DOCUMENT RESUME

ED 328 405 SE 051 877

AUTHOR	Penick, John E., Ed.; Krajcik, Joseph, Ed.
TITLE	Chemistry. Focus on Excellence, Volume 3, Number 2.
INSTITUTION	Iowa Univ., Iowa City. Science Education Center.; National Science Teachers Association, Washington, D.C.
SPONS AGENCY	National Science Foundation, Washington, D.C.
REPORT NO	ISBN-0-87355-052-8
PUB DATE	85
CONTRACT	NSF-MST-8216472
NOTE	52p.; For related documents, see SE 051 874-878, ED 243 689-691, ED 281 723-724, and ED 301 408.
AVAILABLE FROM	National Science Teachers Association Publications Department, 1742 Connecticut Avenue, N.W., Washington, DC 20009 ($7.00).
PUB TYPE	Reports - Descriptive (141) -- Guides - Classroom Use - Guides (For Teachers) (052) -- Viewpoints (120)
EDRS PRICE	MF01 Plus Postage. PC Not Available from EDRS.
DESCRIPTORS	Biochemistry; *Chemistry; Critical Thinking; Demonstration Programs; *Excellence in Education; High Schools; *Innovation; Science Activities; *Science and Society; Science Curriculum; Science Education; *Secondary School Science; Teaching Methods; Technology
IDENTIFIERS	Project Synthesis

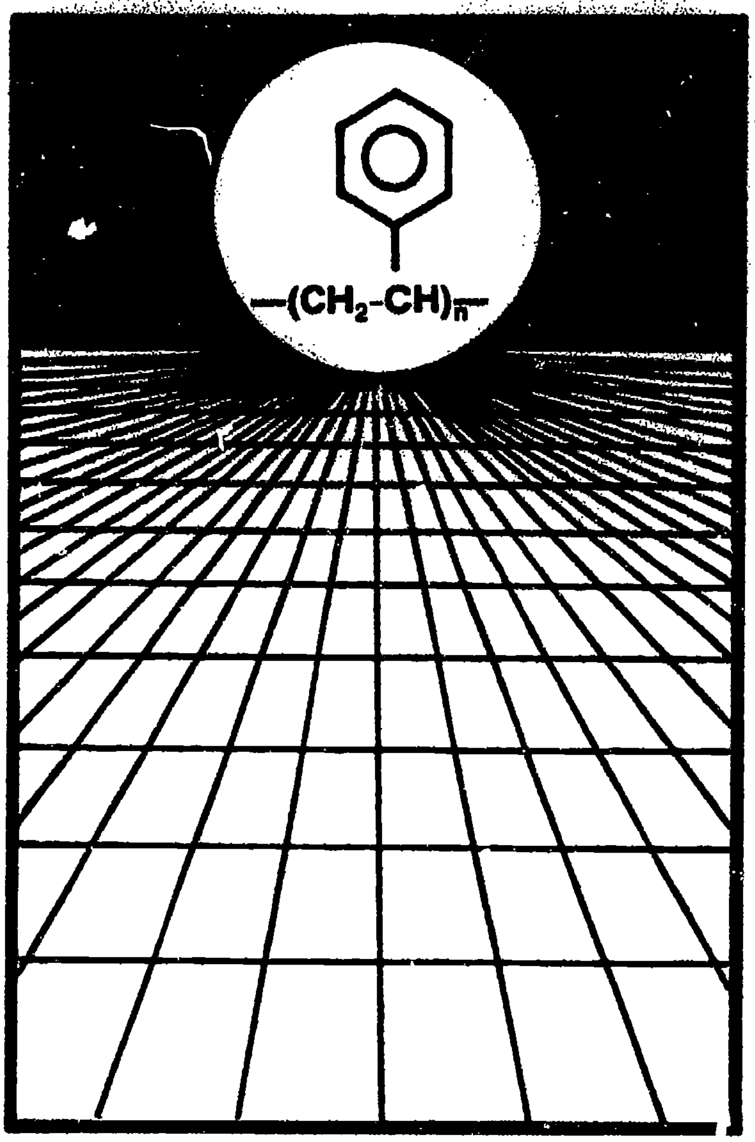
ABSTRACT

Eight examples of innovative and outstanding chemistry programs are described. These programs were selected using state criteria and at least four independent reviewers. While Project Synthesis offered a desired state, these examples of excellence provided views of what is already a reality. Included are the goals of an exemplary science program and the criteria for excellence. Programs described are: (1) "Chemistry for All"; (2) "Chemistry-Biochemistry"; (3) "Chemical Concepts Through Investigation"; (4) "High School Chemistry--An Equilibrium"; (5) "Using High-Interest Activities"; (6) "Chemistry: Three Courses, Five Levels"; (7) "Individualized Chemistry"; and (8) "Humor in Chemistry." An analysis of exemplars in chemistry is presented. (KR)

NATIONAL SCIENCE TEACHERS ASSOCIATION

FOCUS ON EXCELLENCE

Volume 3 Number 2



Chemistry

BEST COPY AVAILABLE

John E. Penick, Joseph Krajcik, Editors

Focus on Excellence

Chemistry

Volume 3 Number 2

Edited by
John E. Penick and Joseph Krajcik
Science Education Center
University of Iowa
Iowa City, Iowa 52242

Acknowledgments

We are indebted to J. Dudley Herron, Jim DeRose, Jan Harris, Henry Heikkinen, T.J. Kalous, and Ed Mellon for their insightful description of what an exemplary chemistry program should encompass.

Funding for the Search for Excellence in Science Education and the "Focus on Excellence" series has been provided by the National Science Foundation, the University of Iowa, and the National Science Teachers Association.

Volume 3, describing programs from the 1984 search, includes separate issues describing programs in:

Energy Education
Chemistry
Earth Science

The "Focus on Excellence" series, Volumes 1 and 2, included separate monographs on:

Volume 1
- Science as Inquiry
- Elementary Science
- Biology
- Physical Science
- Science/Technology/Society

Volume 2
- Physics
- Middle School/Junior High
- Non-School Settings

Other monographs reporting on the search for excellence include:

- Teachers in Exemplary Programs: How Do They Compare?
- Centers on Excellence: Portrayals of Six Districts
- Exemplary Programs in Physics, Chemistry, Biology, and Earth Science.

Monographs may be ordered for $7.00 each from:
NSTA Special Publications Department
1742 Connecticut Avenue, N.W.
Washington, D.C. 20009

This monograph has been prepared with partial support from the National Science Foundation (MST-8216472). However, any opinions, findings, conclusions, or recommendations expressed herein are those of the staff of the Search for Excellence project and do not necessarily reflect the views of the National Science Foundation.

ISBN Number: 0-87355-052-8

Table of Contents

Preface
The Search for Excellence in Chemistry Education

Chemistry! The word sparks images of test tubes, chemicals, and exciting experiments. Students see themselves making discoveries, learning little-known truths, and delving deep into the realm of science.

Like most fantasies, this isn't quite what happens. While the task force doesn't suggest this vision as the criterion for excellence in chemistry education, we do feel strongly that the eight chemistry programs described in this issue of the "Focus on Excellence" series have succeeded in making chemistry more exciting for students.

The National Science Teachers Association (NSTA) hopes that these descriptions and this monograph series will highlight alternatives to typical chemistry programs. These ten chapters should provide you with inspiration, ideas, and resources, as well as descriptions of successful programs. We hope that you will be stimulated by reading about them and will contact individual authors for more information. You might even wish to visit some of these innovative chemistry classrooms.

The NSTA Search for Excellence in Science Education began when Robert Yager, NSTA President for 1982–83, became a member of Project Synthesis. The project goal was to analyze more than 2,000 pages of information, three National Science Foundation (NSF) reports, and data from the National Assessment of Educational Progress.

Twenty-three Project Synthesis researchers worked in small teams, each focusing on one aspect of science education such as elementary science, biology, physical science, science/technology/society, or inquiry. They used synthesis and analysis to develop a description of an ideal state for a focus area and then compared the actual programs to it.

Leading science educators in each state (generally state science consultants) nominated outstanding science programs from their regions according to the criteria. The task force considered these nominations at the national level.

All nominees provided detailed information on demographics, texts used, the nature of the school, descriptions of their program, and examples of materials. In addition, nominees described five major aspects of their program:

- The setting, including community location, size, specific features, school science, and organization;
- The nature of the exemplary program as to grade, level, class size, curriculum outline, learning activities, and evaluation techniques;
- How the program exemplifies the criteria for SESE;
- How the program came into existence;
- What factors contribute to the success of the program, and what is needed to keep it going.

Chapter 1 describes criteria for Excellence in Chemistry Education; Chapters 2 through 9 offer descriptions of the eight programs selected as exemplary during the 1984 Search for Excellence. Chapter 10 is an analysis and critique of the ideas, descriptions, and realities taught in these programs. Along with this, we offer a number of generalizations and recommendations relating to excellence in science education for chemistry.

We hope you will use these examples of excellence to enhance your own chemistry program. This continuing NSTA monograph series is designed to help you.

—**John E. Penick**

Chapter 1
Ideals in Teaching Chemistry

J. Dudley Herron
James V. DeRose
Jan Harris
Henry W. Heikkinen
D.J. Kallus
Edward K. Mellon

NSTA Task Force On Excellence in Chemistry Teaching

Goals for teaching chemistry in secondary schools have been described repeatedly. Ideally, everyone would study chemistry. A major goal of public education is well-educated citizens, and one who does not know chemistry is not well educated. Since practical issues usually involve varied factual information, chemistry teaching must encompass knowledge of chemistry, the development of rational thought, and learning skills that will enable students to obtain information independently.

Ideally, chemistry teaching exposes students to career opportunities in chemistry and related fields. The necessary background should be available for those seeking careers requiring postsecondary education. However, technical skills should not be required of those who have little need for them.

This ideal state of chemistry teaching in secondary schools has not been reached.

Background

Project Synthesis, the model of this undertaking, identified four goal clusters and described actual and desired states of science education within those clusters. We have organized our thinking within that framework. The four goal clusters identified in Project Synthesis include:

- *Personal Needs* Science education should prepare individuals to utilize science for improving their own lives and for coping with an increasingly technological world.
- *Societal Issues* Science education should produce informed citizens prepared to deal with societal issues.
- *Academic Preparation* Science education should allow students who wish to pursue science academically and professionally to acquire the knowledge needed.
- *Career Education/Awareness* Science education should make students aware of the nature and scope of science-related careers.

Even though our task is to describe chemistry as it ought to be, we cannot proceed without giving some attention to how it is and what part of the "how it is" can be transformed into the "should be."

Project Synthesis made clear that virtually no attention has been given to personal needs, social issues, or career education in the existing science curriculum. The only goal taken seriously is academic preparation.

Project Synthesis emphasizes that science has a low status in the school curriculum; it is neither required nor elected as often as science educators would like. Enrollments are low, in spite of the obvious importance of science in our highly technological society.

An additional fact about the status quo that Project Synthesis apparently ignored is the serious shortage of well-trained chemistry teachers in secondary schools. Many chemistry classes are taught by ill-prepared teachers who necessarily stick close to the text and treat it as an infallible authority. The text represents a far higher level of expertise than their own, and they have little reason to question its correctness.

To describe the ideal state of chemistry teaching without reference to these realities can serve little purpose. Thus, we begin with some assumptions about what we are unlikely to change:

Assumption 1: Chemistry teachers of the future will come from the same pool drawn from at present. Most current chemistry teachers majored in subjects other than chemistry. This does not mean that they are ignorant of chemistry. Many biology or physical science majors have become fascinated by chemistry and have learned it on their own or gone back to school for more formal preparation. However, the fact remains that few chemistry teachers majored in chemistry as undergraduates. There are real differences in the attitudes, interests, and aptitudes of chemists and chemistry teachers.

There is little reason to assume that the public will fund education at a significantly higher level or that teachers will adopt a salary schedule that would allow chemistry teachers (and others in short supply) to be paid salaries competitive with industry. Therefore, many high school chemistry teachers will continue to exhibit only a marginal understanding of the field.

Assumption 2: Secondary school education will remain textbook oriented. Teachers do not believe that textbooks provide the best possible course; they rely on them because circumstances make it difficult to work otherwise.

Many chemistry teachers, with less training in chemistry than we or they would like, teach at least one other subject. Many teach two or three other subjects. This is particularly true in the sparsely populated western states and in the rural areas of other states. Some teachers teach five different classes and coach after school. Under these conditions one does well to survive. There is no time for developing a creative, individualized, inquiry-oriented laboratory course!

Assumption 3: Textbooks produced by commercial publishers will continue to be influenced more by market research than by pedagogical research. Publishers, as profit-making concerns, are necessarily more sensitive to economic considerations than to pedagogical ones. While producing what their market research suggests will sell, they will never be a major source of innovation.

Assumption 4: Financial support for schools (with few exceptions) will continue to limit the quality of chemistry programs. In many areas lack of funds for teachers' salaries, professional development, laboratory facilities, and expendable supplies limits the curriculum and discourages teachers. Financial support for schools is unlikely to increase enough to affect this situation.

Within this frame of reference, we will return to the four goal clusters identified by Project Synthesis and our statement about ideal chemistry teaching in secondary schools.

Goals Concerning Academic Preparation

Project Synthesis reports that only academic goals, those preparing students to take more science courses, are taken seriously in secondary science teaching. However, even here, we are far from achieving the goal.

In striving for the ideal in chemistry teaching, what content should be stressed? What is a sensible organization of the content? How can we develop the intellectual skills needed to analyze information?

As early as 1904, Moore complained that high school chemistry courses attempted to teach too many facts, failed to organize those facts into a sensible whole, and did not train students in the scientific method (Moore, 1904). Similar charges were leveled just before the post-Sputnik curriculum development (Pode, 1966). We still read that science courses are encyclopedic, that they stress memorization of isolated bits of information, and that the spirit of inquiry is foreign to most courses (Harms and Yager, 1981). The steady criticism over nearly a century does not imply a static curriculum. There have been changes. However, the changes have not solved the problem.

We assume that chemistry teachers should provide chemical facts and understandable theory, enabling students to make sense of what they observe and experience. If students know little about the continuous chemical events happening around and within us, there is nothing to make sense of. We must teach chemical facts so that students recognize those we are able to describe in the available time as merely representative of thousands that can be observed.

Here we encounter a dilemma. There are far too many important reactions to learn. Chemical reactivity is too vast to comprehend unless it is organized and generalized. The curriculum reformers of the 1960's recognized this and set out to impose the necessary organization that was missing in earlier texts.

We said that we must teach chemical facts and understandable theory. This goal is not always achieved. The ideas that are most useful and understandable to experts are not necessarily the most useful and understandable to beginning students; yet they are the ones that we are most likely to teach. These theoretical ideas are useful to experts in synthesizing vast quantities of chemical information. The temptation to begin instruction with a careful presentation of our most useful theories is apparently irresistable. The motives are commendable, but the results are chaotic.

The best understanding that we have now about the way we learn indicates that learning is a constructive process. We construct information internally rather than passively receiving intact knowledge from others (Johnson-Laird and Wason, 1977; Bransford, 1979; Anderson, 1980). This constructive process is idiosyncratic, depending on facts and our own intellectual skills. Theoretical notions that are perfectly transparent to a professional chemist can be hopelessly opaque to the beginner.

We cannot perfect our chemistry teaching until we consider how people learn. In general, we learn better when our efforts are purposeful, when we begin at a point close to past experience, and when we begin with observations and knowledge embedded in direct experience. We have problems with generalized concepts and theoretical ideas until there is enough information that we need to organize it into generalized categories and to relate one idea to another through hidden similarities. When we need such a theory, only those ideas that are personally meaningful can be used. Memorization of more powerful but incomprehensible constructs is pointless!

Introductory chemistry (at any level) must focus on observation and description of common chemical reactions and the subsequent rationalization of what has been observed in terms of simple models describing structural similarities among compounds with similar reactivity.

This leads to other questions: What reactions are most important to study? What models and theories are most useful for beginners? How far should one go? Because we want chemistry to be taught to all students—students who vary considerably in background, interests, and abilities—no general answer is possible. We can provide no better advice to those who design curriculum materials for a particular group of students than the four general criteria used in developing the CHEM Study materials:

- Is the idea so important that . . . [this] course is [in]complete without it?
- Can the idea be developed honestly at a level comprehensible to high school students?
- Can it be developed out of experimental evidence that high school students can gather or, at least, understand?
- "Does it tie into other parts of the course so that its use can be reinforced by practice?" (Pode, 1966).

Much of the content in existing textbooks might meet these criteria if it were organized differently, clearly noted direct observations close to student experience, and were reduced to a comprehensible size. What we try to include is important in itself. The problem is that we include too much. We don't leave enough time for students to organize the information and clarify important relationships. The problem is pervasive, important, and yet subtle.

Both textbooks and teachers often present chemistry as conclusions. There is only the faintest hint of how those conclusions were reached or how tentative many of them still are. "These are the facts. Learn them!" comes through loud and clear. A better message would be: "Based on observations such as those that you have made or can make, chemists have reasoned that thus and so must hold true. Does this seem sensible to you? If so, why? If not, why not?" This, it seems to us, is what the scientific method is all about.

The call for teaching science in the spirit of inquiry has been loud and persistent, but the response has been weak. We can't assume that chemistry teachers haven't heard the cry or suggest that they callously ignore it. There must be valid reasons why so little inquiry is taught.

Inquiry is tentative, and that sets poorly with adolescents. It calls for constant questioning, a consideration of all possibilities, a realization that new information can invalidate assumptions on which conclusions were built. The realization that all knowledge is tentative is somewhat frustrating to all of us, but it is particularly difficult for young people to accept (Perry, 1970). Most of us have tried to teach in the spirit of inquiry, only to have students ask impatiently, "Yes, but what is the real answer?"

Inquiry is a mixture of attitudes, values, and intellectual skills. Successful inquiry presumes knowledge, the ability to synthesize ideas into new and more complex patterns, and the ability to apply knowledge in new and unfamiliar contexts. Recent research on problem solving in science and mathematics indicates that experts bring to bear vast quantities of information and use a number of intellectual skills subconsciously. People who are good at inquiry are not always good at teaching others to inquire. We are only beginning to understand the intellectual skills commonly used in problem solving and to invent procedures for teaching those skills to others.

Because we are just beginning to understand inquiry, it is probable that many who teach the process have little skill in using it. They may lack knowledge of techniques to teach the skills and even be unable to model the inquiry process for their students. Our society clearly values the products of inquiry. Unfortunately, teachers often focus on transmitting the vast body of accumulated knowledge rather than on developing the skills used to generate and understand it. Despite limited success in the past and our lack of specific information about fostering development of rational thought, we offer the following recommendations for academic preparation in chemistry:

- Structure and reactivity should be emphasized.
- The number of topics should be drastically reduced, with far more attention given to the integration and explanation of the remaining ideas. We should point out relationships among chemical concepts and principles, as well as important connections between chemistry and other areas in students' experience. How an idea can be useful should receive as much attention as the idea itself.
- Application of concepts and principles in new contexts must be seen as evidence of learning, with less emphasis on recall of definitions and routine application of rules. Knowledge that cannot be applied has little value.
- The ability to apply knowledge in new contexts and to derive new knowledge independently are so important that every chemistry teacher should use all available resources to foster such development.

Goals Concerning Personal Needs

What are personal needs? A full belly, a dry head, love, and a sense of self-worth. What about understanding chemistry? Modern medicine is based on synthetic drugs, transportation depends on fossil fuels, synthetic fibers take the drudgery out of wash day, and chemical fertilizers promote abundant harvests. But those benefits are indirect. A few chemists can produce wonders for us all, and we need to know chemistry to enjoy the fruits of their labor no more than we need to understand music theory to enjoy a concert.

But consider another side of the analogy. Those who know music theory probably enjoy a concert more than those who don't. Likewise, those who understand chemistry are better able to appreciate the wonders of modern science. We would urge everyone to learn as much as possible about chemistry, as well as art, music, religion, mathematics, history, cooking, and all of the other knowledge areas than can enrich our lives.

No one knows what information a person will need in the future. Research on retention of factual information suggests that such information is unlikely to be recalled when needed, even immediately after instruction. In contrast, skills related to the interpretation of reading passages containing factual information, skills related to the organization of information, skill in using logical analysis to distinguish statements that are supported by data from those that are not, the ability to generate many possible outcomes or courses of action under a particular set of circumstances, and the ability to distinguish correlated events from those that appear to be related by cause and effect are skills retained over time. They satisfy personal needs in a complex technological society and thus should be stressed in chemistry and other subjects. Chemistry's major contribution to education for personal needs is the development of rational thought.

