CHAPTER 8

Does Chemical Education Fulfill Its Customers' Needs?

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ABSTRACT

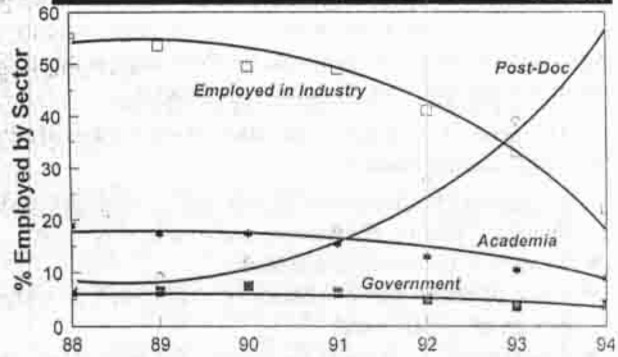
In 1987–1989, a group of 138 new technical hires and 102 supervisors at Exxon Chemical were surveyed to determine how well their traditional academic training had prepared the new hires for their jobs. About the same time, 427 technical hires at Dow Central R&D took a similar survey. In 1995, a cross-section of seasoned supervisors and chemists in about 26 companies were surveyed. The results are strikingly consistent: Traditional education stresses sound technical concepts but fails to teach communication, team interaction, application of concepts to solutions, environmental and safety requirements, and even some important technical skills such as sampling, statistical design, and modern analytical instrumentation. These conclusions are not new; an ACS report issued in 1973 found exactly the same issues. Today, however, there are fewer job opportunities in academia, and about 80% of Ph.D. chemists now seek employment in industry, a situation for which they are ill prepared.

Education, according to an old sage, is what's left over after you have forgotten everything you learned—a bundle of capabilities, attitudes, skills, and experience. But for what? Most of us chemists—something like 80%—end up in industrial employment (or at least, we used to . . .). Most of us spend anywhere up to 12 years or more preparing ourselves for such a career. This preparation time is a major sacrifice at a time of life when our energy and creativity are at their highest level. Is it a worthwhile investment?

In the past, we seldom asked the question. A Ph.D. used to be a passport to a comfortable salary and an interesting, prestigious job. But in the late 1980s, Ph.D. employment by the chemical industry took a nosedive (Figure 1; see Editor's Note also), and there was a startling increase in the number of candidates who had to accept post-doctoral positions (*1*). Sadly, some of these graduates, with growing despair, are still moving through a shadowy succession of post-docs from which some may never emerge.

Clearly, some sea changes in the chemical industry are responsible for this dramatic difference (*2*). But now that Ph.D. chemists are in oversupply, those who will be most successful in getting jobs and in keeping jobs will be those who understand and meet their customers' requirements. And we, in the business of education, need to make our students aware of these requirements and help to prepare them for the real world. This task may call for a departure from traditional thinking. The Doctor of Chemistry (DChem) program at the University of Texas at Dallas, for example, takes a very nontraditional approach, and its graduates report no difficulty getting jobs, despite an almost total lack of post-doctoral experience. Their prepa-

Figure 1. Employment of Ph.D. Chemists
(Source: ACS Presidential Task Force 1995 Report)



(Editor's note, p. 34)

Table 1. **Surveys of Customer Satisfaction or Need**

Date Investigator	Scope	Respondents
1973 ACS[1]	96 Companies nationwide	Senior managers
1989 Exxon Chemical (Hochgraf)	240 Technologists East Coast & Gulf Coast	New campus hires (1–5 years) and their supervisors
1992 Dow Chemical (Lehman/Lorenz used Exxon Survey)	427 Researchers at Midland, MI	New hires (1–5 years)
1995 University of Houston (Taylor)	35 Companies in United States	Experienced chemists and managers (20 years experience)
1996 Chavez Roche-Syntex; Cuernavaca, Mexico	35 Companies in Mexico	Managers of manufacturing units

[1] *Chemistry in the Economy*; American Chemical Society: Washington, DC, 1973; Chapter 24.

ration seems to have brought them closer to meeting employers' requirements.

No one needs to wonder what those employers' requirements are. In Table 1, we have listed five independent surveys, over a 20-year period, by industry, by a major university, and by ACS, at locations all over the United States and even in Mexico. The surveys have questioned senior managers, new campus hires, experienced chemists and managers, and even managers in manufacturing units. The answers are all consistent. One would have to be unusually creative to find a reason to doubt these data.

1973 ACS survey of industry needs

One of the earliest decisions of the ACS Committee on Chemistry and Public Affairs more than 25 years ago was to provide a "broad and thoughtful look at the place of chemistry in the U.S. national economy." With financial help from NSF, this study was completed and published in 1973 (*3*). Chapter 24 of that report correlates chemical education with industry needs, based on a survey of research managers, directors, and vice presidents of 96 companies.

