Does Chemistry Really Work this Way?

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What view of chemistry would you hold if all you knew about the discipline came from an introductory textbook? Many college students take only one science course and many introductory chemistry textbooks are written precisely for courses for the non-major; consequently, it is relevant and important to ask what ideas about science, its history, methods, and values are expressed in those textbooks.

Our study, "Value Presuppositions in Science Textbooks: A Critical Bibliography" [1] covered 40 introductory college level textbooks. Recognizing that the central core of factual knowledge would be common to every book, we concentrated upon identifying some of the general attitudes, assertions, and disclaimers about the growth of science, its power and limitations, and its role in contributing to the discussion of social issues such as drugs, pollution, and nuclear energy. Many of the predominant normative assertions in these books cluster around three themes or categories: (1) "Truth and Progress" as exhibited in the history of science, (2) "The Scientific Fix" as a means of solving contemporary social problems, and (3) "Skills and Drills" as definitive of the aim and purpose of a chemical education. We will present each of these categories in capsule form and offer some questions or criticisms.

Truth and Progress

Many textbook authors give the history of chemistry in this way:

> Chemistry was born sometime around the last half of the eighteenth century (primarily with the work of Lavoisier) in a triumph over ignorance embodied in phlogiston theory. From that time chemical knowledge has progressed ever closer to the Truth; a fact attested to through our greater understanding and control of nature. The overt effect of this result is the elaborate technology that we have constructed using our scientific knowledge. This technology has given us all better lives and promises to continue doing so.

Examples to support this history of progress always appear in one of two forms. The first is the citation of a name and date of a famous figure in an otherwise factual discussion of a principle. A typical example might be found in the gas law section of a text: "Robert Boyle (1627–91), an English chemist, discovered in 1660 the law named after him." The second mode of presentation of history is a slightly more elaborate technique where the author relates a brief anecdote about a particular great figure. Some common examples are Becquerel's discovery of radioactivity, Kekulé's dream of the snake-benzene ring, and Lavoisier's calx experiment. When history is reduced to these brief citations, the only recourse is to believe that science moves in a series of leaps from one enlightenment to another through the actions of great men and women. That is to say that chemistry progresses by an accumulation of one discovery after another, each one refining our knowledge and bringing us closer to the Truth.

This concept of chemistry is further reinforced through the use of social or personal issues to demonstrate the relevance of chemical facts. For instance, an author might choose to discuss nuclear power in a section on radioactivity or the development of antibiotics or painkillers in a chapter devoted to organic chemistry. The form these examples take is such that it emphasizes the past achievements of chemistry and shows how every problem has a chemical solution. Each topic discussed is one more triumph for chemistry. The net result is to promote the view that the work of chemistry is inherently progressive since every problem encountered will become a solved problem.

The primary difficulty with the truth and progress concept of science is that it is highly selective in its emphasis of great figures and narrow in its vision of what it contributes to the growth of knowledge. The great historian of science, Herbert Butterfield, labelled such selection "Whigish history" because it treats every development as a triumph of one party, the "liberal enlightened" party.[2] Science does and has owed much to the work of less luminous individuals in the second and third rank, but the role is undervalued and never mentioned. The Truth and Progress story perpetuates a confusion about the relationship between an accumulation of fact and the meaning of "progress." There has been a growth in scientific knowledge, but to identify chemistry's activities and products as progress is to attach a label which works like a persuasive definition. It, in effect, defines what is as what ought to be. Under this definition, anything can be labelled as "progress."

The particular concept of scientific truth embodied in the truth and progress view also has its faults. It assumes that the nature of the scientific enterprise is amoral, objective, and value-free and that absolute truth can be achieved. Neither of these ideas is undebatable. Consider the very difficult problem of separating a basic discovery from its application. Or the more difficult one of distinguishing "pure" and "applied" chemistry when all science is intertwined with political economy. Moreover, the history of science fails to substantiate the absolute nature of scientific knowledge. Such revolutions as quantum mechanics, relativity, and electronic structure of the atom clearly show the provisional nature of scientific truth. In this context it is not surprising to find that virtually every text in our survey failed to discuss the fact the experts disagree and expert scientific witnesses are available for both sides of many issues. The significance of disagreement does not fit into the truth and progress picture of science, and that is a distortion of the way things are.

[1] Factor, Lance and Kooser, Robert, "Value Presuppositions in Science Textbooks: A Critical Bibliography," **1981.** Copies available from the authors.

