HISTORY of SCIENCE SOCIETY

1993 Annual Meeting
Santa Fe, NM

50 Los Alamos
NATIONAL LABORATORY
1943 - 1993

Nahum Kipnis

Bakken Library and Museum
3537 Zenith Avenue South
Minneapolis, MN 55416
612-927-6508; Fax: 612-927-7265

HISTORY OF SCIENCE ENTERS THROUGH THE BACK DOOR

History of Science Society
Panel on History of Science in Science Education
Santa Fe, NM, November 12, 1993

The question of whether or not to use the history of science in teaching science has been debated by historians for quite a while. The advantages appeared obvious, but so was the fear to compromise the history of science by not being able to present it properly. Consequently, when some historians (Holton) attempted to incorporate the history of science into science curriculum, they did not receive much support from their colleagues. While historians argued among themselves, science teachers at both secondary and post-secondary levels took the matter in their own hands and started using history as they saw fit. "You do it all wrong," historians began to object, but the practitioners didn't listen. What shall historians now do: to join the train *Improving Science Education* or to stand by and criticize the engineer and passengers?

Probably, only a few will join, and each individual will address the problem depending on his/her background, current job, and an experience (if any) in teaching science. While trying to keep a balance between history and teaching science, some (Douglas Allchin, for one) will be more concerned with the former, and others (myself including), with the latter. Let me explain my position.

I do both research in the history of science and teaching science, and, which is especially important, I teach science teachers (everyone agrees that we shall start the revolution with educating teachers). Thus, my situation appears to be ideal for helping teachers to transform the "technical" science they teach into the "liberal" one (in Michael Matthew's terms). The trouble is that teachers are not quite familiar even with the "technical" science, which means no foundation to build on. If so, what shall we teach such teachers first: history and philosophy, or science? My answer: "Both, if you can; otherwise, science."

To become receptive to the change historians and philosophers want, the secondary-school science has to undergo first another change. Currently, "learning science" means memorizing a certain number of terms, rules, laws, and equations. Students are unable to apply this knowledge to any new problem. Memorizing a few more dates or names of scientists will not add much. If students are not accustomed to ask "why" relative the ordinary subject matter, why should they be more curious about historical or philosophical issues? The first stage in reforming science education is to shift the emphasis from memorizing facts to developing skills of thinking, reasoning, and systematic purposeful work.

Another problem is a preoccupation with the deductive method. First, students learn a theory (or a law), and then how to illustrate it by experiment. Finally, there is an obvious obsession with modern science, which in physics is simply ridiculous. The only thing students can do about such a concept as "coherent light" or "super-conductivity", presented in a short paragraph, is to memorize it without any understanding.

Can this primary change in science teaching be done without involving history/philosophy. The answer is: "Yes." That is exactly how I start with teachers. The motto is: "Back to basics" (or "Back to Nature"). These refer to the subject matter and the methodology involved. As much as possible, I use the inductive method: observing phenomena, then deriving empirical rules or laws, and finally connecting them with a general theory. I concentrate on activities which enhance students' participation, creativity, and thinking abilities, and allow them a better understanding of nature. This means qualitative experiments, it means laboratory and home experiments, and it means investigative experiments. I could do all this without involving any history but I chose the opposite: to use history as much as possible even where it was not necessary. The idea was to sell history by packaging it with other attractions.

Whether we like it or not, we have to humble ourselves to the idea, already noted by Doug, that to teachers history of science is a teaching tool and not a subject. As a subject, the history of science can be taught only to those who have already mastered science, and this is very difficult to achieve even at a college level. What does attract science teachers in history? Some discuss the history of certain scientific discoveries and biographies of scientists. To enliven their lectures teachers are eager to use any funny detail they can find ("did Tycho Brahe have a silver nose?"). Naturally, there are many other ways to entertain students, and only the "historically-inclined" teachers- a tiny minority in the science teaching community - chooses history for this purpose.

In addition to these two applications of the history of science, I use others, which are more important, albeit less known. I found one of them in 1984 when watching Sam Devons demonstrating historical experiments with electrostatic generators and Leyden jars made from shampoo bottles: a cheap apparatus must be an irresistible attraction to a teacher, and in many cases a prototype of such an apparatus can be found in history.

The benefits of other applications were not so obvious to teachers and had to be properly presented. One of them is the usage of old theories. Raised on textbooks promoting the "modern" theories as the only correct ones, teachers need time to realize, for instance, that many electrical phenomena can be explained by the concept of an electrical fluid combined with hydrostatic and hydrodynamic models much easier than by electron theory. Aside from practical considerations, using old theories stimulates an important discussion of the relation between new and old theories, the purpose of new theories, etc.