Much of this chapter reads as if it had been written yesterday. The slowing of the job market in the 1970s, compared with that of the 1950s and 1960s, was already evident; the fact that the job market would become more selective, especially for Ph.D.s, was recognized. The preamble concludes by stating that "a better matching of the qualifications of new graduates and the requirements of employers is obviously desirable for their mutual benefit—and in the interest, too, of society in general."

The general findings of the study were summarized in "five outstanding themes."

- Programs characterized by pursuit of elegance more than by "clarity, directness, and practicality"
- Tendency to overspecialization
- Lack of many basic laboratory skills such as proper design of experiments
- Insufficient awareness or respect for economic constraints, commercial applicability, or social implications
- Amazing lack of competence in communication skills (*3*)

These general findings are underlined by some comments applying to Ph.D. training in particular.

- "All too often—brought up in the images of their professors who are largely ignorant of professional requirements outside the university."
- Need for "more quantitative fundamental problem-solving courses rather than survey courses that do not broaden, but dilute."
- "Graduate program—oriented unconsciously if not consciously toward careers in academic research."
- "The bulk of the annual 2000 or more chemistry doctors are being unrealistically trained" (*3*).

One cannot help noticing how little has changed in the intervening two decades. We have, no doubt, heard each one of these comments restated by colleagues in industry within the past two years.

This landmark study also came up with recommendations for changes: more course work; less highly specialized research; and inclusion of focus areas such as chemical process definition, statistical and data analysis, chemical marketing, economic evaluation of research projects, and patent and legal considerations. Wasn't it Yogi Berra who said, ". . . déjà vu all over again"?

If there is anything missing in this 1973 ACS report, it might be a mention of what was right about Ph.D. training programs. By the 1990s, we had discovered the concept of political correctness, and a modern report would be more palatable if it presented a more balanced view. However, as far as the issues are concerned, our colleagues in 1973 were right on.

1989 and 1992 Dow and Exxon studies

In the late 1980s, Exxon Chemical set in motion some survey work that was complementary to the 1973 ACS study. Whereas the ACS survey targeted senior managers, this activity focused on the researchers themselves. In 1989, Exxon Chemical surveyed 240 technologists at their East and Gulf Coast facilities; these included 138 relatively new campus hires with one to five years experience and 102 supervisors. A few years later, Lehman and Lorenz at Dow Chemical, using the Exxon methodology, surveyed 427 technical hires at Dow's central R&D facility in Midland,

Table 2. **Survey of Skills Preparation and Importance of Skills to Job**

	Exxon Chemical (1989)	Dow Chemical (1992)
Populations	138 Campus tech hires (1–5 years experience) 102 Supervisors	427 Tech hires Central R&D < 5 years at Dow
Response	68%	82%
Disciplines	Chemistry-related 13% Engineering-related 76% Other 11%	Chemistry-related 40% Engineering-related 37% Other 23%
Degrees	Bachelor's 52% Master's 25% Doctoral 23%	Bachelor's 38% Master's 15% Doctoral 47%

N. N. Hochgraf, personal communication.

MI; most had been with the company five years or less. Chemistry-related and engineering-related disciplines were represented, as were all three degree levels, bachelor's, master's and Ph.D. (Table 2).

These Dow and Exxon studies did ask what was right about the education process and they identified three areas in which academic training did indeed offer skill preparation that matched the importance to the job: knowledge of basic science and engineering concepts, the ability to acquire and retain information, and the ability to work independently (N.N. Hochgraf, personal communication). However, the young scientists and engineers at Dow and Exxon also identified several other areas in which there was a significant gap between their academic preparation and the requirements of their jobs.

- Plant operation/equipment control
- Environmental/safety requirements
- Apply concepts to reach workable solutions
- Effectiveness in a team
- Explaining ideas and concepts
- Getting co-operation
- Setting priorities and developing plans
- Judging time & effort appropriate to problem
- Gathering necessary information

The tone is probably best captured in the verbatim sampling of responses to an open-ended question: What aspect of your academic training was uniquely helpful?

- Team interaction to solve a large complex problem
- Searching literature, writing reports, speaking to an audience
- The only positive points were basic chemistry and scientific method
- Ironically, a technical communications course
- Summer internships, technical writing, presenting papers
- An English professor graded our reports and presentations
- Really there is none: Job is "hands-on"; academia emphasized theory and simple models

Most chemistry education programs offer little or nothing in the areas the respondents typically mentioned.

These findings differ from the 1973 ACS results in one important aspect: The earlier recommendations concentrated on additional things that the students needed to know such as marketing or legal or economic facts of life. The 1989 and 1992 recommendations stressed a need to change HOW learning takes place and underlined the need for such skills as working in teams, getting co-operation, judging appropriate effort, communicating, and applying concepts. These points of emphasis illustrate the changing expectations and dimensions of technical jobs (*2*), at least in major companies.

And this raises an obvious question: If these views are true for employees of Dow and Exxon, are they equally true for the rest of the industry? We strongly suspect that they are; however, we are presently conducting additional studies that will include smaller companies in other geographic and product areas (N.N. Hochgraf, personal communication).

