A Time of Ferment, A Time of Change

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This is a time of ferment and a time of change in chemical education. The school reform movement has been underway for five years, since the publication in 1983 of the report of the National Commission on Excellence in Education, *A Nation at Risk* (*1*). Five years later the report card isn't very good. Secretary of Education William Bennett says we deserve a "B" grade; Ernest Boyer of the Carnegie Commission says the performance is no better than a "C". A mixed report at best, and we see the mixed results everywhere around us. In chemical education, many teachers are working outside their field of expertise. This often leads to insecurity; uncertainties exist about what and how to teach. How can we sustain the progress we have made in recent years, and how can we continue to improve?

Certain identifiable forces are creating ferment and driving change. These translate into new directions in curriculum and instruction, teacher education and research, and they are leading to a rapidly emerging world of informal chemical education. Let's look at three factors that are currently prominent.

1. The new technologies available for instruction (e.g., the computer and the laser disk) are driving change. Learning to use the new technology in the classroom and laboratory is one of our current challenges.
2. Recognition of science and technology education relative to human resource needs, particularly those associated with developing a sufficient scientific and technological work force to maintain our own quality of life and a competitive edge in the world. Among other strategies, we must more successfully reach minorities and women and attract them to careers in science and technology.
3. Recognition of the need for scientific literacy for everyone—chemistry for all. Chemistry plays a very major role in everyday life; it is a prominent factor in social issues. The necessary thinking, problem-solving and decision-making skills for civic responsibility and everyday living can be taught through the study of chemistry.

In England, there is concern that chemistry may be disappearing as a discipline (*2*). It has been left too long untended. In the United States, chemistry has been slightly more successful in maintaining a central role. This is partly as a result of very active American Chemical Society programs that recognize and actively promote both education for careers and the public understanding of chemistry. The Pimentel report, *Opportunities in Chemistry* (*3*), and the Pimentel junior report, *Opportunities in Chemistry: Today and Tomorrow* (*4*), have brought recognition to the scientific community and to the extended education community that advances in chemistry are changing our lives in the 1980's and hold even greater promise for the future. Another factor in keeping chemistry the central science has been the rapid advancement of interdisciplinary areas such as biochemistry, biochemical technology, and environmental and material sciences as subdisciplines of chemistry, and chemists' increasing recognition that rather than being subsumed, consumed, or cannibalized, it's time to take a leadership role. In chemical education, too, teaching in these areas is becoming more a part of the system.

Indeed there is a nip in the air—have you noticed it? It feels a bit like the '60's again. There is an air of change, driven by the computer and technology revolution, the need for scientific know-how and advances, and the recognition of social concerns and the relevance of science for all—male/female, young/older, majority/underrepresented, etc. Chemical education is becoming a part of education for students from kindergarten through high school.

Let's take a look at curriculum development, teacher education, research, and the newly emerging informal chemical education scene. How did we reach our present state? What do we seem to be accomplishing now? And where might we be going in the future? I'm optimistic enough to think that positive and substantive change is occurring.

Curriculum Development

The report of the Garrett Committee (*5*), chaired by Alfred Garrett of the Ohio State University, was completed in 1959 under the sponsorship of the American Chemical Society. This report called for reform in chemical education and spawned both the Chemical Education Materials Study, CHEM Study (*6*), and the Chemical Bond Approach, or CBA (*7*).

CHEM Study has been used ever since, and its films are now being revised (*8*). CBA was also an excellent program, but they both appealed to the upper 15–20% of students in the secondary schools. CHEM Study was somewhat less theoretical and more concrete, and it has survived longer. It also spawned a growing concern about reaching many more, perhaps all students.

In the 1970's, the Interdisciplinary Approaches to Chemistry (IAC) program (*9*), an innovative modular program designed to reach the large numbers of high school students who are not particularly interested in science, was developed at the University of Maryland. In this approach there was an attempt to relate chemistry to other disciplines (e.g., biochemistry, environmental chemistry, nuclear chemistry) and to present a chemistry that was more descriptive, less mathematical, more conceptual and laboratory-oriented, and more enjoyable. This program began to move chemistry teaching away from its rather pure orientation toward more interdisciplinary and applied aspects. Unfortunately, IAC was given to a nonscience publisher; it was never promoted through advertising or exhibits at regional or national meetings. It's spread mainly by "word of mouth" from teacher to teacher, and many teachers still say, "When are you going to revise IAC? We need it for our students."

