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At the University of Northern Iowa we have four so-called "Current Curricula" courses - one each in junior high science, biology, chemistry, and physics. Each is preceded in the teaching degree programs by a course called "Orientation to Science Teaching." Most students who take these Current Curricula courses are juniors or seniors and have had at least part of their professional sequence in the College of Education.

The idea of having "Current Curricula" courses is rooted in the notion that science curricula are in a constant state of change. What is "current" today may not be current ten years from now, as a look back will surely indicate.

Chemistry gradually appeared in American high schools after 1800 but it had no central purpose. More teachable theories came out of chemical science after the Civil War and laboratory was popularized as a means of creative expression. In 1886 Harvard added "laboratory chemistry" to its list of courses for advanced standing, and Professor Josiah Cooke proposed a rigid high school course of experiments designed expressly for this advanced admission standard. Many modifications were made in the course as it was found to be too advanced and abstract, but high school chemistry continued to be college-dominated for the next generation. There was a swing toward more terminal courses in applied chemistry and other science — for example, a course called "civic biology" was offered in the schools in 1900 in response to the unsanitary and poor health conditions that prevailed at that time. About 1915, when America was being industrialized, it seemed important to include in chemistry courses such things as the mining of sulfur, the manufacture of sulfuric acid, the smelting of ores, and the making of steel. The depression years of the 1930's led to courses in "consumer science" whose major goal was to use knowledge of science as a basis for the wise purchase of goods and services.

In 1950 the State of Iowa published a small volume entitled "Chemistry and Physics for Secondary Schools" as part of the Iowa Secondary School Cooperative Curriculum program. Acknowledging that not all students should take chemistry and physics, the college preparatory function of these courses was emphasized, but the general education value of chemistry was recognized as well. It was noted that chemistry had experienced an increase in enrollment since World War II. The shift to interest in science was attributed partly to the recognition of the role that chemistry plays in modern society. It was noted that chemistry teaching was undergoing some important changes, particularly in the area of laboratory work. Not a trend toward *more* laboratory work but a trend toward *less* laboratory work involving individual experimentation by students. More emphasis was placed on demonstrations by student committees or the teacher. The committee expressed their belief in the soundness of this change:

> "Some individual laboratory work must be included to develop skills in working with simple apparatus and to permit students to become familiar with the properties of common substances. But the routine working of experiments from the cook-book directions of manuals has little to commend it. Learning through demonstrations is likely to be more effective and much more economical of time and money than is learning through routine laboratory work."

The committee noted some other important changes taking place in teaching high school chemistry:

1. Greater emphasis on the applications of chemistry in everyday situations. (The psychological soundness of drawing on familiar experiences was emphasized.)
2. More use of a-v materials — films, models, charts, and fieldtrips.
3. Greater attention to teaching students to read and how to study chemistry materials. (Included in this was the notion of developing a chemistry vocabulary.)
4. More emphasis on problem-solving as a means of teaching procedures in scientific method. (The so-called steps in the so-called "scientific method" were emphasized in most text books of that period. The problem-solving emphasis here included those well-known steps, but the motivation value of student interest was also included. Some examples mentioned: the boy who brings a piece of ore to school; the girl who is curious about the composition of cosmetics; the student who has a special interest in photography.)
5. More flexible time schedules.
6. Greater attention to extensive reading — learning how to locate materials and using them. "It is probably more important for a student to know where to find reliable information on softening water than it is for him to be able to prepare hydrogen or some other simple substance in the laboratory."

The materials suggested for the chemistry course were organized as ten illustrative "resource units." These were intended to be suggestive and flexible, and presented for students at the 11th or 12th grade level.

The unit title questions were:

I. What are the methods and values of chemistry?
II. How can elements, compounds, and mixtures be identified?
III. What is the nature and significance of solutions?
IV. Of what importance are non-metals and acids?
V. What is the importance of metals and bases?
VI. What are the important uses of the less common groups of elements?
VII. How does man use carbon, silicon, and their coupounds?
VIII. How does chemistry help in the maintenance and improvement of health?

IX. Of what use is a knowledge of chemistry in the home and in the community?

X. How does chemistry benefit agriculture and industry in Iowa?

This approach to teaching chemistry came under severe criticism in the 1950's and what happened in the next decade is well-known.

The 1960's were characterized by the most sweeping curricular reform ever experienced in secondary school science. This was not just a period of curriculum revision; there was a unanimous decision among the reformers that little could be done to bring the science courses into line with modern science, and it was necessary to start from the beginning and develop new courses.

Who were these reformers? The public critics of science teaching in the 1950's felt that it had grown soft and out-of-date in terms of content and was too pupil-centered or "life-adjustment"-centered. It was speculated that students would learn more if improved methods of learning were used. Scientists had such comments as "while biology, chemistry, and physics is taught, there is little of the *science* of these subjects presented." Others felt there was too much applied science and technology in high school science textbooks, with the likelihood that a false impression of the scientific enterprise was being created in the student's mind.