Goals Concerning Social Issues

We cannot assume that a student who interprets an experiment in the chemistry laboratory can and will apply these same skills when considering a referendum on school funding or waste disposal. To encourage the use of rational powers in a broad arena, we must provide opportunities to use those skills in many contexts. Underlying intellectual skills have broad application. Just as scientific thought processes do not automatically transfer to other knowledge domains, clear communication, careful computation, and social decision making do not automatically transfer from one subject to another. We must support cooperative efforts of chemistry teachers, English teachers, mathematics teachers, and social studies teachers. Integrated projects encourage the use of these important intellectual skills in the various classrooms.

Most social issues are complex. Even problems that are clearly related to chemistry (such as disposal of chemical wastes) are also economic, political, and/or moral issues. Chemists have no more to contribute to discussions of such issues than economists, politicians, or ministers.

Chemistry teachers must not ignore social problems; neither must they assume sole responsibility for them. Social issues, whether considered as part of the chemistry curriculum or elsewhere, require involvement of people with expertise in all facets of the issue.

Goals Concerning Career Education

When teachers know that they are not achieving their major goals of academic preparation, secondary goals such as career education are likely to receive less emphasis. Still, career education is important. The best way to provide it is to make career education the responsibility of those most concerned.

Professional and industrial organizations should insure that career opportunities are accurately described and made available to high school students. Such activities already take place, but could be improved through coordinated effort.

The High School Office of the American Chemical Society (ACS) and its local sections, industrial groups, and NSTA should cooperate to provide chemistry teachers with career information updates, salary information, profiles of young chemists working in nontraditional jobs, and names of speakers who could provide first-hand information concerning the various careers related to chemistry.

Other Concerns

The bulk of our paper has dealt with goals of chemistry teaching, because we believe ends are more important than means. While holding definite opinions about curriculum, instruction, evaluation, and teaching, we would agree to almost any arrangement that accomplishes our goals.

Curriculum

Evidence suggests that dedicated teachers who consider the interests, intellectual level, and educational needs of students are able to offer courses that attract students of varying interests and abilities to chemistry. However, in many schools chemistry attracts only students who are highly motivated, academically able, and science prone. The chemistry offered in such schools should be expanded to meet the needs of all students.

So long as you provide chemical education to a large portion of the school population, it is not necessary to confine it to a course called chemistry. There is nothing wrong with an integrated approach to the European pattern of offering chemistry courses for several years. This might mean scheduling one or two hours of instruction each week for the entire year, or perhaps 9- or 18-week courses could be offered on a rotating basis. In either case, spreading out chemistry instruction over several years would provide a better opportunity to develop complicated ideas and observe the development of intellectual skills over the high school years.

Whatever the pattern of presentation, there should be more chemistry instruction in secondary schools for average and below-average students. This instruction should deal with substantive ideas related to the experiences of the students, and the intellectual skills used to arrive at these ideas should be developed along with the ideas themselves. Students should not be given course credit until students demonstrate understanding of the basic ideas and utilize the fundamental intellectual skills associated with rational thought. Such understanding and skill development is well within reach of average high school students. We should not be satisfied until those goals are reached by a substantial portion of the population.

Instruction

We advocate no one approach to chemistry teaching. If a teacher can lead students to an understanding of interrelationships among basic concepts of chemistry, a knowledge of how those concepts apply to everyday experience, and an ability to apply the powers of rational thought to solve real problems through lecture alone, we may be awed, but we will not be upset. Our experience has been that one learns by doing, and that what we learn is influenced by how we learn.

Suppose a student is told that density is the ratio of mass to volume and shown that it can be expressed as $d = m/v$, then is asked to calculate the density of materials never seen from masses and volumes printed in a text. This student will arrive at a different understanding of density and of science than a student who is handed samples of pumice and granite and asked questions such as: What is the difference between these two rocks? How could you describe that difference quantitatively? How could you obtain measures on these samples to describe the property you observed? What good is a measure of this kind? What can it tell you about objects that is worth knowing?

There is a place for both kinds of activities, but some important educational goals are unlikely to be reached without activities like the second example.

Evaluation

Evaluation provides the key to success for any program.

No matter how we describe our objectives, students who want to succeed will concentrate on learning what we test. If integration of ideas and application of skills are our goals, they must be evaluated. If we expect students to transfer knowledge to problems they have never seen, we must test such transfer on a regular basis.

Some of our goals (those pertaining to the development of rational thought, for example) are likely to develop gradually over months or even years. Unless some procedure is established to observe progress over extended periods of time, teachers will become discouraged and lose interest in working toward such goals.

Writing good test questions to reflect higher level objectives is difficult. This may be one reason why even inquiry-oriented teachers may overemphasize recall of facts and application of algorithmic skills. However, it does not explain why so few textbook publishers provide teachers with excellent examination questions. By doing so they could contribute immensely to the quality of instruction.

In the past several years objective tests have achieved wide acceptance, and we applaud that development. However, the test format should be determined by the objective and not the other way about. In chemistry, students should learn to make sensible statements about chemical facts, but objective tests do not grade this ability. Some teachers will obtain ample evidence of such skills on laboratory reports, but essay exams, term papers, book reports, and oral reports of experimental work or library research are also valuable evaluation tools. We see no reason why such tried and true teaching devices should be used less in chemistry than in English or history.

Teachers

The teacher is the single most important factor affecting the quality of chemical education. We need the best we can get. We would be delighted if we could raise the standards for all chemistry teachers to that of the best in today's schools, but we do not expect that to happen as long as present salaries and working conditions persist.

Like other social issues, this one is complex. Since economic and political solutions must be found before we can staff all schools with outstanding teachers, we insist that solutions should be sought.

We believe it is possible to make substantial improvements in the education of chemistry teachers by consolidating resources. There are more than 2,000 colleges and universities in the United States that occasionally graduate chemistry teachers. None of these produce many, and it is not economically feasible to design special courses for prospective chemistry teachers. Consequently, very few chemistry teachers graduate from college with either the knowledge of chemistry or the teaching skills that they should have and could have if there were a program designed specifically for them and staffed with the best chemical educators in the country.

Science education should move in the direction taken by the medical profession after the Flexner Report: marginal programs should be closed, resources should be concentrated in a few institutions, and students should be given financial support to attend these special programs. If this bold step were taken, and if we absolutely forbade the teaching of chemistry by anyone who failed to meet the standards achieved by graduates of such special programs, we still might not reach our desired state of chemistry teaching in secondary schools, but we believe we would come much closer.

Summary

In summary, the desired state of chemistry teaching in secondary schools will have the following characteristics:

- Chemistry will cease to be taught only as a college preparatory course for bright students headed for science-related careers. A broad program of instruction in chemistry will provide appropriate education for students of different abilities and varied interests.
- Chemistry instruction will focus on observation and description of common chemical reactions. This would lead to tentative explanations, using simple models to describe structural similarities among compounds that exhibit similar reactivity.
- The number of topics covered in secondary school chemistry courses will be drastically reduced. Far more attention will be given to the integration of remaining ideas; the interconnections among the concepts and principles of chemistry should be clear, and important connections between chemistry and other areas of the students' experience will be stressed.
- Far less emphasis will be placed on routine application of rules and technical skills, recall of definitions, and memorization of theoretical models. More emphasis will be placed on description of common chemical changes and the use of simple structural models to explain chemical change. As a rule, only those theoretical constructs and mathematical models needed to explain the chemical phenomena that students have observed and wish to have explained will be introduced.
- Intellectual skills will be developed, enabling students to make rational decisions about complex issues. Habits, attitudes, and skills needed to learn independently through informal education will be stressed.
- Class assignments, laboratory activities, and evaluation procedures will reflect the emphasis on the development of intellectual skills.
- A variety of text materials that are pedagogically sound, scientifically accurate, and appropriate for students of varying abilities and interests will be available to teachers.
- Complex social issues will be considered as part of the school curriculum, and provisions will be made to involve persons with expertise in the various disciplines that relate to those issues.
- Professional organizations and industrial groups will routinely provide teachers with information about career opportunities related to chemistry.
- Salaries and other inducements will be provided to attract outstanding individuals to secondary school teaching.

References

American Association for the Advancement of Science and the American Association of Colleges for Teacher Education. (1960). *Improving science and mathematics programs in American schools.* Washington, DC.

American Chemical Society. (1967). Conference agrees on high school needs. *Chemical and Engineering News, 45,* 159-164.

Anderson, J.R. (1980). *Cognitive psychology and its implications.* San Francisco: Freeman.

Bransford, J.D. (1979). *Human cognition: learning, understanding and remembering.* Belmont, California: Wadsworth Publishing Company.

Flexner, Abraham. (1925). *Medical education: A comparative study* New York: The Macmillan Co.

Harms, N.C., and Yager, R.E. (Eds.). (1981). *What research says to the science teacher.* Vol. 3. Washington, DC: NSTA.

Johnson-Laird, P.N., and Wason, P.C. (Eds.). (1977). *Thinking: Readings in cognitive science.* Cambridge, England: Cambridge University Press.

Larkin, J.H. (1981). (1979, December). Processing information for effective problem solving. *Engineering Education,* pp. 185-188.

Larkin, J.H. (1981). Understanding in problem-solving in physics. In J.F. Robinson (Ed.), *Research in science education: New questions, new directions* (pp. 115-130). Columbus, Ohio: ERIC Clearinghouse for Science, Mathematics, and Environmental Education.

Lippincott, W.T. (Ed.). (1981). *Source book for chemistry teachers.* Washington, DC: Division of Chemical Education, American Chemical Society.

Moore, R.B. (1904). *A chemistry laboratory,* Philadelphia: J.B. Lippincott.

National Science Foundation and Department of Education. (1980). *Science and engineering education for the 1980's and beyond* (NSF 80-78). Washington, DC: U.S. Government Printing Office.

National Society for the Study of Education. (1960). *Rethinking science education.* Chicago: University of Chicago Press.

Newell, A., and Simon, H.A. (1972). *Human problem solving.* Englewood Cliffs, New Jersey: Prentice-Hall.

Perry, W.G., Jr. (1970). *Forms o' ',tellectual and ethical development in the college years.* New Yor'. Holt, Rhinehart and Winston.

Pode, J.S.F. (1966). CBA and CHEM Study: An appreciation. *Journal of Chemical Education, 43,* 98-103.

Reif, F. (1?82). *How can chemists teach problem solving? Suggestions derived from studies of cognitive processes* Paper presented at the annual meeting of the American Chemical Society, Las Vegas.

Chapter 2
Chemistry For All

Angie L. Matamoros
Coral Springs High School
7201 West Sample Road
Coral Springs, Florida 33065

Coral Springs, a rapidly growing city in the northeast area of Broward County, Florida, is home to over 50,000. Coral Springs High School, one of two high schools in the city, enrolls 2,500 students in grades 9–12. We have a mixed student body in terms of ethnic background, ability level, and vocational orientation. Students come from the north and southeast parts of the city and from smaller surrounding communities, generally from average to high income families. As we are located only 15 miles from the main campus of Florida Atlantic University (FAU), about 60 percent of our graduates go on to college.

We want chemistry to influence every possible student in our school and to reach students with all types of academic backgrounds and ability levels. In designing the program, we took full advantage of the resources of the industrial and business community and of nearby FAU.

Our Program

To reach students coming from varied backgrounds, we provide an exciting and innovative laboratory-oriented approach to the study of chemistry. The program is unique, can be transported, enjoys great success, and includes relevant contemporary topics. In any school where there is an established chemistry curriculum, you can adopt the main aspects of our program with only small modifications. Providing appropriate and challenging courses for students with little prior interest in science or mathematics is essential to the goal of Chemistry For All. We also have relatively advanced courses for determined and eager science students. Our solution to the challenge of meeting all these needs is a four-level program. A brief description of three of our levels and a more extensive review of our most advanced course should give you an adequate impression of our total program.

Number of Classes	Course Name	Text Title	Number of Students	Immediate Goal
5	Consumer Chemistry	*The Chemical World, IAC Modules*	150	2-yr. college, allied health area, and anyone interested
4	Chemistry I	*Chemistry: A Modern Course*	120	4-yr. college, liberal arts major
2	Advanced Chemistry I	*Chemistry: Experimental Foundations* (CHEM Study)	50	4 yr. college, in science, eng., pre-med, nursing
1-2	Organic Chemistry	*Organic Chemistry: A Brief Course*	25-40	4-yr. college, in science, eng., pre-med, nursing

Consumer Chemistry

This science literacy course was designed for the student who has not done well previously in mathematics or in abstract quantitative reasoning. Major course objectives include providing students with a general understanding of chemistry and its role in their lives and stressing a rich and widely diversified laboratory hands-on program in a warm and accepting atmosphere.

This new course, started in September 1981, has rapidly grown from two sections to six. Although most students taking this course are academically in the lower half of the junior and senior classes, 92 percent of those enrolled have met with success. The four instructors associated with the program in the last three years feel a very strong responsibility to develop scientific literacy, confidence, problem solving, safe laboratory skills, a humanistic outlook, and the belief that chemistry is truly a "new subject."

Relevant topics are discussed, preparing the students to apply science as informed citizens. Students become very proficient in laboratory skills. They calculate percent composition of a mixture, such as percent water and fat in hot dogs and percent protein in various brands of milk. Class results are plotted and discussed routinely. Students master graphing techniques, data interpretation, and statistical presentations of data. Adults need these skills in order to be wise decision makers. In consumer chemistry students study foods and food additives, pharmaceuticals and drugs, nuclear energy, plastics and polymers, environmental chemistry, agricultural chemistry, and the chemistry of home care and personal products (cosmetics).

Chemistry I

In this college preparatory course for the liberal arts student, we place strong emphasis on developing a qualitative understanding of chemical concepts. As in all of our courses, laboratory work is a major part of the program. Approximately 25 laboratory experiments are performed by students and, in addition, many teacher demonstrations are an integral part of this course. We do not stress memorization, and testing is biweekly.

Relevant and applied topics are favored, especially in laboratory work, where students titrate samples of vinegar and household cleaners brought from home and explore the chemistry of air and water pollution by determining percent lead found in soil samples. As in the Consumer Chemistry Course, over 90 percent of the students in the program have met with success.

Advanced Chemistry I

This program is offered to juniors and high-ability sophomores with strong mathematical backgrounds who are interested in a career in the sciences, engineering, mathematics, or medicine. It provides a more theoretical, yet still lab-oriented, approach. Advanced topics such as chemical kinetics, thermodynamics, redox systems, and electrochemistry make the course academically rigorous. We require students to complete an experimental research project and over 35 lab activities, including making esters and qualitatively analyzing unknowns. Students in this course compete in local, county, national, and international science fairs and talent searches. They have compiled an impressive winning record. Their superior scores both in advanced placement and chemistry achievement tests indicate the success of this aspect of our chemistry program.

Organic Chemistry

The second year advanced program, concentrating on organic chemistry and research, is the only one of its kind in Broward County and possibly in the state of Florida. Organic chemistry frequently is a traumatic experience for college students. Prospective biology and chemistry majors, premed, predental, prevet, engineering, and allied health professionals (psychology, agriculture, and home economics) often find that this required subject represents the biggest hurdle in successfully completing their majors. Many medical schools use student performance in organic chemistry as a measure of the analytical ability they seek in their prospective students. Given the rigorous nature of our advanced inorganic program, we felt that a second-year program focusing on organic chemistry would be more useful to our students than another year of inorganic chemistry.

The organic class, a one-year junior-senior level advanced program, is taught in a manner as close to a college course as possible. Its prerequisites are first-year chemistry and instructor approval. The class is scheduled the last two periods of the school day, alternating with advanced physics. The research portion of the course is team taught with the physics instructor, and a flexible schedule allows labs that are two or three hours long. Participating students leave campus whenever their research demands they go to a nearby university, community college, or industrial facility.

One of the primary goals of the program is to expose students to a college-level approach to teaching. Students are expected to make good use of time and to schedule most activities themselves once they receive a course syllabus. Most general assignments are neither collected nor graded (as in a typical college course). We accept only students who are capable of self-motivation, have adequate academic preparation, can utilize abundant free time wisely, and have demonstrated an inquisitive attitude, a great deal of maturity, and an interest in scientific knowledge.

A variety of written materials are available for student use. These include college texts such as Morrison and Boyd's *Organic Chemistry*. The course provides a comprehensive overview of many of the traditional topics covered in a college-level organic course. Many of the major concepts taught in inorganic chemistry are reviewed and reinforced in a new organic context. Bonding and hybridization of carbon, the stereochemistry of organic species, nomenclature, and the reactions of major functional groups are introduced. Oxidation of alcohols, aldehydes, and ketones provides a review of balancing redox systems. The study of carboxylic acids and their derivatives serves as a review of acid-base equilibrium, buffers, and acid-base indicators. Kinetics are reviewed through a treatment of major organic reaction mechanisms.

Extensive laboratory work allows our students to become familiar with refluxing, distillation, recrystallization, extraction, chromatography, and synthesis techniques. For example, students isolate caffeine and cholesterol, perform TLC analysis of analgesic drugs, and synthesize aspirin, soap, common esters, and polymers.

The research project allows each student to locate, research, and develop a project in an individually chosen science area. This project requires explicit training in the use of library materials and research statistics. Students gain the "know-how" of perusing scientific literature, writing a report, and presenting and defending a scientific paper. They develop the experience and confidence necessary to enable them to walk into a lab, plan their attack on a research problem, familiarize themselves with new instrumentation and procedures, and make steady progress toward its solution.

Scientific research demands much more creative activity than the mechanical manipulation of laboratory work. Research and development have a direct influence on the growth and productivity of American industry. Our students have a first-hand opportunity to experience a glimpse of the excitement of research. They often carry out at least some of their experimental work in a nearby university facility or an industrial or medical complex.

Field trips to local industrial plants provide first-hand knowledge of "chemistry in action" and are an effective teaching tool as well as a motivational activity. We try to include at least two such visits during the year. Companies have generally been cooperative, improving their "show" from year to year.

Students are encouraged to enter science fairs, local, state, and national competitions such as the Westinghouse Science Talent Search, the JETS competitions, and the ACS Chemathon. They become active members of the school's Science Research Club, serve as judges in the elementary school fairs, and present special "chemistry shows" to local elementary schools.

Students' grades are based on their lab work, class participation, homework, quizzes, and chapter tests.

Classroom Design

With the exception of a few formal lectures, students are free to organize their work as they see fit. They are given a syllabus containing the due dates for all laboratory and reading assignments at the start of each grading period. An experiment listed for a particular week could be done any day that week or the next, as long as the product or write-up is turned in on time. Students plan their research and lab work to fit their needs. The ability level of the students and the two-hour time block allow us to cover material faster and yet more effectively than would have been possible in a conventional setting.

The instructor acts as a consultant, helping with problems encountered in lab procedures or in the research process. Informal small-group discussions are common. Peer teaching from students who have already completed a particular lab procedure or assignment is very helpful and effective in reinforcing information that students have learned.

Diversity characterizes this type of classroom structure. Some students may be doing the paper chromatography of food colors while others separate indicator dyes through the use of a packed column. Those who have made previous arrangements may be at nearby FAU or at a local optometrist's office working on some aspect of their research. Worksheets and lecture topic materials are handed out periodically, with the instructor providing individual help during the day and after school. Tutorials as well as drill and problem solving software for three Apple IIe computers are available for all the major organic families. Copies of *Discovery*, *Scientific American*, and *Chemical and Engineering News* dating back several years are on counters around the room, along with a fairly extensive collection of chemistry and biology reference material. Students have free access to all of these.

Each lab group pair is assigned a glassware kit and a tote tray containing all of the additonal glassware and equipment needed in the course, including a Thermowell electric heater and Powermite control unit, since the use of an open flame is prohibited in the organic lab. This equipment is properly labeled and stored on shelves around the room. Chemicals on carts or tote trays are labeled with experiment numbers so that materials may be returned properly. Reagents are kept available for the class by lab associates—students who have already taken the course and receive an elective science credit for assisting students, preparing solutions, and setting up labs.

The laboratory component of the course has been greatly enhanced. Two-hour time periods are now available for lab procedures without disrupting other classes and without the need for students to remain after school in order to finish a lab. However, an after-school open-lab policy gives students the opportunity to make up absences and experiments which just did not work the first time around. (A common occurrence in organic chemistry!)

Finally, the team teaching approach provides an opportunity for one instructor to be available some time each week for individual consultation and for making necessary contacts with outside resources. For example, in the last two years we have assisted students in locating, requesting, and receiving materials from at least ten major governmental agencies and industrial concerns across the nation, in addition to the many materials obtained locally.