IAC initiated the modular and relevant approach to chemistry instructional materials, and in some ways served as a prototype for *Chemistry in the Community* (*10*). The goals of both programs are similar—to attract a much larger audience of students into the study of chemistry.

Early in the 1980's, a consensus was building that chemistry had to be more in touch with the everyday affairs of individuals, more relevant, more society-oriented, able to aid future citizens in decision making, and *Chemistry in the Community* (*ChemCom*) was born. *ChemCom* has been

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through trial testing and publication and is now entering the schools in force this fall.

But other things are happening in the curriculum that are part of this ferment, part of this change. For example, chemistry teaching once occurred almost exclusively at the 11th grade level, with possibly an advanced placement program in the 12th grade. Look around now. Chemistry is being taught in every grade, from kindergarten through 12th, in one form or another. New materials are emerging. The National Science Foundation has just announced seven new grants for elementary school science materials, and several of these, including Full Option Science Systems, or FOSS (*11*), at the Lawrence Hall of Science, have elements of chemistry for grades K–6. The Great Explorations in Mathematics and Science, GEMS (*12*), series being published at the Lawrence Hall of Science picks up chemistry as an enrichment theme for elementary and middle schools. The Chemical Education for Public Understanding Program, CEPUP (*13*), has just received an NSF grant to complement its funding from chemical companies to develop chemically oriented, participatory activities for middle and junior high schools and for use in the community and informal education groups as well. For example, 4-H organizations are adopting CEPUP, as is the Federation of Women's Clubs of America. *Chemical Activities* (*14*), an ACS middle school publication, is just off the presses and available from the American Chemical Society.

At the senior high school level, not only are CHEM Study, ChemCom, IAC, and conventional chemistry being taught, but a new need is emerging that is related to chemical education. In many states, including the state of California, the legislature has mandated a one-year laboratory-based physical science course for high school students who do not wish to take chemistry and/or physics for an entire year. It has become a necessity to develop a physical science course that is a combination of chemistry, physics, and earth science. The chemistry component must be strong; it has been neglected in the past.

In California, such a course is being tailored through a state-funded institute, Project Physical Science (PPS), for 70 physical science teachers. After a 1988 intensive summer institute on *ChemCom*, teachers will examine the physical science course. Select portions of *ChemCom*, *Conceptual Physics* (*15*), and new *Earth Science* materials (*16*) will be used in classrooms in either a coordinated or integrated course for senior high students. Thus, chemistry through *ChemCom* can reach a much larger number of students who are not normally interested in regular chemistry courses.

Some of the ferment, some of the changes evident in '80's curriculum development include: (1) chemistry at all levels, K–12, (2) chemistry as part of physical science, (3) more urgent discussion of concurrent teaching of chemistry (with physics and biology) for at least three years through the senior high school level, (4) the possibility of upending the curriculum so that physics, which may be most basic, comes first; chemistry, which is most central, comes second; and biology, which may be most sophisticated, comes last, and (5) a rapidly emerging expansion of chemical education through the informal system [e.g., museums (*17*), industrial/research laboratory connections (*18*), media (*19*)].

As school systems experiment with better ways to improve chemical education and reach larger numbers of their students, these curriculum reforms are being tested. Yet more than 3,600 high schools in 1987 taught no chemistry at all (*20*), and others teach chemistry only every other year. Many young people still have no opportunity for chemistry of any sort.

What's ahead in the 1990's for the chemistry curricula? Let's do some crystal ball gazing, figuratively speaking, not through the occult but through informed opinion. One of the newest advances on the horizon, and one of the most exciting, is the initiation of international curriculum and instructional materials development to address global issues. For example, the Department of Energy (DOE) laboratories are interested in developing curriculum materials on CO_2 and global warming. Since this is not a local issue, but in fact affects people throughout the world, it has the potential for an internationally oriented curriculum. To carry this trend even further, with centers at the Lawrence Hall of Science in Berkeley and York Univeristy in the United Kingdom under the aegis of the International Commission of Scientific Unions/Science Teaching Committee, a very exciting new curriculum project may get underway in 1989. The intent is to select global issues and begin to develop very short instructional units that can be used to enrich the current curricula in any country. Among global issues that may be considered for development are acid rain, the ozone layer, the nitrogen cycle, CO_2 and global warming, and desertification. If this program goes (it's in fairly early stages of exploration), the intent is to develop materials, trial-test them, and, when workable prototypes are established, invite chemical educators from interested nations around the world (e.g., Japan, Thailand, Nigeria, Brazil, China, France, Australia) to join by developing their own national versions of units and creating new materials that can feed into an international pool for further development and dissemination. Exciting? I think so. The curriculum at the pre-university level is anything but static.