Instead of talking how discoveries were made, teacher can offer to students to repeat certain historical experiments and make the conclusions themselves. By slightly modifying an original apparatus in many cases their replicas can be made so inexpensive as to allow the experiment to be conducted as a lab. Let's take, for instance, Thomas Young's experiment with a hair. A hair mounted on a slide frame is held near the eye against the pupil. When looking at a narrow source of light (candle flame) a student can see multicolored bands on both sides of the flame. This is a diffraction spectrum. This experiment can be performed qualitatively or quantitatively (measuring the wavelength) and is a much better introduction into diffraction than the traditional experiment with a diffraction grating because Young's device itself and its theory are much simpler. Unlike Doug, I am trying not to use any instrument or technique unavailable at the time. But this is done not for the sake of "purity" of the experiment, but to show that scientists were able to achieve important results with very simple instruments but with a lot of diligence.

Usually, I do historical experiments with teachers as investigative labs and recommend them to do likewise with their students. Only at the end students (teachers) learn how close their findings were to the original ones and whether or not their procedures and arguments resembled those of Newton, Young, and other famous scientists. The lab format allows each student to play a scientist, which not only improves their experimental skills but also enhances their creativity and self-confidence. Time constrains do not allow an exact reproduction of history. Still, there is enough history in it (instruments, logic, sequence) to give students an idea how the new knowledge is created.

I am always presenting historical experiments in their connection with relevant theories, including the background of the experiment and its outcome. Whenever possible, I use scientific debates to show teachers that there is always more than one interpretation of an experiment, and the final conclusion results from a controversy between supporters of different views. Sometimes I introduce the opposite views before the experiment, and ask teachers to find out who was right (Galileo or Huygens in the dispute on isochronous pendulum, Aristotle or Kepler on the rectilinearity of light, etc.) In cases such as the Galvani-Volta debate, where historical experiments were inconclusive, I summarize teachers' results myself. Naturally, when reviewing old theories one does not follow all historical convolutions: first, there is no time for that; and second, not all pieces of the puzzle are equally instructive. Thus, simplification and selectivity are as unavoidable with theories as with experiments. Does it lead to a certain misrepresentation of history? Certainly. But if a historian cannot do it properly, what can we expect of ordinary teachers? It sounds as if the "purists" were right when warning against using history in science education.

However, before making the conclusion that a truncated history of science is inadmissible in the science class, let us see how "correct" and "complete" is science itself. It turns out that with science it is even worse, because there the flaws do not originate from teachers' ignorance: they are sanctified by the authority of textbooks. The errors are usually the errors of omission. For instance, while "verifying" Ohm's law with an incandescent bulb students obtain silly results and wonder whom to blame: Ohm, their instruments, or themselves. They don't know that the real culprit is the textbook which says nothing about the limits of applicability of Ohm's law (or any other!). Another example: how many textbooks note that the uniform motion is simply an abstraction that does not represent any real phenomenon?

Can this flaw be overcome? The answer seems obvious: "Of course, just add to the textbook a little bit of this and a little bit of that." Unfortunately, it won't work. A student needs a certain degree of intellectual maturity and experience in dealing with the subject to understand the "fine print" of science. For this reason, a simplification in presenting science is correct. The idea is that learning science occurs in stages: you start with something very simple and try to use it. For a while, you are successful, but then you realize that you don't understand something in a specific law (or concept). Then you go for help to a teacher, or another book, or you investigate it yourself; and so it goes, *ad infinitum*.

But, if the principle of approximation is good for learning science, why can't it be applied to the history of science? I do not teach a comprehensive course of the history of science, instead I do case studies: selecting certain concepts or laws and showing how they were introduced into science. Going from one topic to another, student will notice certain patterns, for instance, in the interaction of experiment and theory, and realize that it is valid not only for specific phenomena but for science in general. Students will learn how difficult it is to obtain consistent experimental results, that not each hypothesis turns out to be correct, that a small improvement in the apparatus or the procedure can make all the difference, etc. This firsthand experience will give students a much better appreciation for successes and failures of famous scientists of the past. Thus, learning the history of science bit by bit year by year and in different subjects (imagine we have enough teachers capable to do it), students may receive a fair idea of how science works, and how it interacts with philosophy, technology, and society.

I call my method "historical-investigative" to emphasize its two major components and their strong interdependence. [It is described in my book *Rediscovering Optics*.] Teachers found that the historical aspect is appreciated by a smaller number of students than the investigative one. However, they all learn science, learn in a proper way, and there is hope that with time their attitude towards history will improve. That what I see in teachers: the more investigative historical experiments they do, the more interest in the history of science in general they display.