Evaluation

Many of our students perform well in advanced placement, achievement, and CLEP exams in chemistry. Others enjoy great success in their college chemistry courses or exempt freshman and sophomore chemistry at institutions like Wake Forest, Brown, Wesleyan, and Rensselaer. An unusually large number of our students have pursued careers in science, medicine, and engineering. Letters from theses students indicate that the organic course was of great help to them.

Coral Springs High organic chemistry/research students have generated a tremendous amount of public relations for the school, the science department, and the chemistry program in local newspapers and school publications as a result of their outstanding performance in science competitions. Here are the highlights of student and program achievements:

- A top 40 Westinghouse Science Talent Search winner in 1983 and a $500 scholarship. (First top 40 winner in 13 years for Broward County)
- Seven Westinghouse Science Talent Search Honors Group winners. Three of the seven were offered full tuition college scholarships.
- A $500 grand award winner at the International Science and Engineering Fair in the area of biochemistry in 1981. Two more students attended the 1984 International Fair in Columbus, Ohio.

- Six first-place awards out of 11 categories at the 1983 Regional Science Fair. Nine of the 22 students representing Broward County at the 1983 State Science Fair were CSHS students.
- A first-place winner in chemistry at the State Science Fair in both 1983 and 1984.
- Four of four first-place winners at the Regional Science Talent Search in 1983. First-place winner in physical science (chemistry) at the State Science Talent Search in 1983.
- Overall winner in the physical science category at the Broward County Youth Fair in 1983 ($100). Overall winner in Science Division (chemistry project) at the Broward County Youth Fair in 1984 ($500).
- $1000 Pembroke Pines Hospital Scholarship for Outstanding Project in Health and Medicine in 1983, 1984, 1985.
- A first-place winner in every science category (eight) at the 1984 Broward County Youth Fair.
- Eight out of 12 first places and six second places at the 1984 Regional Science Fair, including best of show and runner-ups in both the biological and physical sciences. Twelve of the 23 students who represented Broward County at the 1984 State Science Fair were CSHS students.
- Over $28,000 in scholarships, cash awards, and grants have been received by students involved in the organic/research program in the last three years alone.
- Both teachers directly involved in the program have received extensive recognition at the local, state, and national level.

Areas of Concern

Although the program has been successful, there are some specific areas of concern which need to be addressed:

- The inquiry approach demands many hours of planning and preparation time, as well as an extensive background in laboratory work on the part of the instructor.
- The potential for safety hazards associated with many organic procedures is a definite concern, and adequate training of students in safe organic lab techniques should be a first priority. Laboratory facilities must be functional; adequate equipment and supplies have to be available. Poor facilities and inadequate supplies would severely hinder this type of program.
- With the extensive curriculum that must be covered, we have little time to discuss the many social issues created by chemical and technological developments. Whenever possible, students are made aware of these concerns to stimulate further thought and investigation.
- Because the success of this program depends so much on the effective use of community resources, we spend much time identifying key personnel and facilities in business, industry and the academic community. In the last three years the local Coral Springs business and industrial community donated over $3,500 to provide scholarship and cash awards to students in the program.
- Because of the complexity and potential safety hazards associated with many organic lab procedures, careful screening of prospective students is necessary.

A Concluding Thought

Our entire program is based on the philosophy that a successful experience will make that student a chemistry advocate who in turn will help sell chemistry to others. My classroom is open, spontaneous, and adaptable to change. I try to be warm, flexible, and humorous, and to communicate to my students an excitement for the subject matter that goes beyond the content itself. This philosophy of fun, hard work, and academic excellence is greatly responsible for the success of the organic chemistry course at CSHS. It is also responsible for the success of the consumer chemistry class and the rest of our program. I consider it essential to the successful implementation of the course.

Chapter 3 Chemistry–Biochemistry

David C. Tucker
Mount Baker Junior–Senior High School
Box 95
Deming, Washington 98224

To the east, pasture lands and berry fields slope into the Cascade foothills where the giant Twin Sisters mountains pierce the sky at 6,800 feet. To the north, Mt. Baker, the most northerly peak in the Pacific "Ring of Fire," emerges from clouds and mist. Its glaciated slopes are forested with Douglas fir, cedar, and western hemlock, while its streams feed the Nooksack River which curves close to our school before flowing gently on in a great arc to Bellingham Bay.

In such an inspiring setting our students at Mt. Baker can observe the forces of nature at work. Their surroundings compel them to ask the fundamental questions: What is the world made of? What is my relationship to this world? How can humans live in harmony with nature?

Come visit our school, where tradition is as solid as our river and mountains. Walk under the big leaf maples into the old brick building, built in 1926. On the long walls of one corridor hang photographs of each graduating class.

Our facility has grown since 1926 into a campus school complex with a fine library and modern buildings for horticulture, music, art, home economics, and the sciences. We have a new fieldhouse, a dome enclosing an indoor track, and satellite rooms. Our field house offers the best weekly entertainment for miles around, a tradition with the Deming folks who support their student atheletes.

The school, with 200 miles of bus routes and 400 students, is the heart of a great network. Many students sport logger boots and red suspenders, evidence of the primacy of forest occupations here. Some work at Carol's Coffee Cup, saving their tips for college expenses. Their parents—loggers, ranchers, small farmers, dairymen, berry growers, and city commuters—are drawn to the school, the only institution that affects everyone. Their support is the strongest tradition in our school district.

Regardless of what lies ahead, the students of Mt. Baker High School today will be the voting citizens and adults of tomorrow. Some will graduate from college with professional degrees. Many more will graduate from high school, perhaps terminating their formal education with courses at a local community college or vocational/technical school and enter the job market. Some will choose the occupations of their parents, and some will drop out of high school. But these students, regardless of their future occupations, will live and work in a world filled with science. I impress upon them that understanding and applying science are vital for successful living. If this is properly accomplished, science education will pay dividends ten times over.

I work to help my students improve their logical thinking and decision-making skills. To accomplish this, I offer a course that is not restrictive, and I work to keep students in the class. Michael B. Leyden, in an article in *The Science Teacher* (March 1984), says it quite correctly. "The problem with most science classes today is that many of the best problem solvers are the kids we won't let take science. They are the noncollege-bound students who aren't smart enough to take such hard courses as chemistry and physics and are put into such 'menial courses' as auto mechanics and home economics." Many science courses have filtered out average and below-average students through teachers' academic sophistication. Similarly, many high-ability students are not scientifically literate for the same reason. While it is true that the more intelligent person can handle more abstract material, the question is, "What should high school teachers really attempt to accomplish?" I do know that if we expect students to become scientifically literate, we will have to teach scientific literacy.

Mt. Baker High School is the only school in the Mt. Baker School District. For that reason we do not have to be concerned with a district-wide program. The junior high school science program consists of one-year, activity oriented courses at the 7th and 8th grade levels. We attempt to infuse as many of the successful characteristics of our chemistry program into these areas as possible. The biology program is also being designed with exemplary characteristics in mind. The biology teacher, Don Shepard, has played a vital role in establishing the proper base for future success in science classes.

The chemistry program at Mt. Baker Jr.-Sr. High School is an interdisciplinary, career-based, activity-oriented experience in science that students enjoy. The career-based nature of the course allows students to practice decision-making skills at an important stage of their maturation. The course stresses applications of chemistry as well as the impact of chemistry on the environment. Societal issues concerning chemical processes are emphasized to insure that the student finds a place in a scientific world.

Resources

The chemistry/biochemistry course has been developed over a period of 10 years, allowing a variety of resources to develop. Reading materials include newspapers, journals, and pamphlets, as well as textbooks. Our proximity to a regional university allows us to obtain materials and equipment for experiments that would otherwise be impossible to conduct. A range of community members and individuals from local service and product oriented businesses serve as guest speakers and resource people. For example, the Northwest Air Pollution Control Authority has provided valuable help and materials in establishing an air quality monitoring system in the school district. Our laboratory consists of the entire geographical area of Whatcom County. We have studied the various soils, the lakes, Puget Sound, Nooksack River, streams draining the crater of Mt. Baker, and its adjoining glacier ice. In addition, my undergraduate training in chemical engineering allows me to approach problem solving, applications, career awareness, and technological innovations from a variety of perspectives.

Our Goals

I make chemistry available to all by grouping students according to ability. For the most part, students entering chemistry find a comfortable, nonhostile class environment. The course has been designed to be relevant, useful, and comprehensible. We are concerned about maximum appeal and purposely try to avoid frustration. This element of frustration runs deep in high school science education. Think of how many comments you have heard about science being too complicated, too abstract, or too detailed. We have not taken the hard work out of science at our school. We simply start with the philosophy that all students should be taking science and that science can be taught in a positive environment. Once this atmosphere becomes apparent to the students, we can accomplish many objectives.

Secondly, I believe I have a responsibility to help students become intelligent voters, knowledgeable consumers, environmentally conscious citizens, and long-range goal setters. I am convinced that a two-year program is needed to achieve these objectives. Our second year of chemistry is really a blend of biology and chemistry, so much that we are really offering a three-year, interdisciplinary program in chemistry and biology.

The most important goal of any high school science program should be scientific and technological literacy. Many teachers say we need to prepare the students for college chemistry; this is a fallacy. We do need to teach them some mathematics skills, but most importantly, we need to give them an interest in science and a nonthreatening attitude about science. Interest can carry them far. Looking at science topics and the way these topics are covered in college, I seriously doubt that high school science could prepare students adequately. The old saying, "We have to study this now because you will need it later," has no basis in fact.

The primary goal of any science course should be to meet the needs of the students who take it. We are intent upon improving scientific and technological literacy, consumer awareness, career motivation, and environmental consciousness. We want to:

- Help students become intelligent citizens in our society so that democratic processes and ideals can be perpetuated.
- Help students develop a love of learning that will last for a lifetime.
- Help students develop decision-making strategies that will insure future success.
- Help students acquire strategies to cope with a rapidly changing world filled with many choices.
- Provide part of a broad and flexible high school education necessary for a scientific/technological world.
- Help students become aware of career options, social issues, and applications related to chemistry.
- Provide prerequisite academic information for students who contemplate careers in science.

Description of the Program

In first-year chemistry, the content begins with elements and compounds. We break down the compounds to develop atomic theory. We use the atomic theory to establish a scale of atomic masses and discover the rules of stoichiometry. Side excursions are taken to gases, liquids, and solids. Next, we explore solutions. We backtrack to discover the order of atoms and the periodic law, as well as atomic structure. Bonding is covered in these last two units. We finish the first year with solution dynamics by studying thermochemistry, kinetics, equilibrium, and acids and bases. The last unit explored is oxidation and reduction.

Practical applications are embedded in all of the units to stimulate interest and keep the topic understandable. For example, during the unit on gases we measure the percent of oxygen in air and study various forms of air pollution. We determine the air quality of Whatcom County experimentally, with the Northwest Air Pollution Control Authority providing valuable assistance. This is an ongoing class experiment that, over the years, has provided data needed to spot long-term trends. Another example in the solutions unit is our local water quality experiment. Much like the class experiment on gases, we determine the local water quality of our individual drinking sources and of the Nooksack River that flows through the district. This study has been valuable to the local Whatcom County Health Department in providing base-line data for the river. In my 14 years of teaching here, many new homes have been built along the river. The continued monitoring of the water quality gives the students a visible appreciation of long-term pollution.

Various teaching strategies help students learn. In the unit on gases, students organize into groups with the purpose of developing a plan of action to solve a local air pollution problem. In the unit on liquids, a panel discussion is organized consisting of a number of local water users to examine conservation methods and potential pollution sources.

In second-year chemistry, I use the foundations of first-year chemistry (and biology) to accomplish a valuable goal: awareness of life in a chemical world. Study begins with hydrocarbons, hydrocarbon carcinogens, and explosives. Next we study alcohols and alcoholism, followed by chemical and biological warfare and poisons. The next unit explores pesticides and insect attractants. We then study esters, acids, soaps, and detergents. The organic bases (amines) and amino acids follow next. We have a strong unit on polymers, a short unit on photochemistry (chemiluminescence), and then an extensive unit on drugs. We conclude our study with enzymes and nucleic acids. These topics have an obvious connection to other aspects of the students' lives. We take advantage of this by emphasizing societal issues and controversial aspects of these topics.

Regardless of the importance of science in our society, my objectives cannot be accomplished unless the students have a personal understanding of the value of science. Students will care about what they do in the classroom if it is relevant or useful after they leave school. One way a teacher can successfully convey the relevance of science to society is to help the students improve their long-range goal setting and decision-making capabilities. I do this through career awareness.

Nationwide statistics clearly show a problem in American schools. Out of 100 students who enter junior high school, 5 drop out before high school; another 17 drop out of high school and, of the 78 who do graduate, 43 go directly to work. Of the remaining 35 students, only 10 will graduate from college. And yet many science classes are structured to serve only the needs of the college-bound science minority. We must prepare all students for a science-filled world.

The Comprehensive Career Education Model (CCEM) developed at Ohio State University defines eight elements that can be infused into the curriculum of any subject area:

- Development of knowledge and appreciation of a variety of occupations;
- Improvement of self awareness;
- Improvement of decision-making skills;
- Improvement of education awareness;
- Improvement of career awareness;
- Improvement of economic awareness;
- Identification of beginning competency skills;
- Improvement of employment skills.

Career education techniques can be added to a science program by changing the direction of assignments and activities. Developing a career-oriented unit in place of a knowledge-based unit is limited only by the interest and energy of the teacher.

At the beginning of the school year all students complete an interest inventory consisting of items related to job preference, likes, dislikes, and choices. We discuss these in class. Through this process the students find out a lot about themselves. The class then develops a questionnaire to be used when guest speakers visit the class. The questionnaire includes items related to job satisfaction, working conditions, education, salary, and feelings. It is important for discussion to take place at this point. Because of the real-world science emphasis in the program, resource people are unlimited. We sample careers ranging from carpenters to chemical engineers. Field trips also provide onsite opportunities.

I distinguish between two learning modes: active and passive. Students become truly interested in a class when they are participating actively. Students can perform classroom demonstrations or experiments just as effectively as the teacher. All that is required is a little preparation by the student and a schedule to show when these activities are to be performed. Of course, teacher help is needed. The same idea can be used to handle some important topics within a unit. Instead of the teacher "telling" everything, short reports by students accomplish the same goal. Students learn from their peers. One of the most effective teaching strategies I use is the "problem" or "mystery" approach with lab experiments. The students continually try to identify and solve problems.

Reading lists should be flexible, both for credit and extra credit. I have substituted book reports for some hour exams.

Lists of discussion questions should be handed out at the beginning of a unit and include such questions as: Why do you think . . . Predict what might happen if . . . What should we do . . . Organize the data to . . . .

Students are graded on tests, homework, experiment write-ups, quizzes, report summaries, question sheet handouts, and skill papers, as well as effort and attitude. There are numerous possibilities for extra credit or alternative credit. By far the most important element in the grading scheme is the experiment write-up. Logical thinking, creative thinking, skill development, mathematical usage and manipulation, as well as writing skills and scientific process skills, are measured. I give unit tests, and a final exam. All students are required to keep a notebook consisting of handout sheets for each unit. This unit is graded while the unit exam is being taken.

Classroom Design

Our chemistry facility is fairly typical. There are seven lab stations around the perimeter of a large room. The facility was constructed in 1982 with the idea of maximum flexibility. Each year we seem to have a few independent students working on advanced projects. With this idea in mind, two satellite rooms are equipped with a lab station, gas, and water. One other satellite room is our resource reference library where supplemental texts, journals, etc., are located. There are common prep and storage areas between the chemistry and biology rooms. Eventually this area will also have to serve as a computer center for science.

Equipment for the second-year chemistry program is also standard. We do a number of experiments that require more sophisticated electronic equipment at WWU in Bellingham.

Evaluation

Our program provides superb instruction to reach the goal of science and technological literacy but it also relates science to human affairs. We devote considerable time to examining societal issues related to chemistry. Mostly we do this by reading newspapers and holding debates or panel discussions in the classroom. Students have often commented that they have an increased awareness or familiarization of issues presented in the news media.

Another indicator of success is the popularity of the program. At Mt. Baker we have a four-year sequence of courses beginning with biology, then chemistry, biochemistry, and physics. We counsel 80 percent of the 9th grade students into biology. We are getting about 70 percent to 80 percent carryover from one year to the next. This means that about 40 percent of the entire high school population is taking four years of science. Considering that we are a small school (400 enrollment) in a semirural setting, these statistics are positive. I might add that just because we are small does not mean that students are locked into this science sequence—there are many courses to choose from.

The program is also adequate in preparing students for careers in science-related fields. Rough statistics for our school over the past seven years show a higher than average number of students choosing science careers. I am sure the interest and career-awareness aspects of this program might be labeled by some as being "watered down" or "consumer chemistry" for average-ability students. However, we cover every concept that most traditional chemistry programs do; it's just that we do it in two years, with much high-interest material added. Along the way we emphasize different objectives, such as societal and career aspects.

We continue to survey graduates who are in colleges and universities majoring in science-related fields to find out what our program is lacking. Generally our graduates indicate that they have been very adequately prepared. This surveying also provides ideas to improve the program.

One perplexing aspect that has surfaced is the effect of time spent on societal issues/applications/career awareness compared to theoretical concept development. We have found over a 10-year period that when more of these "human science activities" are incorporated into a program, less time is spent on traditional concept development—the kind of concepts tested for on nationally standardized, college qualifying, entrance tests. I can truthfully say that as long as colleges require tests with these kinds of questions we will have to find better ways to teach them. But there is only a limited population of students who should be tested in this manner: the extremely high ability science-oriented students. There is a far greater population of students for whom scientific literacy should be stressed.

We have found a way to teach and test theoretical chemical skills that allows us to have the best of both kinds of chemistry. The answer lies in the use of computers. Later in this chapter I have outlined a teaching strategy called the Chemical Skills Ladder that has improved chemical skill comprehension in our program. This seems to me to be a very reasonable purpose for computers: perform tasks that are individualized and time consuming so that class time can be used for more high interest, group type activities.

Plans for Improvement

The chemistry/biochemistry program at Mt. Baker is good, however, there are areas that still can be improved. The emphasis on career awareness requires the modification of many assignments or activities to incorporate career awareness concepts. This has been a slow and tedious process. From a teacher's point of view, reasonable goals must be identified and attained. The resources for career awareness activities add an entirely new dimension to the program. Unfortunately, resource people also have schedules to contend with, making the organization tricky. Simply stated, infusing career awareness concepts into a program takes time, energy, and, above all, patience.

A second area of concern is the development of appropriate teaching/learning strategies for the chemistry skills that are a part of any computer program. We have developed a strategy that uses the computer for tutorials, drill and practice, and testing. We have either written or purchased software packages that cover the appropriate skills for each instructional unit. These are required assignments to be completed either in the school computing center or on one of the computers in the chemistry room. We have written a number of good programs, mostly in Basic, for the Apple IIe.

The testing has become an extremely valuable process. Not only do we determine a skill grade but, in addition, this process identifies weaknesses, enabling us to use this method as a diagnostic tool. The process, called the Chemical Skills Ladder, has been constructed as follows. Once all of the desired skills have been identified for each unit, the testing programs are written. For example, suppose the first skill was to name elements and symbols. Skill Level #1 will have one question on this skill. The student challenging Skill Level #2 will face two questions, one as a review of level #1 and a new question on the second level. A student must answer both of these questions correctly to move up the ladder. Quarterly, semester, and yearly goals can be established and, equally important, weaknesses can be identified. This is a good way to achieve comprehension. Virtually any skills can be loaded into the sequence. This strategy has significantly helped students prepare for the AP chemistry test. Also, when students return for the second year of chemistry we have noticed a much stronger retention of these skills. For a program like ours, this strategy is appropriate. Incidentally, I gave these written quizzes every other Friday.

Some Concluding Thoughts

Many factors influence the success of a science program. Some of those factors have already been discussed in this chapter, such as teacher background, local support, up-to-date teaching strategies, modern curricula, appropriate goals, etc. We have made gains in all these areas. The science education obtained by the students ot the Mt. Baker School District is far better because of our efforts. However, one factor that we are now addressing could undermine the program: the desire to seek and maintain excellence in education. A program such as the one we created will not survive unless the local support continues. Support comes in many different sized packages. Support manifests itself in subtle actions by local administrators, school board members, and local community leaders. The thread that binds educational excellence is every bit as fine as the thread of life.