Teacher Education

Now let's turn our attention away from curriculum development and toward teacher education, because that area isn't static either. Teacher education is moving, too, although it's perhaps more conventional and dependent on curricula change, thus slower to change than the curriculum area. If we look at teacher education in the 1960's, we see that it was primarily summer institutes and academic-year programs. Teacher education almost disappeared in the 1970's and then was completely laid to rest in 1981 with the advent of the Reagan administration. Slowly, slowly, slowly, it is returning to the science education scene, as the NSF Division of Teacher Enhancement funds programs such as the Dreyfuss Institutes (*21*), the Institutes for Chemical Education (*22*), the Hope College program (*23*), and many others to bring teacher education back to life.

In the late 1980's, in-service institutes are primarily operated in the summer. They bring together the underprepared teachers who have been reassigned from their field of expertise to teach chemistry, the experienced teachers in advanced (e.g., instrumentation) courses, and the chemistry teacher/leaders into special challenge projects. Much of value is emerging from these programs, which are now into their fourth or fifth year since funding became available again. But more has to be done, and more is happening.

The Reactivty Network (*24*) funded by NSF is introducing teachers to new ideas directed to descriptive chemistry and new laboratory experiences that not only lean heavily toward reaction chemistry but also go below the microscale level to the microscopic scale, using microscopes to observe chemical reactions.

The Dreyfuss participants have worked diligently to develop more than 40 microlabs that are being tested and considered for further use (*21*).

The ICE/Berkeley Laboratory Leadership (*22*) group has begun a most challenging and difficult project, to learn how on a national scale to assess the learning, higher order thinking, and skills that students gain in the laboratory. It is evident from the results of the International Chemistry Olympiads (*25*) that our students do not have the quanity nor the quality of laboratory experience that is possessed by competing students from other countries. Throughout the world there is growing recognition that laboratory learning and performance must be more strongly encouraged and effectively measured.

In the current summer institutes there are very notable changes toward more cooperative learning, decision making, and problem solving. Becoming more prominent in these programs are attention to misconceptions and evaluation across all experiences. The necessity for academic-year follow-up is widely recognized. The participation of the private sector is needed and sought.

An industry/education partnership program that shows strong results is the Industry Initiatives for Science and Mathematics Education (IISME) program (*18*). Teachers are placed in positions in industrial laboratories for eight weeks during the summer, paid a stipend that is approximately equivalent to their monthly salary during the academic year, and provided with academic-year follow-up, including telecommunications networks, instructional materials development based on their experience, and credit-bearing courses to extend their professional growth and development. This is an industry-driven program. It is a powerful means of rejuvenating, professionalizing, and upgrading chemistry teachers. Similar courses have also been developed through the Department of Energy National Laboratories (*26*) and through Research Corporation (*27*), signifying a growing trend for teachers to participate in research activities during the summers.

A new area of ferment and change is in the pre-service preparation of teachers. Although this change has been very slow in coming, there are some promising activities in chemistry, three of which will be mentioned. One is the proposed ACS-accredited degree (*28*); second is the ChemSource project (*29*); and third is the Midcareer program at Mills College (*30*) and similar programs at Harvard and elsewhere.

First, the ACS-accredited degree in chemical education. The ACS Committee for Professional Training (CPT), in a dramatic, far-sighted move, has recognized that chemistry has been too narrowly defined to be fully relevant in today's world. The CPT has now developed a core of 28 semester hours of chemistry for every chemistry major that includes physical chemistry with a variety of options for completing the degree. After this core of courses is completed, a student may earn an ACS-accredited chemistry degree by specializing in any one of several areas: the traditional organic/inorganic/physical specialization, biochemistry with a strong base in biology; polymer science; and chemical education. A person preparing to be a chemistry teacher will soon, if all goes as planned, be able to earn an ACS-accredited degree. That's a great step forward. The Carnegie Commission, the Holmes Group, and the National Academy of Sciences through their study group are also pushing for a full academic major for chemistry teachers (*31*, *32*).