Educational research had virtually no influence on the science curriculum reform of the 1960's. In the absence of useful help from this area, organized groups of scientists attempted to improve the situation. On examining the textbooks and curricular guides they found that practically no changes had been made over the years in the conceptual structure of the subject matter. Textbooks had grown by adding new knowledge in bits and pieces; seldom did one find a traditional topic dropped.

The conditions underlying the need for reform were partly rooted in the changes in the social, economic, and cultural structure in American life, but advances in science had a lot to do with it. A revolt over the status quo of science courses had been developing for about 20 years, but it took just one incident to ignite the spark — the launching of the first earth satellite by the Russians. As a country we had just been embarrassed by our lack of technological progress in the space program and we were determined that this should not happen again.

In chemistry, the reform movement started in 1957 when a group of chemists and high school teachers met at Reed College in Oregon to consider ways of correlating or articulating high school and college chemistry. The committee met at the request of the American Chemical Society and noted that there really had been little change in high school chemistry textbooks since 1920, in spite of major changes in the field of chemistry.

The committee met in 1958 and 1959 to develop a new college preparatory chemistry course. The idea was to close the gap between high school and college teaching of chemistry and to present modern chemistry at the level of the high school student. The end result was what was called the "chemical bond approach" or "CBA", since the subject matter was organized around the central theme of the chemical bond. This was the principal explanatory system — "since the making and breaking of bonds *is* chemistry." The rest of the core was made up of the concepts of energy changes and reaction mechanisms. All topics were closely integrated and new levels of understanding were built on information acquired earlier in the course. The laboratory program served this conceptual design, with an underlying emphasis on "thinking about" the problem in terms of which experimental data are needed, and how theories, models and concepts can be used for interpreting data. Students were not asked to do experiments that merely demonstrated what they already knew. As laboratory techniques were learned, the student was expected to devise his own procedures.

More attention was devoted to the intellectual and theoretical aspects of chemistry than was typical of conventional introductory courses. It should be remembered that this course was intended to be strictly a college preparatory course; one of its stated objectives was "to identify promising students." Another was to develop analytical, critical, logical, quantitative thinking skills.

In 1959, the ACS set up a committee of college and high school chemistry teachers that soon led to the revision of the conventional high school chemistry course known as the Chemical Education Materials Study (CHEMS). The rationale for this revision was that the important concepts and generalizations of chemistry should be developed inductively, based on data the student can understand, and whenever possible gathered by the student in the laboratory. The laboratory was viewed as a place to raise questions and develop new ideas. Learning something about the nature of the investigative approach and the uncertainties in all scientific measurements was an important goal. The CHEMS laboratory instructions gave explicit instructions for making observations, but the experiments were open-ended as to results and interpretations.

The emphasis in the original CHEM Study was on structural chemistry and chemical dynamics, based on the notion that, from the chemist's viewpoint, chemistry is not just a study of reactants and their products, but of the dynamic mechanisms by which chemical changes occur.

The CHEMS focus was on the student understanding of where facts come from and what it means to "explain facts." It was hoped that students would leave the course knowing chemistry in terms of the structure of a system and its dynamics — not only electron structure, but geometrical arrangement of atoms, relative sizes and shapes of atoms, intermolecular forces, and what influence these have on chemical properties. The educational goals of the CHEM Study program were to diminish the separation between scientists and teachers in understanding science and to encourage teachers to improve their teaching methods by studying chemistry courses.

There was a particular teaching style upon which the success of CHEM Study depended. Broadly described it was the maintenance of an inquiring atmosphere within the classroom. Experiments were carried out *before* associated readings were done or discussed. Concepts and ideas were developed inductively; the inquiry environment was maintained through pre-lab and post-lab discussions between the teacher and the students and between the students themselves.

Supplementary instructional materials were developed with the original CHEM Study, including a separate laboratory manual, a comprehensive teacher's guide, open book achievement tests, programmed instruction booklets on exponential arithmetic and the slide rule, and several outstanding motion pictures.

One of the stated goals of the CHEM Study was to stimulate the development of other new materials for high school chemistry. The original commercial version came out in 1963. In 1968 three revisions appeared all of which adhered more-or-less to the philosophy of the original. The considerable feedback from the teachers of 300,000 students who took CHEM Study prior to 1965 made it clear that a revision was needed to correct errors, improve readability, improve some laboratory experiments, and rearrange the material for better consis-

The stimulus for the 1960's curricular reform may have been quite illogical, but the impact of those curricula in science is still very noticeable, both at the high school and college level. This is especially true in chemistry, as shown by the relative popularity of various textbooks in Iowa schools and the nature of the chemistry courses that most chemistry teachers took in college.