Our science program has really been the first step into the realm of educational excellence for our district. Although our school district does have some fine accomplishments to cite, quite frankly, our community people have been satisfied for a long time with an average education. Many still think science is for smart students. These same students come from homes where the parents' expectations are low and nonchallenging. Many parents and school officials of our district do not feel the urgency of improving academic excellence as I do. Whether I like it or not, our science program has to take responsibility to some degree for a lack of desire for academic excellence demonstrated by some other programs. The changes occurring in our country with regards to society, lifestyle, career expectations, and family make it imperative for teachers to communicate ..fectively with parents and community leaders. Parents and teachers must become "tuned in" to each other's ideas. We live in a world filled with innumerable choices.

Students make choices, strong parental support groups are needed. If parents are to make responsible decisions for their children, they will have to thoroughly understand the goals and benefits of an educational system based on excellence. The school cannot remain a "black box" any longer. It must be illuminated with new understanding of the role of scientific education in a complex society.

As exemplary programs continue to evolve, they seek new strategies, new ideas, and up-to-date content, so that students can be challenged to do their best. Teachers of exemplary programs, like teachers of all other programs, need to be rewarded, complimented, and challenged to improve. Teachers should be paid both monetarily and professionally to attend workshops, conferences, and the like. Proper evaluation must follow. The newspaper headlines stating "education excellence must begin" are over. Now the hard work begins.

Chapter 4
Chemical Concepts Through Investigation

Diana Doepken and Pat Smith
Air Academy High School
Colorado Public School District #20
U.S. Air Force Academy
Colorado Springs, Colorado 80840

Air Academy High School, a public high school serving 1,100 students in grades 9 through 12, is located on the grounds of the U.S. Air Force Academy just north of Colorado Springs, Colorado. The district's school-age population of 7,695 students attends two high schools, one junior high school, and eight elementary schools.

Our district is increasing rapidly as Colorado Springs grows with an expanding high-tech industry and the selection of Colorado Springs as the location for the Consolidated Space Operations Center and the Air Force Space Command.

The population of our district and the surrounding community could be described as suburban upper-middle class. The district represents a well-educated population, many of whom are professionals or employed in the high-tech industries. Because of our location on an Air Force facility, we also serve the resident military population.

More than 80 percent of our graduates go on to a four-year college, 5 percent enroll in a community college, 3 percent enlist in the military or enroll in vocational training, and about 10 percent find full-time employment after graduation.

These statistics show Air Academy's academic orientation. For that reason we must continue to offer preparation for college emphasizing process to learn content. Our expectations of the chemistry program are met when students return to tell us that college chemistry was easy. The administration at Air Academy High School not only encourages innovation but actively seeks it. For the past two years an Expanded Vision Committee has met to define priorities and creative ways to solve curriculum problems. Next year's priorities are the development of higher order thinking skills and creativity. Our chemistry program fits very well into such an environment.

Introduction to Chemistry, the first course, was developed to provide a better experience for students not especially interested or talented in science. These students need chemistry at their level. The strategies we use with these students were influenced by articles describing the application of the ideas of Piaget to the science classroom. Tony Lawson, Robert Karplus, and John Renner published extensively, presented workshops, and gave speeches about different methods of teaching science. The learning cycle used by Karplus in the SCIS elementary science program was a useful vehicle. Our chemistry program was developed over a period of years, beginning with experiments and finally comprising complete lessons.

The students in the Introduction to Chemistry class responded so well that when we were asked to develop materials for gifted students we used the learning cycle. We also use similar methods in the college preparatory course. Because of student interest and our own perception of the importance of the material, we are incorporating more organic chemistry into all phases of the college preparatory course.

Our Program

Our program includes five different chemistry courses: Introduction to Chemistry, Chemistry, Advanced Placement Chemistry, and TAG Chemistry/Physics 1 and 2. Although the courses differ in content, the philosophies are similar.

All aim to teach the concepts of chemistry by emphasizing the processes and activities of professional scientists, both contemporary and historical. Although students in different courses may study concepts to a different extent, all students are exposed to problem-solving techniques and encouraged to use critical thinking while learning the principles of chemistry. We stress not only the ability to find an answer to a problem, but the means and strategies necessary to solve it.

The content of Introduction to Chemistry deals with such fundamental topics as investigations of the properties of matter; experimental and laboratory techniques; development of a molecular model from observations; kinetic molecular theory and its applications; differences in the physical states of matter; relationships between mass and energy; interactions between the states of matter; the periodic table; acid and base chemistry; and organic chemistry.

The Content of Chemistry and the chemistry portions of TAG Chemistry/Physics I and II are nearly identical. They include:

- A study of the regularities, relationships, and interactions of matter;
- Development of the kinetic molecular theory and how it applies to solids, liquids, and gases;
- Periodicity of the elements and consequences of the arrangement;
- History of the theories of atomic structure and the relationship between structure and properties;
- Nature of chemical bonding;
- Nuclear reactions, transmutation of elements;
- Organic compounds, their structure and properties;
- Stoichiometry of chemical reactions;
- The solution process and expressing concentration;
- Rates of chemical reactions and mechanisms of reactions;
- Acid and base chemistry;
- Oxidation-reduction reactions.

All of the courses, with the exception of AP Chemistry, are designed around the inquiry method of learning of the Learning Cycle. In this teaching strategy, students are directed to perform an exploratory experiment, collect data in usable form, and then analyze the data. We usually make directions for this experiment specific but brief, allowing the students to formalize an exact procedure on their own. Thus the students are directed to "find a way to . . ." instead of being given a recipe from the lab book.

After this exploration phase, students work with the teacher, either in small groups or as a class, to analyze the data and incorporate it into a useable model or theory termed "The Main Idea of the Lesson." After this exercise, students use their ideas and theories developed in the second phase by applying them to another situation, often an everyday experience. For example, after students learn the effect of pressure on the volume of a gas in the lab, we ask them why potato chip bags which are on the grocery shelves here in Colorado are all puffed up.

The role of the teacher in our courses varies with the phase of the cycle. In the exploration phase the teacher provides some direction, but not in specific terms, since the experiments are often open-ended and qualitative in nature. Students are encouraged to record what they see and draw their own conclusions. In the second part of the cycle, the teacher plays a more active role as the teacher and student together try to make sense of the data and observations. In this role, the teacher leads a discussion and asks carefully planned questions to draw out as much student response as possible. A student who "discovers" a principle is much more likely to retain it and be able to apply it than if it is merely presented in a lecture context.

Students are graded in the Introductory Chemistry course using a 90-80-70-60 grading scale which reflects percentage of points earned during the grading period. Individual lessons are examined for completeness and evidence of comprehension of the lesson concepts and graded accordingly. A unit test based on factual knowledge and applications of the principles is given at the end of a unit or when appropriate. Often students perform laboratory tasks (such as finding the density of an object) as part of the exam.

Generally the same grading standards are used in the other chemistry courses. But most of the evaluation is done through testing and work in the laboratory. Problem solving skills are usually tested in every unit. We try to incorporate as much application as possible in designing test questions.

Facility

In our building, the chemistry classrooms are designed for 24 students per class. The front of the room contains moveable student desks with a demonstration table and chalkboard for the teacher. The back of the room holds the laboratory area. Students in introductory chemistry are not assigned to a specific lab desk or area: other chemistry students have their own drawer containing basic lab equipment and a work area.

One unique aspect of the introductory chemistry program is that equipment needs are met with a minimum of expense. The usual array of test tubes, beakers, and graduates must be available, as well as some common chemicals such as acids, bases, copper sulfate, and potassium dischromate. The rest of the equipment and chemicals—balloons, birthday candles, sand, salt, starch, ice, plastic wrap, and carbonated beverages—can often be supplied from the local hardware, drug, or grocery store.

The other chemistry courses require basic lab equipment for each pair of students and the usual stockroom chemicals. No special equipment or chemicals are normally used. Students and teachers use an Apple IIe for programming, word processing, and to run commercial software.

Evaluation

The success of our program can be judged by the success of our students. In the Introduction to Chemistry classes, the number of failures is extremely low, only two or three students a year out of approximately 100. Grades are not the only indication of success, however, and we are always pleased when we get comments from former students such as, "I made chemistry my major," ". . . college chemistry was easy to handle . . .", "I had a far stronger background than most other students at . . ." and "chemistry made a positive impact on my college career." As a rule, the teachers like the program because the students succeed.

Several factors that contribute to the success of the program include:

- The students find the material easy to understand. Mastery of the subject matter is enhanced by lessons designed to have basically *one* main idea.
- Explanations derived by students are more thoroughly understood and retained.
- Concepts observed in the laboratory can be seen to apply to everyday situations.
- The nonthreatening atmosphere of the class is conducive to new ideas, comments, and opinions about a topic.

The different courses of the program are evaluated in an ongoing manner. The introductory chemistry courses have been taught by several teachers over the past five years. As new teachers come in, they learn about the program from an experienced teacher. Each teacher can then add/delete/-supplement material according to student needs and interests. Usually at the end of the year, a teacher will have suggestions to improve the course content which can be passed on.

The other chemistry courses are evaluated by the teacher as a unit is completed. Questions such as "What was successful?" and "How can the objectives of this unit be met more effectively?" lead to an updating and improvement. Learning new techniques, experiments, and demonstrations at workshops and conventions is also a great help in this process. Finally, student comments such as "I never really understood that . . ." or "What a waste!" are of significant help in weeding out material that just doesn't work.

Plans for Improvement

In each chemistry course we recognize the need to offer more career education to our students. This information must be incorporated into lessons presented on bulletin boards or enhanced by a speaker or program. This is done to a certain extent, but could be improved.

To maintain a well-balanced program, we have two specific areas of concern. With a successful program it could be easy for the teacher to allow the learning cycle to become too routine, losing awareness of student needs and inquisitiveness. This routine might then take the form of complacency. It would be easy to say that we have an answer to a student's problem, but that would destroy the very essence of the program. We feel that one of our major strengths is the ability of the teachers to innovate and adapt. If our learning cycle lessons became "the textbook," without yearly revisions and changes, the program would lose effectiveness. It would also be detrimental to the program if teachers did not keep up with progress in areas such as computer technology and instruction, laboratory instrumentation, computer interfacing, etc. These tools are developed and can be used effectively in all chemistry courses.

We plan to keep our program healthy and up to date by:

- Attending workshops and classes which will provide us with new demonstrations, teaching methods, and approaches to a subject. Then we will try them in the classroom.
- Asking the students to anonymously evaluate the program at the end of the school year.
- Having all teachers of a specific course sit down at the end of the year, discuss the program's strengths and weaknesses, and suggest ways to improve it.
- Obtaining new periodicals such as *ChemMatters* and *Science Digest*, and incorporating their content into the daily presentation of the subject.
- Continuing administration support for hiring teachers who not only have an excellent background in chemistry but are people-oriented.

We would also hope for continued support, both financial and emotional, to keep the program thriving.

Chapter 5 High School Chemistry—An Equilibrium

Jerry R. Kent
Hazen High School
1101 Hoquiam, N.E.
Renton, Washington 98056

Renton, a small town of about 34,000, is at the south end of Lake Washington. Seattle is at the north end, about 11 miles away. Renton lies in a valley through which the Cedar and Green Rivers flow, eventually emptying into the lake at the edge of town. There are low hills to the east and west of the city. Because of this geography the school district consists of three distinct areas: a west hill, a southeast hill, and an east hill, each with several elementary schools, one middle school, and one high school. Hazen High School, on the east hill, is where this program originated.

The area began as a coal mining town, with the southeast and east hills bearing coal that was taken to the lake and taken away by barge. The town retains its rich pioneer heritage and communicates this through a special social studies program for elementary students.

Generally speaking, the area serviced by Hazen High School has seen a lot of changes in the past 15 years. The population grew substantially, especially in the unincorporated areas, increasing by 15 percent between 1970 and 1980. But with this population increase came a decrease in children 18 years and under.

There are two large factories within the school district. Boeing Aircraft Company and Pacific Car and Foundry Company. The need for two-year vocational training for students not planning to attend college has motivated the school district to build and support a vigorous vocational-technical school. This training meets the post high school needs of a large part of our student population. About 50 percent of Hazen High School students continue on to some form of higher education other than vocational school or the job market.

The K-12 student population of the Renton School District is approximately 13,000. Over the past ten years enrollment has decreased about 20 percent. Hazen High School has seen similar enrollment declines. It currently has 1,308 students in grades 9-12. Almost 100 percent of each entering class takes biology. Half of each class, a diverse group of students, also take chemistry. Some students need preparation for colleges that are strong in science and engineering. Others attend one of the state's four-year universities, and some start in a community college. The rest of the class goes to vocational school or directly into the job market. Each of these groups has different needs that the program must satisfy. Elements of the program that must be considered include college prep material, practical applied chemistry, understanding the role of chemistry in today's society, and developing decision-making skills based upon knowledge of science and application of its processes. I have found that high school textbooks place little emphasis on applications and societal issues. Over the years I have looked for specific ways to address these areas. This ongoing search led to the development of my chemistry course, "Chemistry—An Equilibrium." I have spent many years strengthening the weak areas of the program and bringing it into equilibrium.

This is a continuing project; new technology constantly requires changes in the examples. My program now includes elements of application and societal impact. Society's list of concerns has grown. The core of the chemistry content remains, but how we use it, on which problems we focus, and how it relates to the everyday world of a modern teenager changes. My program evolves; it is not a static unit of study written for all time. It is a growing and changing program, sensitive to the needs of young people and the concerns of society.

The resources used to build the program include more than demonstrations and labs that illustrate the practical side of chemistry. These resources came from my participation in a number of workshops, summer programs, conventions, and conferences, as well as some research done for publication. Some in-service programs that have added to the program are the Washington Heart Association Fellowship, Hope College AP chemistry program, Dreyfus Summer Institute, and a materials science program on solid state structures. My professional activities in the American Chemical Society (ACS), The Washington State Science Teachers Association, and the National Science Teachers Association (NSTA) have all provided rich information that has added to my program. Another resource has been the safety programs I have attended. The attitude generated in my class about safety and the safe use and disposal of hazardous materials, gives us many opportunities to discuss community safety and the responsibility of companies using hazardous materials.

Goals

The program prepares students to live and operate effectively in a scientific and technological world. It emphasizes teaching students how to collect data, evaluate it, build and test hypotheses, and eventually work through a model system that describes and explains the behavior observed. This type of understanding develops the rational thinking process needed to understand how science works, while providing students with a framework for developing principles within the course. The carryover of this process into other areas of life is invaluable. However, if we expect to produce scientifically literate beings through our course, we must give students an opportunity to apply these skills and use them in making rational judgments. If this is accomplished, the program can boast of teaching both knowledge and wisdom.

The community has long expected secondary chemistry education to prepare students for success in college chemistry. This focus has been realized with the CHEM Study curriculum established in the early 1960s. Those of us who deal with average everyday students not necessarily bound for college understand its weak areas. The application that makes chemistry a real part of the students' lives is missing, as well as career education. I have worked with these areas over the years and have tried not to water down the essential college prepatory content while providing a balanced perspective to stimulate an interest in science and meet the needs of all types of students.

This explains why I developed the program currently used at Hazen High School. Though we have a number of students who go on to a four-year college, an even larger number go on to two-year programs at the community college or vocational school. Over half of the students in the program are not looking for a college preparatory course; they are more interested in how chemistry affects them directly.

I was chairman of the Science Articulation Committee that worked with a citizens committee to establish a set of science program goals in our district. The goals were adopted by our school board and have become the basis for curriculum development in the district. The "Renton Science Program Goals" are as follows:

The Renton Science Program will:

- Provide students with the opportunities to master, maintain, and apply the basic facts, concepts, skills, and processes associated with science.
- Develop positive attitudes in students toward themselves through their relationships with science.
- Foster curiosity, initiative, creativity, and objectivity.
- Encourage student understanding and respect for the environment.
- Develop rational thinking processes which underlie the scientific approach to problem solving, including:
  - Define the problem;
  - Make observations and collect data;
  - Analyze and classify data;
  - Build hypothesis;
  - Design and carry out experiments;
  - Evaluate results and build theories;
  - Build model systems to explain theories.
- Develop fundamental skills in:
  - Manipulating laboratory materals and equipment;
  - Gathering, organizing, and communicating scientific information.
- Develop a knowledge of and a respect for the past contributions, the future possibilities, and the existing limitations of science in solving society's problems.
- Provide for the reinforcement of academic and study skills taught in other areas of the curriculum, such as mathematics and language arts.
- Provide an opportunity for the student to acquire an understanding of the relationship of science to everyday living and various occupations.
- Increase student awareness of historical development in science.
- Provide curriculum opportunities for both college- and vocationally-oriented students.
- Establish and maintain a safe learning environment and develop safety awareness in students.

The content of the chemistry course, established by the chemistry curriculum committee, is expected to be taught in all schools in the district. How to weld the content to the goals and the teaching strategies used are left to the discretion of each teacher. Therefore, I would like to outline the content as expressed in our curriculum guide and explain how I present the material to accomplish the goals and remain consistent with my philosophy of chemistry education.

Course Content

- The Scientific Process
- The Particulate Nature of Matter
- Conservation Laws and Stoichiometry
- The Kinetic Molecular Theory
- Solutions and Solubility
- The Periodicity of the Elements
- Subatomic Particles and their Nature
- Chemical Families and Electron Distribution

- Chemical Bonding
- Energy in Chemical Reactions
- Reaction Kinetics
- Chemical Equilibrium
- Acids and Bases
- Bonding in Solids and Liquids
- Electrochemistry
- Organic Chemistry, a study in applied chemical principles

Chemistry at Hazen

This program is a one-year chemistry course for students in grades 9-12 who have successfully completed one year of algebra. Class sizes are generally 24-28 students, limited to 28 students by the number of laboratory stations. Students normally take chemistry in grade 11 after having taken biology in grade 10. Some students, because of their achievement test scores, begin biology in grade 9. These students will then take chemistry in grade 10, physics in grade 11, and advanced chemistry or advanced biology in grade 12. Five sections of first-year chemistry are offered, and a second year is available for those who wish to pursue their study of chemistry further. Students may select an advanced placement option with this program.

Students with a wide range of interests and abilities enroll in the program. In order to capitalize on the wonder of science and the students' natural curiosity, the program begins with a series of laboratory activities designed to develop understanding of the scientific process. The early hands-on activities set the stage for the rest of the year; each experiment builds and reviews specific objectives. It is important that teachers take time to make sure students assimilate the concepts and observations so that they can internalize and use what they learn. Standard experiments from the Prentice-Hall lab manual are used to introduce the students to chemistry. In addition, they observe some of the following reactions: aluminum foil and copper II chloride, galvanized nails in lead acetate solution and observations of candles made from compounds other than wax. Students learn how to make observations and use them to develop, through the scientific process, an understanding about nature. This unit concludes with the Bell Telephone film, "Discovery," which enlarges the students' world of observations and illustrates each step in the scientific method.

Safety is an integral part of these laboratory experiences. A safety-conscious attitude does not develop with just an introductory lecture and filmstrip, although these help. The teacher's actions should reinforce safety in all laboratory work. In this program, teachers relate safety concerns the students have to what others experience in their jobs and by discussing OSHA standards. By hearing about real laboratory accidents and their results, students learn a healthy respect for chemicals and how to handle and dispose of them. We try to teach respect, not fear.

Students wear goggles during all laboratory activities and are expected to wash up before leaving the class on lab days. They follow these rules with very little prompting.

Learning laboratory techniques, making real observations, properly collecting data, analyzing data, making hypotheses, suggesting tests, and eventually developing theories take up a major part of the first unit.

Through organizing and interpreting the collected data and building a consistent conclusion, the students begin to learn the process of deductive reasoning. This process is reinforced with a practical laboratory exercise of collecting data about different liquids to determine their density.

Science-related social issues are consciously included in the appropriate unit. Examples are:

- Atomic Structure and Radioactivity—concerns of nuclear energy.
- Periodic Table—descriptive chemistry and the production of chemicals important to the well-being of a society.
- Atomic Structure—electromagnetic radiations and their effect on humans.
- Molecular Architecture—semiconductors and this growing industry.
- Energy Changes in Chemical and Nuclear Reactions—energy sources, energy related problems, nuclear fusion, fission, and related concerns and possibilities.
- Rates of Chemical Reactions—air pollution and catalytic converters, outdoor and indoor air pollution.
- Acids and Bases—a taped lecture and discussion on acid rain introduces the chapter and are mentioned throughout the unit, swimming pool chemistry, the chemistry of shampoos, and body fluid chemistry.
- Oxidation Reduction—concerns regarding corrosion, batteries, and energy alternatives.
- Organic Chemistry—polymers, proteins, and carcinogens.