The second very promising pre-service project, ChemSource, is the result of recognition within the ACS Committee on Education that pre-service teachers and crossover teachers who are inexperienced in the teaching of chemistry need help. It has evolved as a result of discussions between and among experienced high school teachers and university chemists. The project has three components: SourceBook, SourceView, and SourcePlan. SourceBook will be an extensive database on more than 30 curriculum topics; it will be available in both looseleaf hard-copy and disk form. SourceView is the video component, to provide inexperienced classroom teachers with concrete examples of everyday classroom visual teacher behavior, and SourcePlan is a computerized toolkit to help teachers access data bases such as *SourceBook*, the *Reactivity Network*, *Doing Chemistry* (*33*), and *ChemCom* to facilitate daily, unit, and annual lesson planning. If funded by NSF, this project will get underway during the fall of 1989 with about a three-year timeline for completion.

The third new direction for pre-service teacher education is to identify, and attract from industry, the military and people not currently in the job market, those individuals with bachelor's degrees in chemistry who now wish to pursue a career in teaching. Mills College and the Lawrence Hall of Science are cooperating in such a project (*30*). The Mills College Science Department is preparing updating courses in the sciences. The Lawrence Hall of Science is preparing eight new "methods" modules, one each in chemistry, physics, biology, and mathematics, and four interdisciplinary modules, designed to prepare teachers to use participatory methods of teaching, with heavy emphasis on student and laboratory activities. The Mills Education faculty is supervising the student teaching and internship work. This is a very exciting two-year program co-funded by industry and NSF.

Research and Evaluation

Let's look briefly at research. Chemical education research is still in a relatively primitive stage of development, and it is essential that such research improve for chemical education to become a full-fledged subdiscipline in departments of chemistry. Dudley Herron recently prepared a report (*34*) for an NSF-funded research conference, wherein he cited some of the foremost research in Israel, United Kingdom, Scotland, and the United States. He and others indicate that the focus of research is on problem solving, misconceptions, learning cycles, and the constructivist view of learning. The need for research in chemical education is apparent and severe. We can learn from the cognitive scientists, physicists, and mathematicians, but we must take responsibility ourselves if we wish to make steady progress.

Many of the researchers in chemical education today are young PhD students, novices who are doing their best to produce a dissertation and earn a degree. What we need are longitudinal studies, research teams to study patterns over time, and possibly mechanisms for bringing chemical educators together for regular exchanges of ideas. To some degree, this occurs through the biennial conferences and ACS meetings. Much more remains unfinished.

Informal Chemical Education

As noted earlier, chemistry instruction is spreading to the informal education system, museums, afterschool classes, 4-H, and Women's Clubs, for examples. An indicator of this trend is the fact that 1988 ACS President Gordon Nelson decided this should be the major theme of his administration. He organized two Presidential conferences, "Chemistry in the Museum Environment", and the Board of Directors has allocated more than \$2.5 million for a 12,000-square-foot exhibit in the Smithsonian (*35*). Other science and technology centers across the United States are also becoming involved in this movement toward informal chemical education through exhibits, after-school classes, and weekend activity.

There is a nip in the air. This is a time of ferment and change. I predict that the Science and Engineering Education Directorate will continue to grow, that the public at large will continue to expand their understanding and awareness of the importance of science education to the nation's welfare and to family and individual progress, and that recognition of the value of teachers through improved salaries and status will grow. I predict that we will turn from a relatively isolationist view to one that looks outward at international chemical-based problems. The atmosphere is international and knows no boundaries. Neither does the hydrosphere. In addition, our cultures are highly diverse—the ebb and flow from nation to nation is so strong now (especially if one looks at new patterns of immigration from Southeast Asia, Latin America, and from Eastern Europe) that there is no longer any excuse for being parochial.

For true success, curricula must be local, national, and international, and fulfill all three dimensions. I see this occurring. I also see increased use of new data bases and electronic methods that will benefit teachers and provide professional development. There will also be greater effort in tapping the talent pool and toward giving women and the underrepresented equal opportunity in attaining scientific literacy and careers.

With so much to do, it is time that we shifted into a higher gear and moved thoughtfully but briskly to provide chemical education for *everyone*. It is too costly to the nation for individuals to remain undereducated in science and technology. It also denies individuals better living and better understanding. Change takes energy; ferment takes yeast. We as chemical educators can provide both to everyone's advantage.

