PSSC PHYSICS: A Personal Perspective

by Uri Haber-Schaim

Introduction

Early in 1957 Jerrold Zacharias called a meeting of the faculty of the Department of Physics at MIT to brief us on his initiative to develop a physics course for high schools. He reported on a conference held at MIT in December 1956 and on plans to hold a working session at MIT in the coming summer to produce a draft of the new course to be tried out in some schools. The meeting was not billed as a recruiting meeting. Nevertheless, thinking of the need of a summer job, and having had experience in tutoring high-school students in mathematics and physics, I thought that it might be worthwhile to look further into this enterprise. After some discussions with Francis Friedman, I was recruited to join the project in the spring of 1957.

My first intensive work on the project was in the summer of 1957, when I was assigned to the Wave Group. Initially, this group was led by Francis Friedman. But a few weeks into the summer, Fran asked me to take over the leadership of the group because he had to move into the lead position for the entire textbook. This was the end of a soft summer job and the beginning of my sustained involvement with *PSSC Physics* that tapered off only in recent years, and which covered all parts of the project except the films and the Science Study Series.

The purpose of this paper is to review the essential aspects of the Physical Science Study Committee (PSSC) project and to see what can be learned from it for the benefit of future revisions of science curricula. To this end I will first describe briefly the physics teaching scene in the country in the mid nineteen fifties before giving a more detailed description of the project itself.

High-School Physics Around 1956

Although textbooks were available from several publishers, Holt had the lion's share of the high-school physics market with their *Modern Physics* by Dull, Metcalfe, and Brooks. The first chapter, titled "Matter and Energy," was 8 pages long, including several photographs, a vocabulary list, and questions. The definitions were the usual ones: "Matter is anything which occupies space and has weight; Energy may be defined as the ability to do work." Protons, neutrons, and electrons were mentioned without a word about how we know about them. In contrast, the chapter on machines was 35 pages long, with numerous line drawings of gears and levers, culminating in the well-known centerfold of the power shovel. In the entire book there were no descriptions of experiments or graphs of results of experiments that would justify any of the book's many assertive statements.

There was no laboratory program to go with the textbook. A check of the equipment catalogs of that time will show that there was little apparatus for sale that was inexpensive enough for student use. Most of the items were intended for college use or, at best, for bench demonstrations by the teacher.

With few exceptions, students taking physics had hardly any previously acquired lab skills. For them science was equated with vocabulary.

The only nationally administered high-school tests were the College Board tests produced by Educational Testing Service (ETS). New York State had its Regents Exams. These tests were geared to the content of the then existing programs.

This was the environment into which *PSSC Physics* was born.

The December 1956 Conference

Zacharias had a general idea of what he wanted the course to do:

1. The course should present physical science. The original idea was to have a two-year combination of physics and chemistry as a living discipline, not as a body of finished, codified facts to be memorized. In today's language, Zacharias wanted an inquiry-based approach.
2. The course should use all kinds of learning aids that could be made available at that time: films, slides, textbooks, laboratory apparatus for students and teachers, homework, and ancillary reading.

Zacharias realized from the start that the project required a large pool of talent. He invited interested individuals and groups to prepare some general ideas for discussion. A group of about 50 people, most of them university physicists, responded and attended a three-day meeting at MIT in December 1956. They came primarily from MIT, Cornell, the University of Illinois, and Bell Laboratories. Among the better-known names were Hans Bethe, Leon Cooper, Nathaniel Frank, Francis Friedman, Philip Morrison, Edward Purcell, I. I. Rabi, Bruno Rossi, and Jerrold Zacharias. The participants were sent a list of high-school books for reading before the meeting, and they came well prepared with concrete ideas.