Strategies used to cover these topics include taped lectures from the ACS "Men and Molecules" series, problems with students working on independent solutions and reading and discussing *ChemMatters* magazine. Since many of my former students have gone into fields related to these topics, I have invited them back to give descriptions of their work. This has been done in such areas as materials science, metallurgy, and medicine. One former student with a degree in chemical engineering works as a bioengineer as part of a university team solving real medical problems.

Another method involves beginning a lesson with a real problem. For instance, we discuss fluorocarbons in the ozone layer and students suggest how we should go about solving this global concern. The lesson continues with the chemistry related to the problem and reading about potential hazards. Eventually materials showing how the problem was dealt with on a national and international level are discussed.

Career information is woven throughout the course. The textbook contains sections describing job opportunities for chemists. I like to extend this to all science-related fields and do so by getting current pamphlets on these other areas and passing them around the class. Over the year we preview and discuss many fields in depth. The school has an excellent career resource area where students can get more detailed information. When resource people are brought into class, the career aspect is always part of their presentation.

This chemistry program includes rigorous and comprehensive academic preparation. Its conceptual scheme is regularly discussed so students can see where they have come from and where they are going. Student expectation is high and minds are stretched. Most will not be chemists, but they learn how to learn. Before they are settled in their lifelong occupation, they will be trained and retrained many times.

Students respond well when pushed to their limits, provided they are encouraged and find a degree of success in their efforts. This is the critical nerve in teaching: providing a stimulating program that accomplishes the prescribed goals, keeping students focused on the task and developing their ability to learn.

The laboratory periods are similar to those in any other solid lab-centered high school program. Each student has private glassware and hardware, and four students share a centigram balance and a hot plate. The laboratory phase follows the normal CHEM Study lab experiments, with additional labs. These include measuring wavelengths in the visible region of the hydrogen spectrum, determining the diameter of a marble molecule indirectly by statistics, taking copper through a series of chemical reactions and back to metallic copper, corrosion studies after galvanizing and tinning a piece of iron nail, making brass, making transparent soap, and measuring the iron content in vitamin supplements.

The unique aspect of this course is not the lab, but the way theoretical chemistry is made practical by the illustrations used, the examples of applied chemistry passed around the class, and the special projects. The social emphasis emerges as an extension of what is learned about chemicals in the classroom and the laboratory.

The evaluation package points out the priorities of the program. I use a variety of methods such as teacher-made tests, chapter tests from the book publishers, standardized CHEM Study Tests (ETS), and the ACS NSTA Cooperative Examination These evaluate the basic core of chemical material, but do little to evaluate what is learned about application. Therefore, I use quizzes and evaluate class participation during discussions. I do not measure the career phase of the program. However, students ask enough questions in this area that I know it has been stimulating.

How the Program Fits into the District Program

The district's curriculum guide for chemistry includes goal statements, an outline of the program, and the specific course objectives. Other parts of the guide include the nature of the students it is designed for, scope and sequence, learning objectives, means of evaluating them, and the materials used to present the course. Teacher committees, citizen committees, administrators, and the school board review the entire document to see if it is consistent with the philosophy and educational scheme of the district. This process ensures that any course developed will work in concert with the rest of the district. A second policy requires that the same course be taught in each of the three high schools. As one of the teachers who participated in building the chemistry guide, I know the content of the course reflects what each teacher feels should be emphasized in the program. These policies have not been restrictive, but have given our district a solid science program. The manner in which teachers present the material, the applications, and the social issues varies across the district and from year to year. This has stimulated me to search out new ways to teach applications, social issues, and career opportunities.

Evaluation of the Program

Each year students who graduate from Hazen High and attend the University of Washington are interviewed after they have been in college for two quarters. We have yet to hear a negative response when these students are asked if their high school chemistry class adequately prepared them for college chemistry. The majority of students who return to visit the school give positive feedback about our program.

As a group, results on the ACS-NSTA Cooperative Examination are well above the national norms provided by the testing service.

The question concerning our program meeting the needs of college-bound students not going into a science-related field is more difficult to answer. However, I recently asked some of my former students to write recommendations for me regarding the program. I specifically included some who did not follow a science track in college. For a variety of reasons, they thought their chemistry coursework was valuable.

The students who do not go on to higher education are more difficult to evaluate. Many do not come back to school and cannot be followed up. Since feedback from these students is very difficult to obtain, I would like to relate the opinion of six science teachers and a science coordinator from several districts throughout the country who were invited to spend a day in our science classes to evaluate our school for accreditation. Their review provided several positive comments, including one commendation that: "The science curriculum seems well planned to meet the varying needs of a diverse student population."

Hazen High opened during the period when chemistry enrollments were on their way down across the nation. Students were not electing to take science in general, and chemistry and physics were at an all-time low. At its highest enrollment level, Hazen offered three chemistry classes. As the program I am describing began developing, the number of chemistry classes steadily increased, even though total school enrollment was constantly decreasing. We are now running five full classes of first-year chemistry and one class of second-year chemistry.

Since the core content of the program is a set quantity, modifications usually include new labs or new demonstrations. I am always looking for new labs and demonstrations that can make the chemistry concepts easier to assimilate and more meaningful. Safety concerns relative to the hazardous chemicals suggested in some of the older lab manuals has prompted me to look for replacement experiments. The cost of silver nitrate has all but eliminated some very effective labs. These have been replaced with labs on copper chemistry. The role of a chemistry teacher seems to be to evaluate and reevaluate the activities and the program to ensure the best possible learning experiences for students. Other areas of the curriculum, such as application and social impact of science, change with the changing technology. Social issues have moved from fluorocarbons in the ozone layer to acid rain to hazardous chemicals. Since the issues change constantly, the techniques for dealing with them change as well. I read the journals, attend conferences and conventions, and keep up on modern learning theory to put together the best learning packages to teach these topics. Change has become a way of life, for no two years in my teaching career have been the same.

Plans for Improvement

An understanding of atomic structure and electron configurations helps students to interpret and explain chemical phenomena. To develop these very abstract concepts properly takes several weeks, and few lab experiments fit into this section. This long time period with few labs is the low part of the course in terms of students actively participating. Textbooks and lab manuals offer nothing to fill this void. I have found three activities that help in this area, but I need more ideas that could get students involved with chemicals.

I prefer to fit social issues into the course when the content relates to the issue. Over the years many issues have been incorporated. Still, many issues come up at the wrong time of the year for students to really appreciate them from a chemical perspective. This leads to a discussion of the issue from a layman's perspective and leaves out the opportunity of using and developing chemical knowledge. I often feel more could be learned if the topic was studied at the appropriate time, but you must act when the opportunity is available. This frequently happens when new issues of *ChemMatters* arrive, but by keeping the issues over the year one can use them when the time is right.

What to Watch For

The pendulum swings back and forth in chemistry education, as in most human endeavors. I have seen the pendulum swing through both extremes. In college I was taught principles and concepts that were organized and developed around industrial processes. When I began teaching, industrial processes were the core of a chemistry program and this was the frame of reference I had for building a chemistry program. NSF-sponsored curriculum projects used a conceptual framework for chemistry and integrated it with the laboratory. We thought we had moved the pendulum back to the center by implementing a program like CHEM Study.

The improvement in curriculum was such a giant step ahead that it took a couple of years to implement it in the schools, and then it began to be clear that the element of practical application was missing. The content of the CHEM Study program provides a sound basis for understanding chemistry. The CHEM Study philosophy of teaching, which emphasizes learning as a scientist learns, is also valuable.

The omission of descriptive chemistry and practical application, coupled with a minimal amount of material on social issues, prompted me to supplement the program in these areas. I believe the balance I have tried to put into my course with these components is the right one for my students in 1985.

The possibility that this perspective would become locked in and unable to address new and different needs in society is a major factor that could undermine the program. We have seen it happen in the past, as education changes ever so slowly, trying to catch up with research and the current societal situations. We easily get into a rut repeating what we did the previous year that it is only with great effort that we modify our programs to meet current needs. As long as this program continues to evolve, being sensitive to the needs of young people and the concerns of society, it will keep the proper balance of elements that maintains the equilibrium of the course.

Methods to Keep the Program Healthy

In order to maintain this course as a viable, healthy program, one must be willing to evaluate, respond, and modify. I evaluate the program on a regular basis in several ways. The ACS-NSTA Cooperative Examination is given yearly; thus I am able to track my students against national norms, which also gives me an opportunity to evaluate specific units in the course. Feedback comes from counselors' interviews with our students in college, as well as from my questions to graduates about which parts of the course were most and least helpful in college. The chemistry teachers in my district regularly evaluate the district chemistry curriculum to see if changes are necessary. Individual chapter evaluations indicate if the material is getting through. Test questions about application and social issues not only help in evaluating the students, they show students what you, as a teacher, believe is important in the unit.

These different means of evaluation provoke concerns about the program that call for a response. As long as I maintain an attitude that says, "It didn't seem to work too well that way; let's see how to do it better," my responses will eventually bring into focus the best way for me to teach chemistry, in my classroom, with my students. Throughout my career I have worked to change things. I continually take courses, attend conferences and conventions, and participate in summer programs, to find new and better ways to do my job.

Modification results in a more effective way of doing some part of the program. I write on the first page of each chapter all the films, labs, handouts, activities, problem sets, and demonstrations that I intend to use. This planning will include the social issues and the methods of working through them as well. Each year I add to and subtract from the list. I often write an example or application of a topic in the margin of the book. I try to make the lists fit the students, the times, and the program goals.

Chapter 6
Using High-Interest Activities

Sheryl Jan James
Scottsburg High School
500 S. Gardner
Scottsburg, Indiana 47170

Scottsburg, Indiana, a farming community of 5,000 situated 30 miles north of Louisville, Kentucky, ranks the lowest in the state for educational achievement of its residents. Scott County, after the recent closing of the Marble Hill Nuclear Power Plant, has become one of the poorest counties in the state.

Scottsburg High School has an enrollment of 838 students in grades 9-12. Although only 20 percent of the graduates enroll in college after graduation, half of the junior class is taking chemistry. Next year, in addition to a 50 percent enrollment in beginning chemistry, we will have two sections of a senior-level advanced chemistry class, a first in the school's history.

Mahatma Ghandi said, "You westerners come to India with your schools, to educate our children. You give them running water, tables, chairs, cutlery, beds, desks, and so on. When they leave your schools, they no longer fit into village life and must go to the cities, where they may or may not survive. In our school, we give them no more than they have at home in their villages. But we teach them what they can do with what they have there. That is real education."

Our challenge in Scottsburg, as in other rural schools, is to prepare both types of students: those who choose to remain in their "villages" after graduation and those who wish to go on to the "cities" (colleges). For this, we needed a program that prepares and appeals to both types of students.

Our Program

Scottsburg High School offers both beginning and advanced chemistry classes which use many types of teaching techniques and resources, traditional as well as nontraditional. About 85 percent of class time is spent on traditional curriculum, with the balance of nontraditional labs and activities. The diversity of high-interest activities and their ties to everyday phenomena help maintain a high enrollment in the elective chemistry classes. The chemistry program operates on a relatively small budget, and half of this is generated by student activities.

We want to integrate chemistry and real-world phenomena for both the academically and nonacademically inclined student. All students experience a high degree of success through the structure and experiences provided by our special labs. These labs produce a spirit of inquiry and provide students with an understanding of everyday chemistry. For instance, after the ice cream lab, we overheard students exclaiming that they finally understood why salt was added to snowy roads in the winter.

About 15 percent of class time is spent on nontraditional activities including labs, computers, photography, and science movies. Some of the nontraditional labs performed in our program include:

- Hydrogen Balloon Lab: The production of hydrogen gas by a simple displacement reaction is the primary objective of this lab.
- Root Beer Titration Lab: First we find the molarity of the base, sodium hydroxide, by titrating the base into a known molarity of hydrochloric acid. We then compare the normality of hydrochloric acid to different substances, such as root beer, Coke, or Sprite.
- Peanut Brittle Lab: ("Partial Thermal Degradation of

Carbon Dioxide Foamed Saccarides with Protein Inclusions") All of the reactants (candy ingredients) are listed by their chemical names.
- Ice Cream Lab: This experiment shows the effect of a solute (salt) in lowering the freezing point of water.
- Popcorn Lab: Students discover the relationship between popping corn and the gas laws.
- Hot Air Balloon Lab: The objective is to find the hover temperature of the balloon, but the gas laws can also be studied.
- Rock Candy Lab: The study of supersaturated solutions and crystal formation.
- Testing Antacids: This lab is performed when studying neutralizations.
- Soap Lab: This lab is performed when studying colloidal systems and/or organic chemistry.

Common chemistry procedures are not sacrificed in these special labs.

We are currently incorporating computers into the chemistry curriculum. These computers are used every day. In fact, many students choose to give up their free time to work on the computers. For example, one student used the computer to graph the data from our melting point determination lab, while another wrote a program to quiz beginning chemistry students about the elements and their symbols. He became so intrigued with computers that he devised a science fair project using the computer to run a robot. His entry won second overall in his division at the regional science fair. He is now in his last semester in electronics school.

Photography emphasizes many chemical principles that can be incorporated into the chemistry program. Each one of the photographic processes (the photographic film, exposure, developing, fixing, and printing) involves a tremendous amount of chemistry. Photography can also become a great motivational vehicle.

We tap another emotional resource by allowing the students to photograph their laboratory experiments. They also take great pride in developing their prints. Our pictures have appeared in local publications and in the national chemistry magazine, *Chemunity*.

Since we have our own VCR and TV, my students enjoy a wider range of chemistry programs and science movies than was available before. Two of the most popular movies are *Andromeda Strain* and *China Syndrome*.

Our program provides opportunities for students to become aware of and involved in chemistry-related societal issues by:
- Keeping students informed of real world situations and chemistry issues on a regular basis by making use of current publications and periodicals.
- Utilizing resource persons from many scientific disciplines. For example, scientists from Indiana University Southeast's "Visiting Scientist" program are invited to the classroom to interact with the students.

Our program stresses career education. Students are exposed to careers in chemistry or chemistry-related fields in several ways:
- Visits from resource persons such as practicing chemists, horticulturists, and nuclear engineers.
- Field trips to a nuclear power plant and local universities.
- Writing career research papers in which the students include an interview with a science professional.

Students are graded on a traditional system of percentage points. They know at all times what their grade is by taking their number of points and dividing it by the total points. Students can then relax and focus their attention on learning chemistry.

Although it is not necessary to have vast amounts of money available to incorporate this program, each year my classes have a radiothon fund-raiser which allows us to double the amount of money available to the chemistry program. This involvement in fund-raising gives the students a personal stake in the operation and direction of the program.

The money raised has enabled us to purchase our computers, videocassette player, color television (which is used with the videocassette player and color computer) and to equip our darkroom.

The radiothon is run at the local radio station from 2:00 p.m. on Sunday until 6:00 a.m. Monday. The students sell commercial spots to local merchants. Part of the money goes to the station for operating expenses and the remainder is profit for the science classes. The students play their own music, read the news and weather, and make dedications. This has proven to be a very popular and successful money-making project. We have earned over $3,000 and plan to make an additional $5,000 in the next five years.

Evaluation

We consider our efforts extremely successful. Although the majority of our students do not pursue chemistry academically or professionally, those who do perform well in college. Some of my former students have majored in chemistry, engineering, veterinary science, medicine, and pharmacy.

More important are the students who have elected to run the family business, farm, or join the military service. Since our program is designed for everyone to succeed, the majority are not sacrificed for an elite few.

While the overall school enrollment has declined by 14 percent since 1978, the junior class chemistry enrollment has gone from a low of 29 percent to the current high of 50 percent. Next year's projected enrollment is also 50 percent.

Our students are enthused about chemistry. Each class wants to know if they too can get on the cover of a national magazine or have a picture in our local paper. One class launched a seven-foot hot air balloon in 20-degree weather while posing for pictures so they could get published. The students are also proud to see their pictures of labs and activities displayed on our bulletin board. My students especially look forward to our nontraditional labs and science movies.

Source of Conflict

Even though the program seems very successful, I have received far more criticism than support from our faculty. Some of the criticisms include:
- There are too many students taking chemistry II. There are not enough academically-capable students to maintain such a large enrollment.
- The chemistry classes should not have a money-making

project.

- School time should not be used to take a field trip to Marble Hill Nuclear Power Plant.
- Computers should not be purchased by the class, but should be considered as "necessary" items to be purchased by the administration.

Our science budget was slashed this year, so finances may be a future problem area. Although this program does not require vast amounts of money, it is necessary to replace glassware, chemicals, and equipment as in any other program. The radiothon money-making project may become more of a necessity.

Another problem area could be with the administration. They need to know the objectives of the program. This way they will understand why there is a seven-foot hot air balloon being launched in the parking lot, why we do non-traditional labs, and why we have a radiothon.

The program could be undermined by administrators and faculty who believe a class should be taught by strictly traditional methods. This problem was partially solved at Scottsburg by the enthusiasm the students show for the program and the heavy enrollment for chemistry I and II.

This enthusiasm was also demonstrated in nonchemistry students using the floating penny. We had nonchemistry students and teachers come in our room to see and feel the "hollow" penny. In this lab we extracted the zinc from a new penny, and all that remained was the copper shell. Students took their pennies with th and they showed and discussed the pennies with family and friends. In this lab the students learned about a single displacement reaction and percent composition. A lab that generates so much discussion and enthusiasm is usually not achieved in a traditional setting.

A Concluding Thought

To keep the program healthy, it is imperative to continue with high-interest labs and activities. This requires a great deal of creativity. Some of the ideas can be generated from science periodicals, but to keep the enthusiasm necessary to maintain a program of this type, continuing education, as well as attendance at science workshops and in-service programs is extremely important.

Chapter 7
Chemistry: Three Courses, Five Levels

William Bleam
Radnor High School
130 King of Prussia Road
Radnor, Pennsylvania 19087

Radnor Township, a 14-square-mile suburban community 14 miles west of Philadelphia, is primarily residential but includes a number of corporate headquarters and smaller businesses. The population center is Wayne, one of six towns located totally or partially in Radnor Township. The others are St. Davids, Radnor, Bryn Mawr, Villanova, and Newtown Square.

The township's population of 27,600 live primarily in single-family units with an increasing apartment/townhouse segment. Property values are high, as is the educational background of the population. More than half of Radnor's residents hold bachelor's degrees.

The Radnor Township area provides its residents with many opportunities for learning, recreation, and entertainment. Several colleges and universities are located nearby. Libraries are readily available. Philadelphia offers a wide variety of cultural and entertainment opportunities. The Pocono Mountains and the New Jersey shore resorts are within easy driving distance. The township has an active parks and recreation program.

Radnor High, with just under 1,200 students in grades 9-12, is a comprehensive high school offering nearly 200 courses. More than 85 percent of its graduates pursue higher education.

The science department offers a four-year sequence of physical science, biology, chemistry, and physics. All courses are taught at several ability levels, including advanced placement and survey courses. Students planning to take advanced placement courses in their senior year are encouraged as freshman to enroll in an advanced/honors program, skipping the 9th grade physical science course in order to take honors biology.

Our Program

The chemistry program at Radnor High School consists of three courses offered at five ability levels. Chemistry is first taught as a process and then as a body of knowledge. Radnor students learn a set of science skills which they can use to gain information about the world around them. The specific content of each course is not an end, but a beginning. The content gives students the background information they need to continue seeking answers to questions about occurrences in their daily lives. It is hoped that this process will continue long after students have left the science class.

Students in 9th grade take physical science and students in 10th grade take biology (except for accelerated honors students). Chemistry is strictly an elective course at Radnor. Even so, the number of students taking chemistry in this program is large. With the total high school population reaching only 1,160 students, 263 students have elected to take chemistry this year at the various levels offered. Of this number, only 16 are enrolled in a second-level course. Thus, 247 students are in the first-year introductory courses.

By the time the present junior class has graduated, 250 of the 304 members of this class, or roughly 80 percent, will have taken at least one chemistry course at Radnor. This percentage has remained relatively unchanged throughout the 1960s, 70s, and into the 80s, despite the nationwide trend toward declining interest and enrollment in science courses during this time period.

The majority of students selecting introductory chemistry (163 out of 247 this year) elect to take the regular college-preparatory course, Chemistry 332. The course's history is integrally tied to the CHEM Study program developed in the early 1960's. The philosophy of that national effort to upgrade science education profoundly affected the teaching of chemistry at Radnor.