All three CHEM Study revisions are still popular in Iowa schools and, of course, have undergone additional revisions since they first came out in 1968. By contrast, the CBA text has undergone no revisions and is well on the way to extinction.

A new wave of curricular reform occurred throughout the '70's in response to declining enrollments in the sciences and greater concern about social implications and the environment. After a period of growing public disenchantment with science and its failure to solve society's problems, the start of the '80's is characterized by a great revival in the public interest. Magazines such as "Science 81," "Discover," "Omni," and "Next" have hit the newsstands. Television programs such as Carl Sagan's "Cosmos" have wide appeal. Writing in *Saturday Review*, (August 1980) Isaac Asimov says:

> "All of a sudden, Americans are fascinated by science — "fascinated," as a person may be by great beauty, grace, intelligence, picturesqueness; held in their spell; and 'fascinated,' as a mouse, cowering helplessly, waiting to be eaten, may be fascinated by the glittering eye of a snake. Americans today view science in awe of the marvels it has showered on us, and with fear of the horrors it has spawned. We feel that if we do not understand science and the changes science makes possible, we may find ourselves overwhelmed, even destroyed by those changes. This fascination with science explains the current boom of interest in all aspects of science — fact and fiction."

Time carried a cover story on Carl Sagan's *Cosmos* program on October 20, 1981. The writer spoke of this resurgence of the public's interest in science:

> "A decade or so ago, much of the public would have turned a deaf ear to these voices of science, eloquent as they are. The subject was unpopular, even in disrepute. Science, or more accurately its offshoot technology, was being blamed for much that was wrong with the world; the growing dipoliation of the environment, the chemical devastation of the Vietnamese countryside, the spread of nuclear weaponry. . . . . . .
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> "But even when science was attracting little popular interest, plenty was going on. Investigators were making enormous studies, especially those involved in basic research — inquiries with no immediate practical pay off. Some researchers were probing the inner secrets of the atomic nucleus; others looked out to the mysteries of the planets and the stars. Still others discovered how the earth's surface, found to be unexpectedly mobile, has been shaped and reshaped over the ages. Perhaps most startling of all were the explorations on the very frontiers of life. For the first time, scientists were beginning to understand and manipulate DNA, the basic stuff of heredity.
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> "Eventually, the awe of science overcame the indifference toward it.
>
> "In a turnabout as sudden as some of the scene shifts in *Cosmos* ennui has turned into enthusiasm. Public curiosity about science, if not financial support of it, seems to be rocketing upward. Some signs: the New York *Times* has created a special weekly section to report the news of science, and other newspapers have expanded their science staffs and coverage. Some half a dozen new mass-market science magazines have been launched within the past few years. . . There is a growing readership for books on scientific topics, as opposed to those on such pseudoscientific hokum as UFO's, astrology and parapsychology."

Can the science curriculum of the 1980's respond to and exploit this "awe" of science? Can it deal with the anxiety about the future created by the accelerating rate of change made possible (and inevitable) by developments in science?

Asimov attributes the current interest in science fiction to this anxiety, saying our stake in science makes us crave for fictional scenarios in which the problems caused by science are marvelously mastered by science in the future. "Changes have followed so closely on each other's heels that is has become nearly impossible to absorb them all. More and more, it is the fundamental crisis of our time that we may lack the ability to understand and accept change. . . Like it or not, change must be a factor in our calculations, and young people, particularly, are becoming increasingly aware of that."

Will curricular changes ever be able to equip students to accept, understand, and guide the changes that will inevitably come? Can students acquire from their science courses some tools to help solve the formidable crises of our times and their future? This is the hope of the curriculum reformers of the 1980's, but if the past is any indication, the science curriculum will continue to respond sluggishly to societal changes and to changes within the disciplines themselves.

Perhaps the most viable and helpful curriculum in chemistry will be the one that emphasizes those durable concepts that promote understanding of the nature of changes in matter on the atomic and molecular level. So long as teachers agree that there is more than one way to accomplish this goal, the curriculum will continue to be only a *means* and not an *end*.

Chemistry curricular materials continue to emphasize the cognitive domain to the virtual exclusion of anything else, in spite of all that appears in the literature of science education on affective learning. This emphasis has strong support from the learning theories of Bruner, Skinner, Gagne, and, of course, Piaget. The development of formal reasoning skills is the objective of many teachers, having recognized that a majority of students taking high school chemistry (and many at the college level) are still at the concrete operational level of intellectual development.

