnology.
- A name change allows departments to establish that they are active in biological research and education. As there is a serious race in many institutions for resources, the need to be responsive to the growth of bioengineering and biomedical engineering programs cannot be diminished. A name change will result in the departments being more competitive for resources at the campus and national levels.
- Students are attracted to biological department and degree names. A change to a compound name including “bio” would act as a draw for a wider range of students.
- A name change formally recognizes contributions chemical engineers currently make and will make in the future to the biotechnology base of this country, and it is an important step in establishing that chemical engineering is a discipline that is intellectually competitive with the emerging disciplines of bioengineering and biomedical engineering. Ultimately this competition is played out in the ability of the discipline to attract the best student and faculty talent. A name change formalizes our commitment to be competitive.

A long list of names was considered. The top three names considered the most likely to be acceptable and their pros and cons are:

Chemical and Biomolecular Engineering

Pros:

- Advertises the scientific base of the discipline
- Acts as a catalyst for curriculum change
- Previously identified by NIH as being at the interface of biology and chemical engineering and with a molecular level. The NIH divided biomolecular
- engineering research into 5 components: production of recombinant proteins; metabolic engineering; cell engineering; molecular bioseparations, and biocatalysis. This definition could easily be expanded to include drug delivery and tissue engineering.
- Is more inclusive modern biotechnology
- Most easily opens doors for collaboration with biologists due to its molecular focus

Cons:

- Stakeholders have a limited understanding of the meaning of this name
- Some aspects of chemical engineering, including some with interests in bioengineering, are not explicitly included
- Compound name may create uncertainty and fear among stakeholders

Chemical and Biological Engineering

Pros:

- The name has scientific symmetry
- “Biological” more inclusive than “biomolecular”
- Emphasizes the similar roles of chemistry and biology in the discipline
- Acts as a catalyst to curriculum change
- Advertises the scientific basis of the discipline

Cons:

- Has been co-opted internationally by Agricultural Engineering
- Has not been formally recognized by NIH
- Leaves the impression of having a low level of engineering
- Is too broad
- The stakeholders in our enterprise have limited understanding of the meaning of this name.
- Some aspects of chemical engineering are not explicitly included

Chemical Engineering

Pros:

- Well understood
- Has long-standing currency among stakeholders
- Recognizes the core curriculum as it currently stands
- Captures the largest single employer of our students

Cons:

- Does not embrace biology as a core scientific discipline
- Is not a catalyst for curriculum change
- Entrenches the status quo
- Has a negative public perception
- Cedes intellectual areas to other disciplines
- Intellectually tied to chemical process industries
- Less helpful in advertising opportunities in discipline

V Path Forward

Workshop participants concluded that the discipline of chemical engineering is at a crossroads. One road forward emphasizes the status quo. The second road expands the discipline by explicitly incorporating biology on a footing comparable to chemistry in the scientific foundations of the discipline. Competitive pressures resulting from the growth of bioengineering and biomedical engineering programs require that chemical engineering departments act decisively to embrace biology or cede intellectual territory to other disciplines. The decisions made collectively will influence the ability of chemical engineering departments to attract and educate individuals who will lead the chemical and biotechnology process industries.

Workshop participants concluded that an understanding of modern molecular biology, including biological chemistry and cellular processes, is a vital to the success of future chemical engineers. Ensuring that undergraduate majors gain an appreciation for this material requires a major revision of how we educate undergraduates. With this revision comes the opportunity to revitalize all aspects of our curriculum.

Corporations and federal agencies charged with sustaining the technological capabilities of the nation are clearly aware of the need for change in how chemical engineers are educated. Corporate participants at the workshop expressed interest in supporting the development of course materials.

Acceptance of name changes and the exact name will depend very much on local circumstances. Workshop participants felt strongly that a cohesive response by a broad cross section of chemical engineering departments is important to ensure that the discipline does not fragment.

Continued consultation among departments in curriculum development, name change discussions, and in outreach to stake holders is essential to have the discipline respond coherently in the time frame necessary to capture developing opportunities in biotechnology and other applications of the disciplines core competencies.

Three action items arose from the workshop:

1) The AIChE Board of Directors will be approached about receiving a presentation on this workshop and the possibility of an open forum at the fall 2002 National Meeting. (Zukoski)
2) Forums and workshops will be organized with the help of department heads to bring together faculty to develop a common structure for expansion of the undergraduate curricula to embrace biology as a core scientific foundation of the discipline. (Armstrong)
3) Methods of working with stakeholders to advertise the changes being undertaken within the discipline will be developed. (Rousseau)

Participants:

Anthony, Rayford G., Texas A&M University
Armstrong, Robert, MIT
Barteau, Mark A., Delaware
Betenbaugh, Mike, Johns Hopkins
Chakraborty, Arup, UC, Berkeley
Chapman, Dr. Tom, NSF
Ekerdt, John G.,UT Austin
Foley, Henry C., Penn State
Ford, Roseanne, University of Virginia
Frank, Curtis W., Stanford
Futran, Mauricio, Bristol Myers Squibb
Gellman, Andy, Carnegie Mellon
Gregg, John A., Kraft
Hawley, Martin C., Michigan State
Kilpatrick, Peter, North Carolina State
Kushner, Mark, Illinois
Leach, Dr. Crystal, Kimberly Clark
Lee, Gil U, Shell
LeVan, M. Douglas
McCready, Mark, Notre Dame
Miller, Bill, Northwestern
Miller, Steve, Shell
Rauchfuss, Thomas B, Illinois
Rousseau, Ronald W., Georgia Tech
Schimmel, Keith, NCA&TSU
Scranton, Alec, University of Iowa
Shanks, Brent H., Iowa State
Shuler, Michael L., Cornell
Tharakan, John P, Howard
Wood, David W., Princeton
Zukoski, Charles F., Illinois