Essentially, the CHEM Study philosophy changed chemistry from a "show and tell" attitude—presenting a series of isolated facts to be memorized, with students having little or no understanding of the relationship between those facts—to one of "do and wonder," a continual process of asking why, collecting data, proposing explanations, and the further testing (by collecting more data) of those possible explanations. The philosophy of chemistry at Radnor is to have students learn chemistry by DOING chemistry. To that end, the laboratory is an essential ingredient in all chemistry courses. CHEM Study has been criticized in the past for its stress upon theory and abstract concepts at the expense of descriptive cnemistry. The teachers of the three college-preparatory levels of chemistry have done much to make CHEM Study more appealing, useful, and understandable to the average student, with many demonstrations, models, and analogies which relate to the students' interests and the world around them. As a result of these efforts, while students still find the course difficult, they also find it challenging and interesting.

The lower level course of college-preparatory chemistry, Chemistry 333, is identical in content and approach to the regular section. The only difference between the two courses is that Chemistry 333 meets seven periods each week, while Chemistry 332 meets six periods each week. This course accommodates those students who feel they need a strong background in chemistry to go on to college, but who do not feel confident in their mathematical and reasoning abilities. The one extra period each week was scheduled into the course to allow the teacher to give students selecting this course extra in-class practice and individual attention. Over the years, this course has always drawn enough students to offer at least one section. In this way the science department has not had to compromise its standards (especially on college transcripts), and yet students can feel the warm glow of success, even if it takes them a little more time.

Honors chemistry, Chemistry 330, is chosen by the gifted and those students who have an avid interest in science and are highly motivated to learn chemistry. The content of the three introductory courses, 333, 332, and 330, is identical, except that Chemistry 330 provides students with avenues to pursue their search for knowledge in several unique ways.

In 330 the course content is developed in a somewhat more historical vein, treating topics such as atomic theory and the periodic table as ever-changing concepts that have developed through time and man's incessant search for knowledge. Students learn that science is ever-changing. In this way, students see that hypotheses are only as valid as the data base (experimentation and testing) upon which they are founded. In-class coverage of course material relies, to a far greater extent, upon student involvement in discussion topics, and to a much lesser extent upon the lecture style of presentation.

Several extra chapters are discussed in Honors Chemistry 330. Secondary bonding topics are covered in honors chemistry, as is a fairly detailed study of oxidation-reduction reactions. These topics are glossed over, if treated at all, in the other two classes.

Finally, students in the honors chemistry classes do outside-of-class work as part of their grade, in a "contract" format. These required points can be accumulated in many ways. Students can perform recommended laboratory experiments; do individual research projects both in the laboratory and in the library; build molecular models; read magazine articles and report orally about their contents; write computer programs illustrating chemical concepts; design programmed instruction modules; and design informative bulletin boards. The only limit to these contract requirements is students' imaginations!

Survey of Chemistry 366 is one of three semester-long courses designed for students who may intend to go on to college, but who have limited abilities in mathematics and the higher-level thinking skills. The other two courses are Survey of Astronomy and Survey of Geology. All three courses meet five times per week and try to include as much laboratory work as possible. Particularly in Survey of Chemistry, laboratory activities play an integral role in presenting course material.

The approach used in this course is an effort to relate chemical concepts to everyday occurrences. Abstract concepts are kept to a minimum; the mole concept and molar mass calculations are not discussed. Instead, concete ideas are presented and related to students' experiences. Swimming pool chemistry, for instance, is shown to be a real application of acid-base chemistry. Soaps and detergents, the chemistry of steel-making, and chemical waste are examples of other topics brought from real life into the classroom.

Finally, Advanced Placement Chemistry 370 is offered to senior students who have completed the regular introductory sequence of biology, chemistry, and physics. The course is taught with all the rigors of a college freshman chemistry course. Laboratory work occupies a large portion of class time with students meeting for seven periods per week. Two double periods give ample opportunity for students to pursue laboratory research. A very brief review of first-year high school chemistry serves as the foundation on which students will build their understanding of physical chemistry and organic chemistry. A qualitative analysis scheme is one of the extended laboratory activities pursued by these students. They also do extensive instrumental work in the laboratory, using Spectronic 20 and ChemAnal spectroscopes, pH meters, centrifuges, and analytical and digital balances.

Personal Needs

Each of the three chemistry courses offered at Radnor High has a carefully chosen textbook which presents course materials at a level commensurate with the majority of students' abilities. Advanced Placement Chemistry has a college-level text to ensure the quality of course content. Text exercises and problem sets are carefully correlated with reading assignments in each course. In addition, extra problems have been generated for several courses to give students the opportunity to do more practice problems. For Chemistry 332 and 330, many readings from outside sources have been secured. These provide students with extra exposure to chemistry topics not ordinarily covered in the course, or at least give them different viewpoints on topics that are covered in the course.

Students are expected to write reports of their laboratory experiences, forcing them to organize information they have collected. This organization might take the form of graphs, charts, or data tables. Students also construct tables from data collected during teacher demonstrations in class. Both the midterm examination and the final examination are cumulative tests.

Students draw conclusions about their experiments and about the meaning of their work. Several of the experiments in the beginning of 330, 332, and 333 are designed to elicit student ideas about the causes of various phenomena. This requires that students hypothesize, test their hypotheses, and then dispose of or at least alter the hypotheses on the basis of new observations.

One experiment dealing with phase changes between gases and liquids requires students to explain the observations noted in the (almost) perpetual motion of the "dunking bird." After many trials involving observations and hypotheses, testing of these hypotheses, and finding them lacking in one respect or another, students finally realize that observations are not always easy to explain. Students make the same type of observations concerning the periodic table and find that there, too, observations are not always easy to explain.

Much of the experimental work done by students in the laboratory involves inductive logic in trying to come to some general hypothesis or theory on the basis of specific information gathered. The very concept of predicting an unknown entity on the basis of some generalization, which is an essential part of the process of science, exemplifies the deductive thought process.

A class discussion early in the academic year deals with the question, "Why does a candle flame go out when a glass is placed over the candle?" Several days of discussion ensue, in which students are allowed to brainstorm all possible explanations. These usually lead to other questions that demand further experimentation in order to explain these new observations. This whole procedure typifies the scientific process which is promoted throughout the course.

Yet another example of this same type of idea generation involves student explanation of the cause of the decrease in the supposedly constant value of 22.4 litre-atmospheres for a mole of gas as the external pressure on that gas is increased to pressures approaching its critical pressure. Class discussion on this type of topic can be very rewarding to the teacher, especially in the honors program, as students show intermittent flashes of inspiration.

In each chemistry course, teachers present students with analogies of chemical phenomena which apply directly to their lives. One area in which analogies seem especially relevant and interesting is the gas laws. Balloons, tires, pressure cookers, and scuba tanks are all items students come in contact with in the real world. These analogies certainly help to explain the rather esoteric gas laws. But more than that, they help make the class interesting to students by showing them that chemistry really does touch their lives in many ways.

Several magazines available to students in these courses also show how chemistry affects their lives. A complete collection of *Chemistry*, an ACS publication no longer being published, is available to students. Many articles have been chosen from this magazine for student perusal. *Chem 13 News*, a University of Waterloo publication, is also available, as is *ChemMatters*, a brand new ACS publication designed specifically for high school chemistry students. Approximately 35 students have subscribed to this publication through the chemistry teachers at Radnor this year.

Although the text material is academically oriented in the three college-preparatory courses, frequent use is made of articles in newspapers and magazines relating to chemistry in the world and local news. The acquisition of a large photocopier has generally helped the teachers to disseminate this type of information not only to their classes, but also to the other teachers in the department. Sharing information in this way guarantees that all students taking chemistry have the maximum exposure to chemistry in the news. Students have made collages in Survey of Chemistry to bring attention to newsworthy chemical issues. Bulletin boards are another way to expose students to the exciting world of chemistry. Many bulletin boards are relevant to students, yet teach chemistry at the same time.

Class discussions on specific topics of particular interest to individual teachers frequently add interest to normal classes. Examples of these topics include nuclear power, chemical waste treatment, acid rain, and other forms of pollution.

An example illustrating the use of scientific and technical information in the decision-making process is a class discussion in Survey of Chemistry regarding water quality control studies to help students (and scientists) decide what quantities of chemicals can be tolerated by stream life. Studies of pH in swimming pools and of acid rain complement the water quality control study. New topics concerned with societal issues are included in courses where appropriate. An example of this is the inclusion last year of a four-week unit on petroleum chemistry and the issue of whether to burn petroleum or use it to build the synthetic materials upon which U.S. citizens have come to depend so highly.

The chemistry program at Radnor requires that students take all three major sciences—biology, chemistry, and physics—before they are allowed to take Advanced Placement Chemistry. By promoting a broader perspective on societal issues, students can see more clearly the interrelatedness of most chemistry-related societal issues, and the need to treat these issues in a multi-disciplinary fashion.

While the rigorous content of most of the chemistry courses precludes taking much class time for resource persons, other avenues exist within the school for such presentations. The Library Forum, for example, offers students programs of special interest throughout the year, not only in science, but frequently science-related. Typical programs that fit here deal with the EPA, environmental pollution, and nuclear debate. Chemistry teachers have worked to bring the school special programs, such as a NASA presentation. The Science Club has also been instrumental in bringing in speakers on current chemistry topics.

Career Education

Teachers disseminate literature received from colleges and professional and trade organizations such as JETS and ACS's chemical career guidance package. Teachers also encourage students to attend science career conferences at local high schools. In addition, teachers are developing relationships with neighboring industries and colleges to take advantage of the expertise of the scientists in these organizations.

Academic Preparation

Several conceptual schemes are developed throughout the college-preparatory courses. These include the development of the periodic table to include electronic structure as the basis of chemical bonding; reaction rates as the basic explanation for equilibrium, which leads to solubility, acid-base chemistry, and oxidation-reduction reactions; and a discussion of the phases of matter to attempt to explain bonding at the macroscopic level, leading to a discussion of reaction rates. These schemes are integrated into a cohesive package encompassing almost all fundamental chemical principles.

Tests stress the application of concepts to new situations, not just the memorization of isolated facts. For instance, we use le Chatelier's principle to discuss solubility of solutions. The use of group hypotheses formation in class discussions fosters the development of the thinking skills needed to apply knowledge in new contexts.

The spirit of inquiry is found in all five levels of chemistry at Radnor. The opening laboratory exercises of the introductory course set the tone for learning by the inquiry method. All other experiments exhibit the search for regularities, the formation of hypotheses from these regularities, and the subsequent further testing of these hypotheses. A film shown to the Survey of Chemistry students, "Marie Curie—A Love Story," exemplifies the spirit of inquiry and the scientific process. Two specific values are stressed: the need to record data accurately, and to do all necessary calculations using only the data obtained in the laboratory, not the expected results. Grades on laboratory reports are based not on right or wrong answers, but on what is right for the students' individual data.

Strengths and Weaknesses of the Program

Overall Program

Strengths

- Strong academic background for future work
- Good laboratory program and facilities
- "Extra" periods for labs
- Enthusiasm, competence, and education on level of faculty
- Good community relations
- Continuing support for maintenance
- Availability of petty cash fund
- Student laboratory assistants
- Computer facilities

Weaknesses

- Limited number of field trips
- Little time in class for career guidance

Honors Chemistry 330

Strengths

- Historical approach gives students flavor of science
- Contact work helps to broaden "data base"
- Exposure to other viewpoints through outside readings
- Emphasis on student design of exposure to computer programs
- Rigor of mathematical approach
- Study of error analysis
- Greater emphasis on self-learning

Weaknesses

- Time constraints of students taking too many honors courses
- May not be challenging for gifted students

Chemistry 332

Strengths

- CHEM Study approach
- All students are invited to take chemistry
- High teacher enthusiasm
- Analogies to stretch student imagination
- Good teacher/student rapport
- Small class size
- Direct access to CHEM Study films
- Availability of teachers for help within and beyond the school day
- Quantity and quality of laboratory experiences—well-integrated and timed with text work
- Lay readers to correct lab reports
- Use of class results to discuss outcome of lab work and to stress concepts—not what is supposed to happen, but what really DOES happen.
- Laboratory work is designed to be both safe and cost-effective, using simple equipment
- Tests require work which is awarded partial credit; tests are then reviewed and discussed in class
- Word-processing ensures continual change in teacher-generated, student-used materials
- Laboratory work is constantly alluded to in later class work
- Extensive Xerox capabilities allowing widespread dissemination of chemistry-related materials to students

Weaknesses

- Little room for student creativity
- Occasional split of double laboratory periods due to rotating schedule
- Little organized opportunity for independent research

Chemistry 333

Strengths

- Seven periods per week
- College-preparatory content

Weaknesses

- Size of class, usually begins large
- Diverse background makes course challenging to teach

Survey of Chemistry 366

Strengths
- Cooperation among teachers
- Use of chemical games
- Course career orientation
- Text shows student as citizen of technological world, not as future scientist
- Text is geared to practical applications of chemistry to students' world
- Text contains career sketches, biographical sketches, and historical highlights
- Films enhance the image of scientists as human beings
- Stress on home chemistry
- Nonmathematical approach
- Experiments adapted to students' ability to read and comprehend instructions

Weaknesses
- One semester is not long enough
- Diversity of ability levels makes planning difficult
- Some students' lack of motivation dampens teacher enthusiasm

Advanced Placement Chemistry 370

Strengths
- Seven periods per week allows two 90-minute lab periods
- Five preparation periods for teacher, just for AP
- Strong laboratory orientation
- Heavy reliance on modern instrumentation and glassware; e.g., Spec 20, pH meters, etc.
- Text is good, solid college text
- Small class size (14 or less) provides students with individual laboratory stations
- Caliber of students is very high

Weaknesses
- Insufficient challenging outside reading materials

Origin and History

The chemistry program at Radnor High School in the 1950s was typical of most programs at that time. Chemistry was taught essentially as a body of knowledge to be learned in Physical Science I, simply a smattering of the material being taught in the college-preparatory course. This course, too, was taught in a learn-by-memorizing fashion. This whole philosophy changed with the launching of Sputnik.

A brand new approach to the teaching of chemistry came with the birth of CHEM Study, a national effort sponsored by the National Science Foundation (NSF) in the early 1960's. Mr. Ellis Kocher, a Radnor chemistry teacher, was asked to be one of 45 teachers on the east coast to pilot this program. (It had already been tried for one year in the west, where it had originated.)

One reason a teacher at Radnor was chosen was that Radnor had (and still has) a reputation for being willing to try innovative ideas. After some persuasion by Kocher, Dr. Edward Rutter, then Superintendent of Schools, agreed to allow Radnor to become one of the first schools in the nation to teach this new course which was to become the standard of chemistry programs for many years.

Kocher attended a summer institute at Cornell University in the summer of 1961 to become familiar with the program. Dr. J.A. Campbell, the director of the project and principal writer of the text, ran the program at Cornell. That fall Kocher began teaching CHEM Study in Radnor. In addition, he attended weekly critiquing sessions at the University of Pennsylvania with 10 other teachers to evaluate the progress and relative success of the new program. The following year, Radnor's entire college-preparatory offering was CHEM Study chemistry.

Kocher also taught at two CHEM Study institutes at Thiel College during the mid-sixties. This gave him a chance to interact with teachers from other parts of Pennsylvania and Ohio. This experience stengthened his belief not only that the program was worthwhile, but that it could be taught in a wide variety of schools, many with limited resources.

In 1964 teachers saw the need to offer some students the chance to spend more time at problem-solving techniques. Chemistry 333 arose at that time, providing seven periods per week for those students. The low-level chemistry course was still given as Physical Science I. (Physical Science II was the physics counterpart.)

In the late 1960s, teachers in the science department recognized the need to offer a course for further study in the sciences for students who had taken all three major sciences. Advanced Science consisted of three trimesters, one each of biology, chemistry, and physics, or options to take two trimesters of one science and one trimester of another. This decision was made to correspond with the philosophy within the science department that students need a broad background of science in high school. The department believed that students have ample time to delve more deeply into one discipline in college. The level of chemistry taught was advanced placement; however, this course was given in two-thirds of the time of a normal advanced placement course.

As student enrollment increased, numbers became sufficient to offer actual advanced placement courses at the senior level. In 1980, Advanced Placement Biology was offered for the first time; Advanced Placement Chemistry followed in 1981.

Physical Science I was phased out in the mid 1970's as a trend toward semester courses in many disciplines arose. In its place, students were offered Survey of Astronomy, Survey of Chemistry, and Survey of Geology, all semester courses. These courses were offered in an attempt to provide unmotivated students with courses which might pique their interest by making science relevant to their everyday lives. Teachers were given paid summer curriculum time to make the program changes needed to produce these semester courses.

Honors Chemistry 330 developed in 1976 as a result of a national drive to meet the intellectual needs of gifted students, although students who were not identified as gifted but who were highly motivated in science were also allowed to enroll. The advent of a system of weighted grading the next year resulted in a substantial increase in the number of students selecting this course. Weighted grading serves as an inducement for students to choose this course, as an "A" grade is valued as a 5.0 in calculating class rank, as opposed to a 4.0 for an "A" in other courses.

Radnor teachers have always been willing to change when change is necessary, and Radnor's administrators have always been willing to help teachers in any way deemed appropriate to effect these changes. One of the ways teachers are able to keep up with the changes going on in science education is to attend conferences. Radnor science teachers try to attend conferences as frequently as possible, and here again, the administrators have provided reimbursement for most expenses teachers have incurred.

Since 1981, I have been active with the ACS Education Committee and recently was asked by ACS to serve on a writing team which produced two units, one on petroleum chemistry and the other on the chemistry of metals. These units will be included as part of a textbook designed to profoundly alter the teaching of chemistry today, perhaps as drastically as did CHEM Study in the 1960s. The new course will bring social issues into the classroom as part of the text, asking students to gather information, both scientific and social, and then debate these issues intelligently. The first of these two units was field tested in Radnor during the 1982-83 school year. The text itself is to be published during the 1984-85 school year.

Thus, just as it was in the 1960s with the advent of CHEM Study, Radnor is at the forefront of science education.

Support Materials

The factors which contribute to the success of the program are many. Some relate to the nature of the students taking the courses, others to the students' parents; some relate to the administration, others to the teachers; and some are inherent in the courses.

Radnor students generally have a high regard for education. This attitude has been instilled in them by their parents, most of whom are professional people. Students come to class wanting to learn. Many have already chosen a career. They know they will have to work hard, particularly in the sciences, to succeed in college and medical school. These students have seen that education has provided their parents with a very comfortable lifestyle, and they are motivated to achieve these same goals in their own lives.

Parents in the district are supportive of education and teachers. Any academic or disciplinary problems with a student can generally be solved with a phone call to the student's parents. All this makes teaching at Radnor less worrisome, but a considerable challenge as well. The parents have a vested interest in the welfare of the school system, and thus take active roles in PTA meetings, school board meetings, and education. Parent groups have accomplished projects which other groups, including teachers and administrators, were powerless to effect.

The administration at Radnor supports the chemistry program in many ways. They offer teachers a partial tuition rebate for taking graduate courses which relate to their teaching. An innovative approach to furthering teachers' education and simultaneously meeting the specific needs of Radnor Township schools is the administration's design and support of courses taught within the district by other teachers who have expertise in a particular area. The courses which have helped the chemistry teachers at Radnor most are those which deal with using computers in the classroom, and with programming in BASIC.

The administration has given at least partial reimbursement for expenses related to travel, meals, lodging, and registration fees for teachers attending educational conferences. Substitute teachers are provided in these instances. Course revisions and new course development are supported by paying teachers to work during the summer to effect these changes. If necessary, release time is given to teachers during the school year to work on curriculum review and modification. Support is also shown by providing secretarial help during the summer to type, photocopy, and collate materials developed during the summer curriculum work.

While funds are established each year for the purchase of supplies and equipment to maintain our present curriculum, the administration realizes that these funds are not always sufficient to cover the cost of beginning a new course. They have solved this problem by providing seed money for the first year start-up costs. By the second year, they assume that the costs of maintaining the course can be incorporated into the annual science budget. A small petty cash fund buys perishable and incidental supplies needed throughout the school year that are more conveniently and economically purchased at local stores.

The administration has provided support for the chemistry program in another unique way, the lay reader concept. We have professional scientists or engineers in the local area read and critique student laboratory reports. This gives students a "second opinion" on the quality of their work, gives teachers more time to help students after school or during free periods, and involves community members in our program.