The most popular high school chemistry text in Iowa appeals to this problem, at least in the Teacher's Edition. It is difficult to detect any deliberate structure in the text that tries to develop formal reasoning, however. The modular program *Interdisciplinary Approaches to Chemistry*, used by a few Iowa schools, makes some attempt to bridge the gap between the concrete and the formal. For example, in the introductory module one experiment is entitled "From Reactions to Equations." Its stated purpose is to "make the transition from paper-and-pencil equation balancing" to realization that chemical equations are based on laboratory observations. One of the revisions of the original CHEM Study textbook made a point of restating all definitions in operational terms, not necessarily in consideration of Piagetean principles but rather to relate concepts to laboratory operations, which may to some extent be the same thing.

These allusions to Piaget have helped less to develop teaching strategies than to understand why some students fail to grasp the abstract and esoteric aspects of chemistry. Bridging the gap between the concrete and the formal is still generally left to the teacher's imagination and resourcefulness.

Recognizing the limits of some students' ability to think abstractly may find its expression in the teacher's concern for the affective domain. One of the stated objectives of the *IAC* program is to improve student attitudes toward the study of chemistry. A "Student Opinion Survey" is provided for administration at least twice during the school year. The flexibility of the modules in *IAC* along with other features are designed to provide for differences among students in a class and differences among teachers in terms of background and philosophy.

Some materials that are less popular with chemistry teachers have, in this writer's opinion, gone too far in trying to overcome a presumed negative attitude toward science in general and chemistry in particular. One uses a comic book format, with material selected almost exclusively from the student's familiar surroundings. Another begins with a preface that almost apologizes for the subject's "complexity," disavowing any undue emphasis on theories or detail.

In the final analysis, how important is any particular curriculum in successful teaching? Roger Bybee made a strong plea for "personalizing science teaching" in a booklet by that name, published by the National Science Teachers Association in 1974. His words are timeless, and in these days of rapid change in science and science curricula, they still get to the heart of the matter: "Effective science teachers combine knowledge of subject matter and awareness of curricula with recognition, understanding, and response to the student's unique needs. These needs can be in the cognitive, affective, or psychomotor domains. In the end, the primary instrument we have to help fulfill another's potential is the ability to use ourselves; the curriculum, textbooks, and technology are secondary means. . . ."

Iowa chemistry teachers appear to choose solid, more-or-less conventional textbooks, judging from the results of a survey conducted in 1978-79. Besides the three CHEM Study revisions, all of which have been somewhat "conventionalized" through successive revisions, only two other textbooks were among those used by two-thirds of the students taking chemistry, and those two are quite similar and quite conventional. A self-paced course was available to about 9% of the students, and the modular approach was used in less than 4% of the chemistry classes.

A survey of this kind doesn't reveal what use teachers are making of their curricular resources. If Bybee is correct, it may not matter that much. After all, "the teacher has been, is, and will continue to be the most important single element facilitating the learning process."

Science teachers do not expect to teach acceptable courses throughout their careers on the basis of what they know at graduation from college. Evidence for this is the continual participation by teachers in workshops, conferences, and in university courses. Teachers usually hope to take home ideas, materials, and techniques that they can put into use at once. Continuing education is a must for most occupations. This fact should be part of the basis for the preparation of pre-service science teachers, providing an education in science that prepares them to learn on their own and to expect to learn more after leaving school than they did in school. And what is true for the science teacher should also be true for the students he teaches. Organizing the curriculum with both a concept and inquiry sequence can place more emphasis on rational thinking as an outcome. Shifting more responsibility for learning to the students will help them to develop intellectual skills and attitudes, both of which are essential in an era of rapid change.

If this can be done enthusiastically, flexibly, and compassionately, using the best curricular resources available at a rate that is appropriate for the student's intellectual development, it should be possible to prepare students for the future without increasing their anxieties.

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Science, Religion and the Classroom

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First Amendment Rights protect freedom of religious choice. Americans are free to practice any religion they choose, or may decide to have no religion. The Federal Government may not establish an official religion and the State may not pass laws that endorse any particular religious concept.

Science is dynamic and has no sacred truths, all assumptions and data must be critically examined concerning natural phenomena. Arguments based upon religious or political authority have no place in the science classroom since they are excluded by scientific methodology. Science attempts to explain how things are, not how man wishes them to be.

There is a clear danger to the scientific process when political or religious factions try to impose their bias on scientific methodology. The danger of having natural laws imposed from above, rather than emerging from scientific methodology is far reaching in a society dependent upon scientific based technology for its survival. Preoccupation with narrow interpretations of religious or political self-interest groups has no place in the science classroom. There is no need for increased Governmental regulation imposing additional objectives, distantly related, if at all, to the fundamental task of teaching the results of and the processes of scientific inquiry in the science classroom.

Creationism is a product of religious thought. Evolution is a product of scientific thought. Religious training is a responsibility of the Church. Scientific training is a responsibility of the science classroom. The government has no responsibility with respect to sponsoring religious views, however, it must protect the personal freedom to pursue the religion of one's choice. This, above all, must be remembered in the Evolution/Creation controversy.

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