State of the Art in the High School Curriculum

William R. Cary
Memorial High School, 201 S. Gammon Road, Madison, WI 53717

The Present State of High School Chemistry

High school chemistry in the United States is in a holding pattern. Many of the things we do, we do well. But they are the same things that we have been doing well for decades. Now that we have an opportunity to grow and expand, we are not sure how to do it. This paper will try to address reasons for our complacency and suggest ways in which we can grow.

One of the things we do well is introduce our students to the language they need to do well in college. Brandwein reports that the typical high school chemistry course introduces more than 10,000 specialized terms, a larger number than the vocabulary expected of a student after four years of French (*1*).

We give our students ample opportunities to experience chemistry in the laboratory through experiments that range from the determination of density to the determination of solubility products. Many schools are even incorporating instrumentation into their experiments.

We are good at preparing students for the next academic level. Because we tend to teach the top students in our high school classes, this has to be a goal for high school chemistry teachers. However, the National Science Teachers Association states that 90% of U.S. science teachers emphasize goals that are directed *only* toward preparing students for the next academic level (*2*). In fact many of us tell our students: "If you do well in this course you will have no trouble with the first semester of your college course." This has to be true because so often we teach the same material that is taught in many entry-level college courses.

In keeping with our goal of preparing students for the next course we have developed fine lecturing skills. You can go into almost any chemistry classroom and find the teacher doing a tremendous job of talking *at* students (*3*).

We have a wide variety of colorful and usually well-written textbooks to choose from, and the authors of these texts have responded to most of our needs and wishes. Furthermore, there is evidence to suggest that we use these textbooks with our students. Harms and Yager reported that over 90% of us use a textbook 95% of the time (*2*).

There is another area in which most of us deserve a great deal of recognition. We are experts in elitism! We are so good at teaching elitist science that one source reports that only 16% of our high school seniors have studied chemistry (*4*). This past summer Lee Marek and I conducted a survey of our fellow Dreyfus Institute participants. One question that we asked was: "What percent of your seniors have had at least one year of chemistry?" The mean for the public school teachers was only 30%. It is important to realize, however, that the participants in this institute represent some of the best chemistry teachers in the country.

On the whole we are doing a good job, and some of us become distraught when we are told otherwise because we are faced with an impossible task. According to R. F. Kempa (*5*),

> The basic problem . . . is that we expect our school chemistry courses to serve a multitude of different functions. They are expected to transmit to the learner the essential characteristics of the subject in terms of its concepts, patterns, and theories, and the processes associated with its pursuit; they are expected to provide a foundation for further chemical studies as well as "terminal" education in chemistry for those who will not study the subject further; they are also expected to develop an appreciation of the scientific, social, economic, environmental and cultural implications of chemistry and, at the same time, make students aware of the transitory nature of chemical knowledge, principles and models. Frankly, I do not think it possible for a single course to respond to and fulfill all these divergent functions.

Does a Crisis Exist in Chemistry at the High School Level?

A large percentage of us are middle-aged or older, and this percentage is growing. Many of us are tired and have lost the youthful idealism that we once possessed. Like a championship athletic team, many of us are resting on our laurels and have become complacent.

Now we are told that there is a crisis! Enrollments are low, we have a shortage of competent science teachers, and scientific literacy is lower than modern society can afford. Are these charges true? Of course they are! Were we forewarned? Certainly! For years, NSTA has been encouraging us to make changes, and THIS JOURNAL has been printing articles concerning ways to increase enrollments and to improve scientific literacy. The problems have been identified, discussed, and written about for years. Why then have they reached crisis proportions?

An answer to this question has been offered: "A problem becomes a crisis when the complainers are persuasive enough and persistent enough to draw the attention of politicians and journalists" (*6*). We have finally gained the attention of the media and the politicians. Now we have a crisis. The nature of the crisis has been best summarized by R. E. Yager, who stated (*7*),

> There is a crisis in science education! However, that crisis is not one of too few science teachers—or, the need for more scientist/engineers—or, the fact that the USSR, Japan, and other nations are doing a better job—or, that test scores on standard measures continue to fall. Instead the crisis is best exemplified in our failure to approach real science, in our failure to plan curriculum and instruction utilizing what we have learned about both, and in our failure to produce scientifically/technologically literate graduates.

That is the state of the art in 1984, as I see it. We high school chemistry teachers are a hard-working group of dedicated professional educators. Unfortunately, our students are not meeting the new demands that our society is placing on them, and we have a crisis. Is this really anything new? Perhaps not, Walford suggests (*6*),

> We are truly in a critical period in science education. In many ways, though, it appears to be the same one we have been in for the past 100 years. It is simply this: How do we best present a science which we believe is essential to a full and productive life, and how do we reach the largest possible audience?

What is the Future of High School Chemistry?

I believe that the future is bright. Both new technology, such as computers, and advances in educational research described by others in this symposium will definitely help advance our cause. Furthermore, our goal has been defined: to present chemistry, which we believe to be essential to a productive and full life, to the largest possible audience. We have an abundance of good chemistry to select from for content, and we have a trained, hard-working professional group of teachers who will once again pick up the torch.