To the best of my knowledge, the deliberations were not recorded. But Laura Fermi, who had been widowed just two years earlier and who was invited to attend as a "generalist," took brief notes. Her notes are very revealing. Readers with experience in departmental discussions of course content might expect that the participants would have argued intensely about the choice of specific topics and ways to teach them. Nothing of the kind happened. Here are some gems from the discussion:

"It is an accident that planets are there."	Rabi
"Show how to simplify, how to investigate."	Friedman
"They know a lot of physics if they know how to order phenomena."	Rabi
"The whole problem is harder than realized."	U. of Illinois

	group
"Choice of subject should be subordinate to purpose. If too difficult—omit."	(Uniden- tified)
"Ideas: regularities, model, extrapolations, limitation."	(Uniden- tified)
"To accommodate development of scientific thought, one must sacrifice some subject matter."	Bethe
"Wave-particle is a beautiful story but extremely difficult—even at graduate level."	Rabi
"Just because it is subtle, we should introduce it early. The difficulty at graduate level is that they had not been exposed to it before."	U. of Illinois group
"Organizations of superintendents, principals, etc., should be involved in implementation. Point is, when?"	Zacharias
"At the very next meeting of the group, so they have a feeling they will be in the process."	Rabi
"Target in 18 months."	Zacharias
"They must be in the process."	Rabi
"O.K. perhaps a meeting for that purpose, but not one of our meetings."	Zacharias

A very important point was made at the December meeting, namely, the distinction between objectives and vehicles. First and foremost, science was to be presented as a human endeavor. More specifically, the following ideas were to play a primary role in the selection of topics and their interrelationship:

- The unity of physical science.
- The observation of regularities leading to the formulation of laws.
- The prediction of phenomena from laws.
- The limitations of laws.
- The importance of models in the development of physics.

For students to understand these ideas, the participants in the December meeting recognized the need for a central theme and a careful selection of subject matter. The central theme was to be the atomic nature of matter in the universe. This decision was the reason for the intention to combine physics and chemistry, as well as for the name of the committee.

From all accounts the conference was informal and harmonious. However, there was one clash on a key question of approach. The advocates of the two opposing approaches were Philip Morrison and I. I. Rabi. In response to an interviewer in 1975, Morrison recalled it as follows:

> Morrison: "There was a big fight that ensued between me and Rabi, and it was very influential in the final design of the course, for good or for bad."
>
> Interviewer: "On?"
>
> Morrison: "On whether the aim of the course should be to take well-defined intellectual threads and follow them through in considerable detail, showing the power of inductive and deductive styles in doing science; or whether the emphasis should be in showing the breadth of science, of physics, and its application everywhere, and making many kinds of arguments that are united in it, a broad sweep of the whole thing—which are two sort of opposing points of view."

Morrison's approach manifested itself in Part 1 of the course, called "The Universe," which he wrote. The example that Rabi gave of his approach was Snell's Law and all that can be learned from it in terms of Newton's particle model and the wave model. Snell's law indeed played a central role in Part 2 of the course, "Optics and Waves."

The Summer of 1957 Working Session

During the spring of 1957, an outline was prepared for at least part of the course. So when a large group assembled for the summer at MIT, there was already an outline and some preliminary models of equipment, such as a ripple tank.

The working session was organized on the principles of system engineering: all aspects of the problem were addressed simultaneously by competent persons in the various relevant fields. The photograph of the group taken during the summer shows almost all the participants (Fig. 1). There were university and high-school physics teachers, editors, equipment technicians, filmmakers, graphic artists, experts on testing, and typists.

Fig. 1. Most of the group working at MIT in the summer of 1957. (Jerrold Zacharias and Philip Morrison are absent.)

The question of testing deserves a special mention. Quite early in the session, when we were still working on experiments and photographs for our chapters and had barely written a line of text, I had two visitors: Gilbert Finlay, professor of science education at the University of Illinois, and Frederick Ferris of ETS. They were developing tests for the course with the aim of finding out whether the course was effective in teaching the students what we wanted them to learn. They could tell from the outline what topics we were working on, but they wanted to know what the Wave Group expected the students to be able to *do*. Our leadership recognized from the start that the new course would be sufficiently different from the existing ones that new tests, consistent with the objectives of the course—not just with the content—would be needed.