1995 University of Houston survey

In real life, one must make choices. If we want to teach students new material that they need to know, which of the old stuff can we leave out? Are the traditional areas of training still important? This was the theme of a survey done by a few members of the University of Houston Chemistry Department in 1995. The survey was addressed to a cross-section of people that we knew—all industrial members of the ACS Committee on Education, plus scientists and managers at about 40 companies with whom we had contacts. Respondents had between 7 and 35 years of experience in industry, but the average industrial tenure of our survey respondent was about 21 years.

In one part of our survey, we asked about the relative importance of different skills or experiences, on a scale where 3.0 signified extreme importance and 0.0 signified not important at all (see box, Results of the University of Houston Survey—1995). Not surprisingly, the key skills are those associated with communication and teamwork. Somewhat surprisingly, there is little perceived difference between the importance of a Ph.D. versus an M.S. degree, and neither is as important as a three-month internship in

Results of the University of Houston Survey—1995

Importance of following skills and experiences (Scale 3.0 = extremely important; 0 = not important at all)	
• Ability to speak and write clearly	3.0
• Demonstrated willingness to be a team player	2.8
• A 3-month internship in an industrial lab	2.3
• Completion of a Ph.D. research program	2.12
• Completion of an M.S. research program	2.08
• Publication of original research in peer-reviewed journal	1.8
• Leadership position in extracurricular activity	1.5

an industrial lab. This may indeed reflect the views of the first-line managers and senior professional staff who filled out our survey questionnaires, but it is not yet reflected in the official hiring policies of chemical companies.

A related question asked for priority ratings on a series of courses, some of which are currently offered in the University of Houston's graduate program and some of which are not. A similar rating scale was provided (see box, Relevance of Courses: University of Houston Survey—1995). Again, communication was to be the hottest topic. Other broadly relevant skills include analytical instrumentation, sampling, scale-up, and online process control. A couple of the existing courses still hold their own, however, notably physical organic chemistry and chemical kinetics.

Other existing courses occur in the "least relevant" ranking, but even here it should be noted that courses such as X-ray crystallography or statistical thermodynamics were still highly relevant to some respondents. Equally surprisingly to us, courses such as polymer chemistry or ethylene derivatives or chemistry of petroleum refining were totally irrelevant to some respondents. When we talk about the needs of the customer, we are clearly not talking about a single monolithic set of requirements; needs do vary, and a properly designed program must have the flexibility to deal with different segments of the job market.

A third and final survey question asked for an estimate of the percentage of technical workload in the respondent's organization that clearly requires personnel with formal Ph.D. training. Although the range of responses was from 0 to 70%, the mean was 27%. This number is definitely sobering, especially because it seems to be validated by the current employment situation. One even wonders whether or not there may be a moral issue in our accepting Ph.D. candidates as graduate students, knowing as we do that for many graduates, there may be no pot of gold at the end of the rainbow.

There is, however, a brighter side to this picture. If 27% of technical jobs do require Ph.D.s with traditional training, can we say what training is required for the remaining 73%? We believe we can. The survey data quoted here are not difficult to interpret. We do know what the industrial customers want. For educators willing to think beyond the traditional confines, there exists a new market—a major growth opportunity with very little competition. And that's our message. Get over your grief; stop wringing your hands; there's a new world out there waiting to be conquered!

Relevance of Courses: University of Houston Survey—1995

Scale

3.0	Highly relevant; important for most jobs
2.0	Sometimes relevant; important for some jobs
1.0	Nice to know, but seldom used
0.0	Not worth the time and effort of learning

Most Relevant Courses

• Communication and presentation skills	2.96
• Modern analytical instrumentation	2.50
• Theory and practice of sampling	2.28
• Physical organic chemistry	2.27
• Basic principles of scale-up	2.27
• Chemical kinetics	2.19
• Online analysis and process control	2.19

Least Relevant Courses

• Quantum chemistry	0.73
• X-ray crystallography	1.00
• Statistical thermodynamics	1.08
• Symmetry and bonding	1.23
• Advanced thermodynamics	1.54
• Computational chemistry	1.65
• Organometallic chemistry	1.69

References

1. *Employment Patterns of Recent Doctorates in Chemistry*; Presidential Task Force on the Study of Doctoral Education in Chemistry; American Chemical Society: Washington, DC, 1995.
2. Taylor, G. L.; Shearer, C. J.; Rothwell, W. P. "Changing times for chemical R&D"; paper presented at the fall ACS National Meeting in Orlando, FL, 1996.
3. *Chemistry in the Economy*; American Chemical Society: Washington DC, 1973.

Acknowledgment

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Editor's Note:

During the discussion of this paper, Dr. Lawrence A. Funke, staff liaison for the ACS Presidential Task Force on Doctoral Education, pointed out that, in Figure 1, the "Year" is the "Year of Award of Ph.D."