Another good feature of the chemistry program at Radnor is the corps of students who serve as laboratory assistants, providing services such as preparing solutions, setting up laboratory materials and equipment, designing and testing experiments, and producing audiovisual materials. In return for their efforts, participating students are awarded work-experience credit. In this position, they learn from working closely with the teachers, both about chemistry and about dealing with people.

Several teachers in the department have written their own study guide books to accompany their courses and the administration has always supported these people by supplying special pre-punched paper and binders for the booklets, as well as some secretarial help to get the work typed.

The teachers at Radnor have worked hard over the years to earn the support of the administration by being continually at the forefront of chemical education. They strive to learn as much as they can to enable them to provide the best possible education for Radnor students. The teachers have participated in summer institutes, academic year institutes, graduate courses, workshops and demonstrations, conferences and conventions. They take information, and give information as well. They have made presentations at conferences; they have run workshops; they have run national conferences. Their eagerness to share ideas with colleagues across the country has made them better teachers. The sharing gives them new ideas to try out in their classrooms, and continually renews their enthusiasm. Their membership in professional associations such as ACS and NSTA also provides them with new ideas and techniques to try in the classroom. The active involvement of the chemistry teachers in their professional endeavors ensures that Radnor Township students are receiving the most modern, yet most academically sound chemistry program available anywhere. Radnor students ultimately reap the benefits of having enthusiastic teachers.

Transporting the Program

This program has unique features and features common to other schools' chemistry programs. Individual courses within the program are not so different from individual courses at other schools; it is the combination of so many different levels of chemistry into one program and its subsequent appeal to students of all ability levels that makes the Radnor chemistry program special.

Specific information within any of the courses could easily be transported to other chemistry programs in other schools. The CHEM Study philosophy of open-ended, discovery-oriented learning can be taught; several teachers in the Radnor program have had the experience of doing just that. Mr. Kocher has taught summer institutes in the CHEM Study approach, and I have held numerous workshops for other teachers on various topics in the program.

Sharing ideas is the best way of encouraging teachers to try new ideas. Our experiences working at and running conferences has helped to further the concept of teachers helping teachers by sharing ideas. My involvement in local, state, and national conference presentations has helped me share ideas with others and increase their enthusiasm.

Workshops where teachers make models and take them back to their school will also increase enthusiasm. For a nominal fee, teachers can spend a whole day (Saturday, no less!) making models for immediate use in their classroom. These idea-sharing and material-sharing workshops multiply the knowledge and enthusiasm of one teacher 50-fold or more.

In this manner we hope the excellent program at Radnor will be transported to other schools.

Chapter 8 Individualized Chemistry

David Byrum
Globe High School
501 Ash Street
Globe, Arizona 85501

Remember chemistry in high school? Was it the course that you loved, or was it the one that made you pray that the end of the school year would hurry up and come?

The chemistry course at Globe High School attempts to provide a course in which every student can succeed and, in the process, learn to enjoy chemistry. Organized along the ideas of Bloom, Keller, and DeRose, the course is divided into 30 mastery units with 15 or so optional units available as a supplement. Each unit is a self-contained package of instructional objectives, learning activities correlated to the objectives, and a self test also correlated to the objectives. Students progress through the course at their own rate, earning grades of A, B, C, or Incomplete based on the number of units they complete each semester. Incompletes are changed to C's when the minimum required number of units are completed. All students who want to will eventually pass the course with a measure of chemical understanding.

This individualized approach has been in operation for the past 12 years, with 900 students taking the course in that time. Student evaluations of the course are generally positive and supportive of our overall goals.

Globe is a rural, copper mining community of 48,000; the high school has been in existence since 1914. The community is family-oriented, with many generations of families having attended Globe High School. The majority of students do not attend college after high school but instead go into the military or, in past years, to work for the copper mines. For the past several years, however, with the depressed copper industry causing a slowdown in mining-related employment, students have not been able to get the traditional mining job and are looking for employment out of town.

As the instructor of these students, I am faced every year with the task of piquing the interest of the curious while motivating and offering hope to the fearful. I believe that if I provide each student with a well-planned and systematic approach to learning chemistry, one which gives the student a choice in how to go about learning a topic, then that student will have the best chance possible to succeed and learn chemistry.

As DeRose stated in 1969, "Students must be faced with situations in which they look to themselves for solutions if they are to develop their potential as contributors and creators." Students in the chemistry course at Globe High School make choices daily.

Through a variety of instructional modes, such as audio, visual, and kinesthetic, the student has a greater opportunity to learn the subject material in a manner that will "stick" longer. The program uses a variety of activities to help the student learn a particular objective. Providing for this range of instructional support materials involves a long-term commitment on the part of the school district. This support, however, is no different from that which is normally provided each year. The program requires no additional support. Every year, the high school instructor submits requests for supplies for the following school year. Using this program, an instructor pinpoints which areas in the chemistry curriculum need additional support materials. Thus, the requested materials will have an immediate impact on next year's chemistry students.

Our Program

This program has as one of its main goals the development of self-worth, self-discipline, and responsibility in the students. Our unit construction emphasizes the ability to relate readings, labs, and multimedia materials to the objectives being studied. The student must learn to look at the unit's objectives, understand them, do the activities, and synthesize them into an explanation of the original objectives. The student needs choices in order to learn the joys and sorrows of making decisions.

This program emphasizes topics central to an understanding and appreciation of chemistry for both the layman and those students who may take further science courses in college. Chemical nomenclature and equation writing, chemical calculations, periodicity, chemical bonding, gas laws, acid-base solutions, and redox reactions, as well as a variety of additional topics such as the shapes of molecules, solution types, and organic chemistry are studied. Students complete more than 50 laboratory experiments in this course. In every unit students perform at least one experiment, and in many units two or three. The organization of unit activities emphasizes the integration of ideas by the students. A student who can learn to "speak" chemistry and leaves this course with an understanding of the major concepts of chemistry should be well prepared for any educational future.

Each chemistry student at Globe High School will progress through at least 14 units each semester. Every unit introduces the student to the topic from a consumer or humorous point of view. Next, the unit's objectives tell the student the minimum level of learning that will be expected. Learning activities are keyed to the objectives. Most objectives offer a choice of auditory, visual, or kinesthetic activities. A student can listen to a taped lesson, view a filmstrip, read a programmed instruction book, or do a lab experiment. Since 1978, the use of computer-assisted instruction has been added to the "hands-on" choice of activities. A student can "do" a lab, "do" a computer program that helps in learning a particular skill, rerun an experiment that may have failed in the lab, or even learn to program the computer to do something new.

When more than one option is available to learn a particular objective, the student must make a choice. As the school year progresses, the student becomes more aware of a personal learning style and thus becomes better at learning. Students who are having problems can select an alternate activity, one at which they can succeed. A positive Catch 22 situation! Because they choose which activity to do, they are now more committed to doing it than if I had assigned the activity. I believe this is one of the greatest benefits of an individualized, mastery-learning type of course. The students take an active part in their learning. Because they have to constantly choose how they are going to learn, the students become more willing to take the responsibility for their own success or failure.

I am always impressed at the end of the school year with the growth that has occurred in each student's ability to be self-motivated. At the beginning of the school year, most students are willing to sit and wait for someone (me!) to tell them what to do. By the second quarter, most of these same students are able to enter the classroom, get themselves organized, and begin their instruction without being told. I believe this is what education is supposed to be all about. Schools should help a student learn to be not only knowledgeable, but self-motivated and self-regulated as well.

After taking a self-test, students bring all of their work to me for evaluation. If the lab reports are written coherently and make sense, if the assignments have been done and show a rising level of learning, then the student takes the unit quiz. The student must score at least 90 percent. A student who does not achieve 90 percent will be asked to either redo some activity, do a previously skipped activity, or be assigned some additional activity. The next day an alternate test can be taken. The student will keep being retested until the objectives are learned, as shown by achieving a 90 percent score on the unit quiz.

In each semester 15 units are covered, with every 5th unit a review of the previous units. In this way, even the topics studied at the beginning of the school year are reviewed at the end of the school year.

The operating mechanics of a course like this are almost as important as the course materials themselves. For this course to run smoothly and to provide an environment in which the students can learn to become self-directed, most of the instructional materials must be readily accessible to the students. For example, most of the lab supplies for the current units are in labeled boxes on a shelf in the laboratory. When ready, a student finds the correct box of supplies, takes the box to the lab bench, and performs the lab. Each lab also has a storage box in the stockroom, where the necessary chemicals and supplies are replenished and stored when the lab is no longer being performed. Thus, at the beginning of each new school year, the supplies and chemicals for a lab are always ready for use. Similarly, the units for each quarter are placed in a "mailbox" in the classroom for easy student access.

When a grading period comes to an end, students who have done well or who have raised their grade are rewarded not only by the improved grade and knowledge, but also by a letter sent home informing the parents that their son or daughter has done well. For those students who have unfortunately not done as well, a letter is sent home indicating some causes and possible reasons for the difficulties. Along with this letter goes a single-page course description for parents, as well as a copy of the suggested due dates for each unit. This parental contact has been helpful, and many have commented on how nice it is to receive a positive letter from the school! In case there is ever a question concerning the number of units a student has passed, every student has a folder in a secure place, where we store every quiz the student has taken. Every student's grade can easily be verified by double checking the units passed as recorded in the gradebook with the quizzes stored in the student's folder.

This course attempts to provide for a wide range of student abilities and interests. A student who is willing to try can learn as much chemistry as individual ability allows. By choosing from a wide variety of activities, the student becomes more aware of a personal learning style and can make a more knowledgeable choice. Students generally become more self-reliant and responsible for their own learning. And finally, when they leave chemistry at Globe High School, most students seem to have a positive attitude about science and their ability to cope with a science course.

Until this year, chemistry was the only individualized course at Globe. This year another teacher, Neil Friend, and I are rewriting the freshman physical science course in this style. The sophomore biology curriculum is being rewritten as well. The members of the Globe High School science department are believers in student responsibility and opportunity for success. We are striving to use the methods of instruction that will best meet the needs of our students. We believe this method to be our best choice for now.

Physical Facilities

The chemistry room at Globe is a traditional rectangular lab room with seven lab benches around the perimeter of the room and a central area for desks. An adjoining stockroom connects with the next classroom. Storage space is at a premium. (Does anyone have a lab where it is not?) No extra equipment has been purchased as a result of using this instructional method. However, equipment and supplies are put to the best possible use, as all purchases are made because of an identified need and will have an immediate impact on the next year's chemistry students.

Evaluation

Success, like beauty, is in the eye of the beholder. This program works because each student is independent, in control of personal accomplishment, and responsible for learning or not learning. An individual student's success may be measured by the grade received, but it can also be measured by how much the student's study habits improve, the attitude toward science in general and chemistry in particular, and by comparison to performance in previous science courses. When a student makes choices, the teacher is no longer "in charge." The teacher becomes a facilitator; the teacher helps things happen for the student. Not every teacher can become accustomed to relinquishing "iron-fisted control." We all know that very few teachers have this type of control. The students may have their eyes open, but their minds are off in Rio. Once an instructor comes to grips with the fact that students can make good, logical, and informed choices if given the chance, an individualized program like ours is exciting to see in action.

Each student's grade at the end of each semester is determined by the number of units completed.

# Units Passed/Semester	Grade
Required 15 plus 3 optional units	A
Required 15 units	B
14 Units	C
Less than 14 units	INC.

To pass, every student must do at least 14 units. Optional units are required to earn the grade of "A". No one can fail without trying. These units provide opportunities for motivated students to study topics such as "Chemistry of Photography," "Minerals," "Paper Chromatography," "Glassworking," and "Glass Etching," that are not included in the regular units. In addition, the student can earn credit for optional units by going to the nearby elementary school and performing demonstrations for the 5th and 6th grade science classes.

Measuring the success of a teacher-designed program can be a difficult task. Most instructional programs at the local level have not been created with an eye to future research papers or professional evaluation. This program is no exception. The evaluation data for this program are mostly anecdotal.

This program has been in use at the two different schools at which I have taught (five years at Salpointe Catholic High School in Tucson, Arizona, and for the past eight years at Globe High School in Globe, Arizona). As the school enrollment declined in each school, the chemistry enrollment maintained a consistent level. At Salpointe it even increased. From 1972 to 1977 the enrollment at Salpointe peaked at over 1,000 students in 1975 and then began to decline to less than 1,000 in 1977. During these years the chemistry enrollment stayed at five full periods of 22–26 students. In the 1977-78 school year, 20 students enrolled in an independent study advanced chemistry course. The enrollment at Salpointe has since increased to over 1,000 students.

During the five years at Salpointe, the general trend in the grade distribution for the chemistry course was:

Grade	% students
A	36%
B	18%
C	30%
D	1%
F	15%

The past eight years at Globe High School have shown a similar trend in the grade distribution. The main difference is a higher number of students who initially receive a grade of Incomplete. At Globe, this is generally around 18–20 percent of each class. The majority of these students, 13–15 percent, complete the semester requirements and earn the grade of "C". The enrollment at Globe peaked in 1980 at a little over 1,000 students, but has now declined to 895. During these years, enrollment in the chemistry classes increased to around 60 students after the first year and has held steady, even though the enrollment has dropped.

I believe these anecdotal data show that the course attracts and holds onto students who should be taking a chemistry course and, in addition, attracts and holds onto the marginally interested student who takes the course because friends are enrolled.

As Bloom, Keller, and many others have demonstrated over the past 15 years, this approach to learning is applicable to many different subjects and many different settings. By and large, student motivation, work habits, and learning methods (or lack of them) are relatively consistent throughout American high schools. When this teaching method is adopted, the major change required is to modify the selection of activities to reflect student ability and the local supply of teaching materials and supplies.

The cycle of identifying the objectives, creating the learning assignments, and structuring self-tests based on the objectives makes this teaching method successful. This objectives, activities-testing cycle provides a self-motivating force. An instructor who is concerned about student progress has the means to identify which areas of the curriculum cause students the most difficulty and can attempt to correct that area by creating and/or obtaining more appropriate instructional materials. Few other teaching methods have such a built-in self-regulating feature.

Plans for Improvement

Any time an instruction method is used which differs from what the students expect, there is a potential for problems. The single most pressing problem at Globe High School is student and parental apathy. Many students at Globe High School do not like to be academically challenged. They expect high grades with minimum effort, and their parents support this view. I use large numbers of handouts, information sheets, letters to parents, and complete documentation of all of the activities to show students and parents that this method of instruction is superior to traditional instruction.

Lack of communication with students, parents, and school administration is a crucial area of concern. The administration at both Salpointe and Globe have been supportive of this chemistry program, in part because they are kept informed about the course and its purpose. It is a sad commentary on schools that anything different must be constantly justified and explained, but it is a reality that must be dealt with.

Acknowledgements

I would like to acknowledge and thank the following people for making this course possible: Fr. Vernon Malley, former principal of Salpointe H.S.; Sr. Ann Elizabeth Beck, former science dept. chair, Salpointe H.S.; Dr. Lon Luty, former superintendent of Globe Public Schools; Mr. James Rhoades, former principal of Globe H.S.; Mr. John Vest, former principal of Globe H.S.; Mr. Al Luna, former principal and current assistant superintendent of instruction of Globe Public Schools; Mr. Carlos Salas, assistant superintendent K-S, Globe Public Schools; and Ms. Carol Warren, principal of Globe H.S. I would especially like to thank Ted Feragne, English dept. chair of Salpointe H.S., for his time, expertise, and understanding in editing this document.

Chapter 9 Humor in Chemistry

Ronald G. Crampton
Omaha Westside High School
87th and Pacific Street
Omaha, Nebraska 68124

You can see the program at Westside High School is unique as soon as you enter the laboratory. The chemistry team uses an unusual approach. Molecular models made from tennis rackets and balls, hamburgers, and french fries are hanging from the ceiling. Unorthodox model materials provide good examples to help students relate the intangible concepts of quantum theory to their environment.

We also use unorthodox presentations. Dr. Flub, the famed chemistry professor from Slippery Rock University who "won't talk to anyone but a Ph.D. candidate," and Ron Crampton, an earnest, cautious high school chemistry teacher who painstakingly corrects Flub's numerous flubs, have opened the course every September for the past 10 years to cheering audiences of juniors and seniors in the Westside auditorium.

A palatable method of introducing students to laboratory techniques and regulations, the routine begins as I introduce Dr. Flub (played by teacher Louis Niemann) as the expert who discovered the following scientific truths: "All experiments must be reproduced so they fail the same way every time" and "all experiments must be conducted so that you can blame someone else for their failure." Niemann proceeds to break test tubes and beakers, spill toxic chemicals, and misguide himself through a maze of mischief and mistakes as I diligently show Flub and the audience of students the right way to conduct oneself in a lab. "We use indirection to teach them things that might bore them otherwise," Niemann said. "And they remember what they learn in this session."

Students often come into chemistry with the idea that it's impossible—laborious, dull, and complicated. Their parents have said, "Oh, chemistry. That was my hardest subject!" The boisterous opening session relaxes students about the subject and their ability to master it, and gets some hard information out with a light touch. It must work, for the Westside chemistry department rivals any in the country in its ability to attract and maintain student interest. Sixty percent of our students take chemistry, while the national average is approximately 18 percent. More than 400 Westside juniors and seniors are enrolled in chemistry courses this fall.

The chemistry team and curriculum are always open to change and have been evolving over the past 15 years. The curriculum is now a hybrid of

- CHEM Study laboratories;
- CBA laboratories and modeling;
- Traditional and descriptive concepts from the textbook;
- Demonstrations in large group and laboratory;
- Classroom humor related to teachers' personalities.

All have been interwoven to organize high school chemistry into a coherent program, what we call "Our Special Order of Chemistry Concepts."

The Special Order of Chemistry Concepts at Westside

1. Physical and Chemical Changes Symbols and Formulas	3 weeks
2. The Mole Concepts	3 weeks
3. The Gas Laws	2 weeks

4. Solutions and Molarity Precipitation Reaction — 3 weeks
5. Atomic Theory and Periodic Table Quantum Theory — 3 weeks
6. Heats of Reaction and Rates of Reaction Catalyst — 4 weeks
7. Equilibrium — 3 weeks
8. Acids-Bases-Salts — 3 weeks
9. Oxidation-Reduction — 3 weeks
10. The Nucleus — 2 weeks
11. Bonding Theory Ionic-Covalent-Hydrogen — 4 weeks
12. Organic Chemistry — 3 weeks

The list includes all major concepts required for a strong background in secondary chemistry. The order of presentation is unique in several ways.

The first unit is designed to capture the students' interest and overcome their fear that they cannot succeed in or like science and math. The first day they go directly into the laboratory and do the award-winning "Aluminum Recycling Experiment." They see, touch, and smell chemistry from the start and realize that chemistry is a laboratory experience.

The "Mole Concept," which every chemistry teacher knows must be the students' foundation, is done in a manner that provides students with every possible means of relating the mole concept to what they have experienced before studying chemistry. We know every student will internalize the mole concept at an individual rate. By introducing the concept early and including the fundamentals in each of the following units, we make sure that everyone will develop the concept before leaving our program. The mole concept is one of our biggest success stories, and "Harry the Mole" becomes the class mascot.

Atomic theory is not presented until unit 5 in our program. We want our students to experience chemistry in the laboratory before we build the model. Once we start the atomic theory, we have a number of laboratory experiences on which to build this concept. We have developed a unique way to teach quantum theory which we call "Quantum Art." This idea was presented at Chem-83.

We have had the greatest success with bonding theory by introducing it near the end of the program, not at the start. We save this concept until other major concepts have been presented. Then we offer bonding theory to explain what the students experienced in the laboratory. This approach provides students with the opportunity to learn through laboratory inquiry and the chance to do their own model building.

Our program has students with and without a physics background, so we have developed a learning climate with a model curriculum to meet this wide range of background. Students work side by side in our open laboratory concept, but each one has opportunities to develop the big concepts at an individual rate according to past experiences and present motivation. The heterogeneous mix in our three-teacher program provides good models for students and teachers.

This team-taught laboratory and conference approach to chemistry teaching emphasizes practical and environmental applications. Students attend an 80-minute large-group session with lectures, films, and exams, followed by a 40-minute small-group session the same day. In the small group, instructors and students pursue topics in depth. Two 80-minute laboratories each week complement the large and small groups.

Each student keeps a supervised notebook, writes a formal paper, creates a poster, and develops a research folder. The paper, poster, and folder all focus on a single element; each student becomes an expert on at least one element. Students may also present an oral seminar on their element. They are encouraged to do independent study activities, once the required work has been completed.