[2] Butterfield, Herbert, "The Origins of Modern Science, 1300–1800," G. Bell, London, **1949.**

The Scientific Fix

This theme can be defined as the belief that given enough time, money, and personnel, scientific research will eventually resolve pressing social issues. The "fix" idea appears in a hackneyed set of examples. For example, an author may place into a section on organic chemistry a paragraph describing the development of biodegradable detergents to solve the water pollution problem. The development of nylon or Teflon® might be highlighted in the same section as an example of better living that chemistry brings. Nuclear power, introduced in the chapter on radioactivity, is often offered as a solution to the crisis in energy reserves. The list could continue, but the point to note is that in the absence of counter examples, i.e., problems which have failed to yield to science or technology's efforts, the student is lead to believe that all problems have a scientific fix. In those instances where the author does reveal that a particular problem, like the energy crisis or the safe disposal of nuclear wastes, does not have a current solution, the discussion of the problem is nearly always skewed so the reader believes that all that is necessary is more knowledge, a further investment of funds or just a matter of time.

Certainly chemists should be proud of the accomplishments of their discipline in producing useful goods and solving certain environmental problems. A certain amount of disciplinary propaganda is understandable; however, an unexamined faith in the ability of science and technology to solve every problem will overlook the human dimension and misses the social, political, and economic forces at work. The "Green Revolution" of the 1960's has not solved the world's food supply. Spraying malathion on residential areas to eradicate the "medfly" is more than the simple application of a cholinesterase inhibitor. While an author of a chemistry text would be expected to treat chemistry favorably, it is a failure of truth-telling on his or her part to preach the unquestioned faith in the scientific fix.

Skills and Drills

One of the distinguishing features of science education is the large emphasis on the mastery of a vocabulary and a set of problem-solving skills. These serve as a basis for more advanced and creative work which usually occurs in the upper level classes in college or in graduate school. In the training of chemists, the demand to master the basic skills is important. Some are useful in the laboratory; others play the role of precepts which help shape a scientific way of thinking. An important question arises here though: should these same skills and problem drills constitute the core of a course taken by students who will never again open a chemistry book much less cross the portal into a laboratory?

Many textbook authors answer in the affirmative to the above question. These "skills and drills" texts are composed of large sections devoted to concept understanding, and drills for solving standard problem types. It is obvious that a great deal of thought has gone into finding analogies and problem solving algorithms which will assist students with minimal scientific literacy in completing the course. Discussions of issues or problems that touch on society are subservient to basic mass of chemical facts. The organization and treatment of this material makes it clear that these issues are illustrations of basic concepts placed there either to show the utility of a chemical concept or to pique the interest of the students.

The "skills and drills" approach does imply a narrow view of science. Chemistry is only achieved knowledge; furthermore, chemistry is reduced to a set of standard facts and problem-solving skills. These facts and drills are ordered in a deductive manner in the text. The implicit message is that this is chemistry. The conclusion a reader would come to is that the nature of scientific discovery and communication differs not one bit from the form and style of the textbook. Of course, as every practicing scientist knows, standardized facts are merely tools. The creative side of chemistry has much more in it.

Conclusions and Recommendations

The three themes, taken as a whole, raise one central dilemma: to what extent is an author (or teacher) obligated to give a more realistic picture of the scientific enterprise in all its ramifications—historical, methodological, and social? If science is, as many texts claim, an open-minded, truth-seeking discipline, then is it not incumbent on teachers and authors to do likewise? To fail to do this is inconsistent at best and dishonest at the worst. Science searches for the truth about nature; textbooks should display the truth about science.

Fortunately, very few students gain their sole impression of a science from a textbook. Certainly, the one-sided, misconceived view of chemistry that many texts espouse is tempered by the more realistic experiences of the teacher. There are numerous resources available which, if used, would counter the misconception of the textbooks. The use of a single thorough case study from either the history of science or the social problems which result from the application of chemical knowledge would dispel many misconceptions. Such studies might be drawn from the history of science by carefully examining such developments as the overthrow of phlogiston theory or the development of the double helix model of DNA. For older historical periods, case studies already exist in the "Harvard Case Histories." [3] Many articles which chronicle events, discoveries, or personages in the history of chemistry have appeared in THIS JOURNAL. These could serve as a resource material in the development of usable case studies by the instructor. Equally serviceable would be case studies developed from some social issue in the application of technology. Examples might be the carcinogenic nature of saccharin, the human toxicology of "agent orange," or the use of nuclear energy for power production.

A case study approach ought to show the student something closer to the truth about how chemistry goes about its business. It should demonstrate that scientists are people, that in every scientific discovery something is lost as well as gained, and that the methods of science are complex, often personal, and illogical. Case studies also ought to bring out the interaction between science and the society. They should show that the experts often disagree. This fact alone might dispel the common misconception that science always has the right answer. The choice of subject for the study would determine what concepts would receive emphasis. A study of the evolution of the idea of combustion would not raise the same issues as an examination of the uses of nuclear power. This latitude should be welcomed by teachers. Just one case study, whether historical or topical, will do more to show the reality of science's growth and interaction with society than a host of historical anecdotes or series of sketches of current problems. Case studies will allow teachers to face the central dilemma by not only expounding some of the truths *in* science but also some of the truth *about* science.

[3] *Conant, James Bryant (Editor)*, "Harvard Case Histories in Experimental Science," Harvard University Press, Cambridge, MA, **1950**.