Literature Cited

1. The National Commision on Excellence in Education. *A Nation at Risk: The Imperative for Educational Reform*, Stock No. 065-000-00177-2; U.S. Government Printing Office: Washington, DC, 1983.
2. Lewis, Jack. "Presidential Address", Royal Chemistry Society, Canterbury, England, April 1988.
3. Pimentel, George C. *Opportunities in Chemistry*; National Academy: Washington, DC, 1985.
4. Pimentel, George C.; Coonrod, Janice A. *Opportunities in Chemistry: Today and Tomorrow*; National Academy: Washington, DC, 1987.
5. Report of ACS Ad Hoc Committee on the High School Chemistry Course (Garrett Committee Report), American Chemical Society, Washington, DC, 1959.
6. *The CHEM Study Story*; W. H. Freeman: San Francisco, 1969.
7. *Chemical Systems*; Chemical Bond Approach Project (CBA): headquartered at Erlham College, Richmond, Indiana.
8. CHEM Study Film Series. Original, 1961–1964. Revised, 1989. Lawrence Hall of Science.
9. IAC Project Team, (Gardner, Marjorie; Heikkinen, Henry, Directors). *Interdisciplinary Approaches to Chemistry IAC*; Harper & Row: New York.
10. American Chemical Society. *Chemistry in the Community* (*ChemCom*); Kendall/Hunt: Dubuque, Iowa, 1988.
11. Lawrence Hall of Science. *Full Option Science Systems*; Encyclopedia Britannica, in preparation.
12. Lawrence Hall of Science. *Great Explorations in Math and Science* (*GEMS*); University of California: Berkeley, California, 1986–1989.
13. Lawrence Hall of Science. *Chemical Education for Public Understanding Project* (*CEPUP*); University of California: Berkeley, California, 1987–1990.
14. Borgford, Christine; Summerlin, Lee. *Chemical Activities: A Sourcebook for the Science Teacher*; American Chemical Society: Washington, DC, 1988.
15. Hewitt, Paul G. *Conceptual Physics*; Addison–Wesley; Menlo Park, California, 1987.
16. American Geological Institute. (Working title: *Earth Science*, in preparation.)
17. Chicago Museum of Science and Industry, Chicago, Illinois. Center of Science and Industry (COSI), Columbus, Ohio. Ongoing.
18. Lawrence Hall of Science. *Industry Initiatives in Science and Mathematics Education* (*IISME*); Univeristy of California: Berkeley, California.
19. University of Maryland and Annenberg Foundation. "World of Chemistry"; videotape series, 1987–1989.
20. International Report Card. National Science Teachers Association: May 1988.
21. Dreyfuss Institute; Woodrow Wilson Foundation. New Jersey. 1983–present.
22. Institutes for Chemical Education (ICE). University of Wisconsin–Madison, University of California–Berkeley, University of Maryland, University of Arizona, and Northern Colorado University: 1984–present.
23. High School Chemistry Institute, Hope College, Holland, Michigan, 1984–1988.
24. Mellon, Ed. Reactivity Network; Florida State University: Tallahassee, Florida.
25. International Chemistry Olympiad program. Education Division office. American Chemical Society: Washington, DC.
26. Otto, Rollie. Residence in Science and Engineering (RISE) Program. U.S. Department of Energy. Lawrence Berkeley Laboratory and other national laboratories: Berkeley, California.
27. Andreen, Brian. Research Corporation: Tucson, Arizona.
28. Society Committee on Professional Training (CPT), American Chemical Society: Washington, DC.
29. Orna, Mary Virginia. *ChemSource*. College of New Rochelle, New York.
30. Bowyer, Jane. Mid-career Mathematic and Science Program, Mills College, Oakland, California.
31. The Holmes Group. *Tomorrow's Teachers: A Report of the Holmes Group*; The Holmes Group: East Lansing, Michigan, 1986.
32. Carnegie Forum on Education and the Economy. *A Nation Prepared: Teachers for the 21st Century*; Carnegie Forum on Education and the Economy: Washington, DC, 1986.
33. *Doing Chemistry*; American Chemical Society: Washington, DC, 1987.
34. Herron, Dudley. "View from the Discipline", *Toward a Science of Science Education*; Erlbaum: in press for 1989 publication.
35. Leber, Eric, Smithsonian Fellow, the American Chemical Society: Washington, DC.