The Element Search

Incorporating industrial and descriptive concepts into a chemistry program provides an avenue to help the student build a deeper appreciation for how fundamental scientific knowledge is turned into technology. This project appears to be a relatively easy way to provide some industrial applications for the student, with the additional benefits of giving experience in writing and oral presentations.

The project has been shared with fellow chemistry teachers at various meetings:

- ACT-ACS meetings in the Omaha-area high schools—past two years.
- ACS Midwest Meeting, University of Missouri—1981.
- GNATS Annual Fall Meeting—1982.
- ACS Midwest Meeting, Kansas City—1982.
- KATS Meeting in Junction City, Kansas—1983.

The response I have received from fellow chemistry teachers has been very rewarding. The Element Search is a low-cost project any secondary chemistry teacher could add to an existing program. Teachers who have used the project say it helped teachers and their students.

Societal Issues

An excellent chemistry program provides opportunities for students to become aware of chemistry-related societal issues and seek solutions. The chemistry program at Westside has a strong thread of science and society built into the framework. The team leader spent two summers at Knox College attending the Science and Society Institutes under the able direction of Dr. Herb Priestley.

The program stresses that chemists must have a strong interest in how their work is used. All of us must be concerned with how fundamental scientific knowledge is turned into technology, desirable or otherwise. Scientists have training that helps them judge the amount of scientific, sociological, and emotional character in a public problem. They should be in the forefront of every effort to make sure that technology serves humans, rather than vice versa.

A number of laboratory experiments were written by the team to help students better understand chemistry-related societal issues.

These experiments include:

- Aluminum recycling;
- Dissolved oxygen;
- Aspirin synthesis;

- Omaha's water treatment;
- Vitamin C investigation;
- Drain cleaner investigation;
- Vinegar investigation;
- Car battery investigation.

Students like societal issues. Here are some of their comments on the subject:

"Chemistry has broadened my perspectives about nature and the uses of it. It seems that everything, plant, vegetable, or mineral, can be used in chemistry. And, in fact, I think that is what chemistry is about, opening eyes to see how useful our resources are and how they are applicable to all walks of life. Chemistry has truly been an enriching class." Dave Spence, Class of 1984.

"It taught me a lot about how the world works around me. It was interesting and informative. I never knew that chemistry or science played such an important role in the environment." Laurie Granlund, Class of 1984.

"Chemistry has really enriched my life. It has helped me to be a better consumer because I can understand how some things are made, which materials can be efficiently recycled, and which chemicals may be harmful. During the dissolved oxygen unit I learned things about nuclear plants that I didn't know before. If there comes a time when I have to vote on an issue like that, I will be better informed. Everything in life involves chemistry, so it is an important subject." Julie Paluka, Class of 1984.

The chemistry team at Westside believes chemistry is for people who want a deeper and more intensely colored view of their environment. It is for those to whom people and ideas are both important, and who care about the quality of modern technological life and their contribution to it. It is for people who value their own versatility, self-understanding, and honesty. It is an excellent training ground for the kind of person we will need in large numbers in the years to come, if we are to solve the problems that confront us.

Careers

The chemistry program provides students with activities that describe careers in chemistry and chemistry-related fields.

In addition, we invite professional chemists to participate in the Chemistry Field Day. The team leader at Westside is the past chairman of the Omaha section of ACS, a relationship valuable in bringing career information to secondary chemistry students. Through "The Element Search" and "Meet the Chemist Program," we believe our students are richly exposed to careers in chemistry and industrial applications of chemistry.

The Westside chemistry program provides two levels of chemistry experiences, one for students who have not taken any science except biology in 9th grade and may or may not attend college, and another level for students who have taken physics and plan to attend college. Both classes share a common laboratory, but the exams and homework are varied in the two programs to meet the needs of the students.

Again, the success of this dual program is best expressed by the students themselves.

"I'm happy I took chemistry for a lot of reasons. I think first of all the academic challenge is good for college and enabled me to go where I wanted. I also think the concepts I learned in chemistry are truly valuable. There were a lot of practical applications to be found in the lab. I learned about my own environment and protecting it and myself."

"High school chemistry is good to take because even if you're not a science person who is going on to major in a science-related field, it is useful knowledge to have. You learn about helpful things that will be useful, such as knowledge about batteries. You do experiments on common household products. High school chemistry also provides a foundation for you to go on. It gives you an idea of the information you'll need to know and will give you a head start over those who have never had any chemistry. The teachers here really try to help you out and make it interesting, fun, and crazy."

We also provide a unique one-semester honors biochemistry class at Westside. This program—designed, written, and taught by the team leader—has received high praise from students, parents, and administration.

I feel I have discovered curriculum material which will help students deal with the human genetics revolution. I call the unit "The Big Three—ATP, RNA, and DNA." This unit has become one of the most valuable components in biochemistry class according to my students' evaluations. The biochemistry program units are: The Physics and Chemistry of Water; An Introduction to Organic Chemistry; Proteins; The Big Three—ATP, RNA, and DNA; Protein Synthesis; and Fats and Carbohydrates.

I feel the Big Three unit has a great potential to help students build the chemical models they need to understand future advancements in human genetics. This has been an exciting unit for me to teach, and the student response has been great. Each unit has similar components:

- Lectures on the chemical nature of ATP, RNA, and DNA;
- Laboratory experiments on the production of fumaric acid, and discussion of its role in the Krebs cycle and ATP production;
- Laboratory on karyotyping human chromosomes and diagnosis of genetic diseases;
- A reading assignment: *The Double Helix* by James D. Watson;
- A written assignment on the discovery of the structure of DNA;
- Technology assessment activity on "The Recombinant DNA Controversy: Science, Ethics, and Politics";
- Major exam on ATP, RNA, and DNA.

This unit could be done in a two- or three-week block of instruction or integrated into the traditional first-year secondary chemistry class. It could also replace the organic unit many secondary chemistry teachers already include in their first-year programs. I feel this unit is a good model to introduce students to organic chemistry, providing the human genetics information many students do not presently receive.

The development of a chemical model for ATP, RNA, and DNA is a necessary concept for students whose society is undergoing a biomedical revolution. Our goal as teachers is to create scientific literacy. This unit provides an excellent opportunity to help students understand human genetics today and deal with the social and political implications of society in the future.

The chemistry program has grown from a one-and-a-half-teacher program in 1969 to a 3-person team in 1983-1984. Now, 55 to 60 percent of the graduating class completes chemistry. Sixty plus students also take the honors biochemistry program each year.

I have been teaching chemistry for 15 years. Chemistry is not just another science to me; it is special in a number of respects. It can help a student develop a distinctive and clear view of what happens in the environment. Chemistry can help expand enjoyment of travel, the out-of-doors, and the intricacies of the environment.

In 1970 the Earth Day activities captured my interest, and my students today profit from the involvement. While meeting with a number of professional people in the Omaha area, I saw the real application of my teaching in their work. I brought representatives from the Metropolitan Utilities District, the Omaha Public Power District, American Chemical Society, and Keep Omaha Beautiful into my classroom to help expand the classroom perspective.

Two summer institutes at Knox College studying the Interrelationships of Science and Society, and an EPA workshop at the University of Nevada provided me with the understanding to match my enthusiasm for teaching environmental and energy concepts in my chemistry class.

Chemistry should make students aware of the quality of modern technological life, and help them understand their responsibility to society. It is an excellent training ground for the kind of person we will need in large numbers if we are to solve the problems ahead of us.

I believe chemistry should be taught with all the humor, enthusiasm, and practical application the teacher can provide.

Chapter 10 Exemplars in Chemistry: An Analysis

John E. Penick
Joseph Krajcik
Science Education Center
University of Iowa
Iowa City, Iowa 52242

"Chemistry for all," the title of Chapter 2, typifies the ideas found in the programs described in this monograph and the criteria for excellence in Chapter 1. In the United States, most students study biology. Only a select few study chemistry in the secondary schools.

Many teachers feel that only these few are capable of studying chemistry, as most students lack the mathematical skills needed to cover the rigorous chemical concepts. Tens of thousands of students have studied an academically rigorous chemistry, generally preparing for further study at the university level. But untold millions have ended their formal study of science with biology or a "physical science" course designed for students deemed not capable of understanding chemistry and physics.

In Chapter 1, the NSTA Task Force on Excellence in Chemistry Teaching describes a desired state where all secondary school students would study chemistry. It states clearly that no one can be considered well educated without knowledge of chemistry and the intellectual skills needed for rational thought and decision making. Along with this, the task force recommends many opportunities for studying careers in chemistry and related fields, and appropriate background for learning technical skills which might be needed in on-the-job training.

While the eight chemistry programs described in this issue do not each fully meet the criteria of excellence as defined in Chapter 1, each represents programs considerably closer to the desired state than most secondary school chemistry programs. Although they differ from the ideal, each offers insights into both the desired state and what could be.

Look at these examples from the perspective of a scientist; see what is useful, meaningful, and real. Look for ways to combine and synthesize ideas from these programs into an even better, third-generation exemplar in your own classroom.

Definitions of the Desired State

Chemistry will cease to be taught only as a college preparatory course for bright students headed for science-related careers. There will be a broad program of instruction in chemistry that will provide appropriate education for students of different abilities and varied interests.

The Task Force recommends expanding the chemistry offered in the schools to meet the needs of all students, particularly those who have exhibited average and below-average performance in other science classes.

Three of the programs (described in Chapters 2, 4, and 7) offer four or five different levels of chemistry to appropriately challenge students at all levels. These courses include Consumer Chemistry, College Prep Chemistry, Biochemistry, Organic Chemistry, and Combined Chemistry and Physics. In offering such a variety of levels, these school programs seek to provide chemistry that is meaningful and of high interest to students, and which also give students a good chance of success.

Scottsburg High School (Chapter 6) is located in one of the poorest counties in Indiana. Though few students continue on to college, the school sustains high enrollments in chemistry by providing a course which is appropriate for student needs. In order to offer a high-interest program for these low-achieving students, Scottsburg teachers have designed non-traditional laboratories using ordinary materials, guest speakers, and photography.

Chemistry instruction will focus on observation and description of common chemical reactions and the subsequent rationalization of what has been observed in terms of simple models describing structural similarities among compounds exhibiting similar reactivity.

The Task Force requests that introductory chemistry focus on observation and description of common chemical reactions. In chemistry, students should mak direct observations close to their experiences.

Chapter 3, "Chemistry-Biochemistry," has students applying their science by determining the air quality of their county and monitoring the water quality of a local river. Through these applications of chemistry to social issues and through a career awareness program, students can see that chemistry is all around them.

Chapter 9, Humor in Chemistry, uses humorous analogies, including a stereotypical mad professor, to help students analyze chemistry and broaden their perspectives about nature and the uses of chemistry in nature. Students can identify with Professor Flub and recognize his mistakes. In the process, they successfully learn chemistry.

In Chemical Concepts Through Investigation (Chapter 4), instruction centers around the notion of a learning cycle. In this cycle, students begin with an exploratory laboratory exercise, develop concepts using observations and data they collect, and apply their data and knowledge to real-world problems. Teachers allow students to make observations, rather than telling them what can be seen. Students observe and describe while they are learning.

The number of topics covered in secondary school chemistry courses will be drastically reduced and far more attention will be given to the integration of ideas that remain. The integration will be of two types: first, the interconnections among the concepts and principles of chemistry will be made clear. Second, important connections between chemistry and knowledge that the student already has will be stressed.

In Chapter 6, the chemistry program in Scottsburg, Indiana, teachers have identified topics that maintain the integrity of chemistry, provide interest, and are useful. By selecting only these critical topics, considerably more time can be spent on each.

The chemistry program at Globe High School (Chapter 8) provides highly individualized instruction, using just 14 units. In each unit students choose from a wide variety of activities, allowing them to take an active part in determining what they will learn.

In making connections between chemistry and other knowledge, many chemistry teachers have chosen social issues as a central focus. At Hazen High School in Renton, Washington (Chapter 5), a key focus is learning to use chemistry to make everyday decisions. One way the program has evolved to do this is through its use of social issues and applications of chemistry, as well as by having guest speakers. Each lesson is woven around a social problem. Through these problems, new chemistry material is introduced. It is successful, as students suggest how to solve a particular issue and then compare their solutions with ones that have been attempted.

Almost all of these programs include applications of chemistry. As stated in Chapter 1, "Knowledge that cannot be applied is of little value." Chapter 2, Chemistry For All, for instance, has four different levels of chemistry, each with contemporary and applied topics as a central focus. They are successful, with more than 90 percent of students successfully completing introductory chemistry.

Most programs include aspects of career development and awareness. Some programs use guest speakers; others have definite units on career education which include reading about careers, interviewing people in various chemical careers, and trying to determine where chemists and chemistry-related personnel might be employed. Students in these programs learn the usefulness of chemistry, the definite place of chemistry in our society, and the fact that chemistry can be understood by everyone.

Far less emphasis will be placed on routine application of rules and technical skills, definitions, and memorization of theoretical models that cannot be applied. Far more emphasis will be placed on the description of common chemical changes and the use of simple, structural models to explain chemical change. As a rule, only those theories and mathematical models needed to explain the chemical phenomenon that students have observed and wish to have explained will be introduced.

Emphasis should be on the structure and reactivity of matter, with students constructing information internally rather than passively receiving intact knowledge. In Chapter 4, Chemical Concepts Through Investigation, the learning cycle where students develop concepts and applications using observations and data follows this rather well. The role of the teacher here is not only to give information but to ask questions, lead discussions, and guide experimentation.

Teachers in these programs actively get feedback from students and use this information to help programs undergo constant revision.

At Globe High School (Chapter 8) the students know what level of learning is expected of them with each unit. Each unit contains different types of learning activities which take advantage of students' varying abilities to learn. Students are free to watch a taped lesson or filmstrip, read a programmed text, do an experiment, or use computer-assisted instruction. After using the materials they have chosen, students perform a self test to find out how well they have done. Teachers in this program feel strongly that the key to success lies in students' choosing the activities they wish to perform.

At Radnor High School (Chapter 7) the specific content of the course is not an end in itself, but rather a beginning. This content gives students background information for questions they have about their daily lives. Chemistry for these students becomes an active part of their lives and not a rhetoric of conclusions.

The development of intellectual skills that enables students to make rational decisions about complex issues; and the development of habits, attitudes, and skills to learn independently through informal education will be stressed.

These exemplary programs strongly emphasize that the major contribution chemistry can make to a person's education is in the development of rational thought. By stressing Chemistry For All (Chapter 2), these program developers have emphasized the notion of chemistry as something necessary. Others, such as Chapter 4, Chemical Concepts Through Investigation, and Chapter 8, Individualized Chemistry at Globe High School, have students making decisions as a significant component of the chemistry class. By making decisions, predicting consequences, and analyzing applications, these students learn to think with chemistry and through chemistry.

Class assignments, laboratory activities, and evaluation procedures will reflect the emphasis upon the development of intellectual skills.

By emphasizing application of concepts and principles in new contexts as evidence of learning, students learn how ideas can be useful. In the process, they come to see how an idea can receive as much attention as a description of the idea itself. While some, like Chemistry For All in Chapter 2, have complete courses stressing the applications of chemistry and the prediction of consequences of those applications, all are concerned with students being able to use their chemistry, rather than with merely knowing it. Test items submitted by several of these exemplars indicate that teachers and program developers view the context and use of chemistry as significant evidence that learning has taken place.

In using ideas, students learn that chemistry can be used and is not merely something to be studied. As less emphasis is placed on describing an idea and more emphasis is placed on how the idea can be useful, students will begin to see connections between their chemistry class, themselves, their society, and their future. In the process, more ideas are generated and more uses of chemistry are stimulated.

A variety of text materials that are pedagogically sound, scientifically accurate, and appropriate for students of varying abilities and interests will be available to teachers.

Humor in Chemistry (Chapter 9) has been created from a blend of CHEM Study, Chemical Bond Approach, and traditional textbooks, as well as from a variety of locally-developed materials, demonstrations, and humorous skits. In devising this hybrid, developers focused on the nature of their students, the skills and personalities of the teachers, and their desire for a strong program for all students.

Individualized Chemistry (Chapter 8) has been designed to take advantage of students' abilities to learn in different ways. It allows students to decide which activities they wish to perform, and it includes computers. Most of the 14 units are introduced from a consumer or humorous point of view. Certainly, these program developers have sought to make their materials appropriate for the learners.

The learning cycle (Chapter 4) takes advantage of the way children learn science. By using research discoveries on learning cycles in developing a program, these developers are closer to having an educationally sound and appropriate curriculum package for all their students.

At Hazen High School (Chapter 5), program developers modified CHEM Study materials to include societal issues, applications of chemistry, career education, and learning to use science in everyday decision-making. By combining this activity-oriented approach with guest speakers, taped lectures, current science magazines, and classroom demonstrations, they now have a program which provides interest, ideas, and applications.

Teachers—We Need the Best We Can Get

Not surprisingly, teachers in all these programs are considerably different from the norm. These teachers have attended an amazing number of institutes, workshops, and professional association meetings. When they say they are active members of teacher associations, they mean they not only read the journals, attend the meetings, and present papers—they help lead the organizations.

Many of these teachers speak of running workshops, including fairly advanced and prestigious institutes at major universities. Their general high level of excitement and energy is apparent as they write and talk. This excitement is probably important to the students as well.

These obviously are exceptional programs, with exceptional teachers. They are doing quite well, as evidenced by the number of students enrolled, the number of students going on to use science in a variety of ways, and the local evaluations. We have no doubt that these are truly exemplary programs which are evolving into even better examples of what can be done in chemistry classrooms.

Some Concerns

While these are exemplary programs, they are still evolving in many ways. As such, they have not yet reached the pinnacle of desirability or success. Although many of these programs have a variety of levels for students with a variety of goals, it still seems apparent that college preparation is a major focus. College preparation seems to mean classical chemical concepts rather than applications. We think much can be done to improve the descriptive aspects of chemistry, the applications of chemistry in daily life, and the use of direct observations by students. We see these programs moving in those directions and are confident that they will achieve it.

Some evidence indicates that the number of topics covered in these chemistry courses is greater than necessary. We would like to see more focus on fewer ideas, as well as on the integration of those ideas with the reality known by students. Making these connections between chemistry and the students' knowledge will help students see the concepts and principles much more clearly.

While social issues seem to be woven into many of these programs, we would like to see social issues not as an addition, but as a central core. For example, the central theme of a course could be social issues with the chemistry principles woven around those issues. We would like to see more curricula developed that make social issues a more prominent part of their chemistry curriculum.

We would like to see more programs which explore topics and ideas with opportunities for applications early in the course. We still see a tendency to present the theory before any application.

As requested in the desired state of Chapter 1, we would like to see students designing their own simple, structural models to explain chemical changes they have observed. By doing this, we would expect to see fewer theoretical concepts and mathematical models used in the classroom.

In all activities, a goal should be that students become able to learn independently through informal education during the rest of their lives. By stressing their need to learn independently and informally, we will be freeing students from many constraints adults put upon themselves.

Evaluation is a weak point in many of these programs. While it is difficult to evaluate how well students can apply concepts and principles, we would like to see such tests developed. Only by seeing students using their ideas in new contexts do we have evidence that they have learned. We also must evaluate how well students have developed their intellectual skills and their rational thought. Perhaps, as suggested in Chapter 1, we should ask students how ideas are useful as often as we ask them to tell us what the ideas are. In doing this, students might begin predicting causes and consequences, look at applications of the chemical knowledge, and view themselves as controllers of their learning and their use of chemistry.

Teachers need to adapt and develop more materials, rather than continuing to rely upon commercially available text materials. When teachers begin developing their own materials for use in their own locale, the curriculum will become appropriate for the students in that locale. We would also like to see more specific teacher inservice programs related to techniques of applying pedogogically sound, scientifically accurate instruction for students of all abilities and interests. While these teachers have described specific teaching strategies and skills, other teachers do not always have these skills and strategies. We would like to see specific inservice programs designed to produce teachers for programs such as these.

Some Final Thoughts

We sincerely hope that these program descriptions will inspire you as they inform you. While no single chemistry program in this issue may be suitable for your school or students, we are confident that the ideas contained here are transportable, modifiable, and ultimately useful. We hope you will analyze, critique, and propose new alternatives to the activities and ideas suggested in these ten chapters. If you as a teacher do this, we know it will have considerable impact on students. For, as we well know from this issue of "Focus On Excellence," from other issues, and from our own general experience, teachers do make a difference.

This volume has been produced by
Special Publications
National Science Teachers Association
1742 Connecticut Avenue, N.W.
Washington, D.C. 20009
Shirley L. Watt, editor