What then do we need to rejuvenate our efforts? We need three things: (1) a model to follow, (2) new materials, and (3) sufficient training and retraining to implement the new ideas, strategies, and materials.

The Model

Although there are many fine leaders in chemical education, I would like to share with you the thoughts and feelings of two outstanding physics educators, Arnold Arons and Paul Hewitt, who might be less well known to chemistry teachers.

Arons and Hewitt have developed strategies and a curricular philosophy which helps to overcome the three aspects of children's learning that can impede science education (*8*).

1) Children have meanings for words and views about how and why things in their natural environment behave as they do from a young age.
2) The views and meanings held by children are sometimes uninfluenced by considerable exposure to science teaching.
3) When children's views change as a result of new learning experiences they sometimes change in ways unanticipated by teachers or curriculum designers.

Arons has commented on strategies that are successful in helping students understand abstract concepts (*9*).

> What one must do is ask simple, sequential questions, leading a student in a truly Socratic manner. After each question, one must shut up and listen carefully to the response; here errors, misconceptions, and missteps of logic are revealed. One learns nothing by giving students "right" answers or "lucid explanations." As a matter of fact, students don't benefit from such "help" at this stage. They are much more significantly helped by leading them to confront contradictions and inconsistencies in what they say, and alter their statements of their own volition as a result of such confrontations.
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> What I must emphasize is that such inquiries must be made by carefully listening to students, and not by arrogantly extrapolating from one's own experience. Those of us who are fortunate enough to become competent professional scientists are among the minority who, for the most part, made the breakthrough in spite of the existing system, not because of it. Our learning experiences are not representative, and citing such experiences leads mostly to fallacy and irrelevance rather than insight into what transpires for the majority of learners.

Paul Hewitt has outlined an excellent content framework for implementing this model (*10*). Throughout the following quotation, substitute "chemistry" every time you encounter the word "physics".

> Physics has a reputation of being a hodgepodge of equations and mathematics of the worst kind—word problems. It has a reputation of being incomprehensible . . . It seems to me that there are many more people interested in learning physics than there are people interested in learning applied mathematics. And I have for a long time felt that the study of physics is too important, too fascinating, too beautiful to be restricted to the few who possess a knack for mathematical analysis. Should people without a mathematical bent be exempt from the study of our discipline? Physics is easy to *teach* mathematically, but we make a mistake by assuming it is easy to *learn* mathematically . . . Let's begin by making physics accessible . . . by teaching conceptual physics . . . a qualitative study of the central concepts of physics with emphasis on mental imagery that relates to things and events that are familiar in the everyday environment. I remember teachers used to say that the only thing you teach nonscience students was history of physics, or a science-and-society type class. It was argued that because these students couldn't do math, they couldn't get into real physics. I have always very much disagreed with this point of view, and feel the task with nonscience students is not to avoid physics . . . but rather to get to the fundamental principles of physics . . . in a language most nonscience students can understand: English . . . the first of my course objectives is to teach hardcore physics with emphasis on the everyday environment. The everyday world is rich with physics. What a mistake to view physics as that which is going on in certain laboratories, or the content of certain textbooks. Physics is everywhere, and my task as a physics teacher is to bring that physics alive in the minds of my students . . . The second of my course objectives is to shape critical thinking. How do we know that such-and-such is valid? . . . My third course objective is to relate the role of physics and technology toward a positive future . . . In each of my three course objectives . . . the end result is the overall flavor that the students take from the course experience . . . education is ultimately the flavor left over after all the facts, formulas, and diagrams have been forgotten . . . Let the first goal of physics instruction be a conceptual understanding of physics and a general overview . . . then let's introduce our students to the mathematically beautiful way in which their initial understanding leads to a deeper understanding. Let's look at the whole elephant before we begin to measure its tail.

In the preceding quotations we have the basis of a good working model. Does it work? Absolutely! Scattered throughout the country are high school teachers who have incorporated all or parts of these ideas into their courses with overwhelming success.

New Materials

To implement this model of instruction we will need a new generation of textbooks and supplementary materials. This was the basis of a symposium that Dudley Herron and I organized at the 7th Biennial Conference on Chemical Education (*11–13*). There is only enough time or space in this paper to suggest that if we want a new generation of materials it is up to us as classroom teachers to make our needs known to the publishers.

Training and Retraining

The training of new chemistry teachers, and the retraining of those of us who have been teaching for many years, is essential for the future of chemistry at the high school level. Fortunately, the Dreyfus Institute on Chemical Education can serve as a model for other programs designed to retrain and upgrade science teachers.

The training of new teachers presents a bigger problem. If our enrollments are to increase, perhaps by as much as a factor of two, we need to double the number of qualified chemistry teachers. Assuming that our profession becomes more attractive, who is going to train this new generation? The obvious choice is the teachers who have successfully used this model, and there are those of us who would be willing to accept this challenge.

Many of the ideas presented here have been incorporated in my teaching for the last 10 years. Today I am enjoying teaching more than at any time in my 20-year career. This enjoyment comes from being liberated. I am liberated because I know that worrying about completing the book in the allotted time is futile and not necessary, because my colleagues at the tertiary level do not make many content demands on me, all they ask is that whatever I do, I do well, and because my students tell me that they enjoy thinking and learning how to understand.

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