1957–1960

Testing the new material started in the fall of 1957 in eight pilot schools; their teachers all participated in the working session during the previous summer. Then in the summer of 1958 there were several NSF-supported summer institutes and many of the teachers attending these institutes taught pilot versions of the program in the 1958–1959 school year.

The feedback from the pilot schools had a strong effect on the preparation of the first commercial edition of the written materials. Feedback was provided not only in written form but also orally at Area Meetings. The chapters on kinematics and vectors had already been rewritten after the first pilot year. Other chapters were worked on later.

It would be a mistake to think that the revisions were limited to extended editorial changes. Zacharias deserves much credit for bowing to reality and going along with major changes in the means of reaching the goals of the program. This is best illustrated by the following two examples:

1) Originally the films were intended to provide the backbone of the course. However, the films took much longer to make than expected and were by their nature not suitable for this purpose. In reality, the textbook and the laboratory guide became the backbone of the course.

2) Originally the equipment for the experiments was to be made by the students. (Anyone from the outside who looked at the shipping platform at project headquarters would have thought that we were in the lumber business!) The pilot edition of the lab guide consisted of several booklets. The first booklet was devoted exclusively to building equipment with simple tools. The acquisition of such skills is desirable, but not at the expense of the physics. Furthermore, no teacher would throw out the equipment at the end of the year and start from scratch the next year. We switched to low-cost manufactured equipment. The first set of booklets was discarded and a new pilot lab guide was prepared.

When the first commercial edition of *PSSC Physics* appeared in the fall of 1960, there was a full set of learning aids, including a textbook, a laboratory guide, an extensive teacher's guide, achievement tests, films, popular monographs, and new laboratory equipment. New knowledge was to be acquired by the students from various sources: sometimes from the textbook, sometimes from the lab work, other times from a film or from the teacher.
The whole battery of learning aids was intended to be used in a new way. To convey the spirit of science, the textbook was written in a narrative style, which demanded that the students follow the development of ideas rather than look for a brief statement of a law. Reading science was a skill that had to be acquired.

The way in which the laboratory work was used was also new for American students in the early 1960s. Gone was the "cookbook" approach, with its detailed instructions and ready-to-fill tables. With economically designed equipment, the lab became the place where the entire class could converse with nature and try to recognize its regularities.

The films not only presented experiments that could not be done in the classroom, but also enabled the students to identify physics with a rich variety of practicing physicists.

The objectives of *PSSC Physics* were so different from those of the standard course that the existing College Board achievement test could not serve as a proper measure for the students in the program. Therefore, ETS was contacted, and a separate achievement test for *PSSC* students was produced that became available in March of 1960. (From 1962 through 1964 students could choose between the standard test, the *PSSC* form, or a combined form. From 1965 on, only the combined form was offered.) For several years the New York State Regents tests also had regular and *PSSC* versions.

In those days, tests were the servants of education, not the masters.

Implementation and Growth

In appreciating the growth in the use of *PSSC Physics*, it is important to remember that adoption of the project was entirely voluntary. Yes, after Sputnik, Federal funding for teacher training and equipment became widely available. However, to use this money wisely required informed teachers.

The system approach used by Zacharias included planning for teacher training. Starting with five summer institutes in 1958, the number of teacher-training institutes rose rapidly (Fig. 2). The institutes were a crucial component of the implementation of *PSSC Physics* because even the most comprehensive teacher's guide is of limited value in developing certain teaching skills, especially those related to the use of the laboratory. This hands-on experience and an understanding of the spirit of the course were acquired in the summer and other in-service programs. NSF funded most of the programs. The effect of the teacher-training institutes is seen in the following two figures (Figs. 3 and 4).

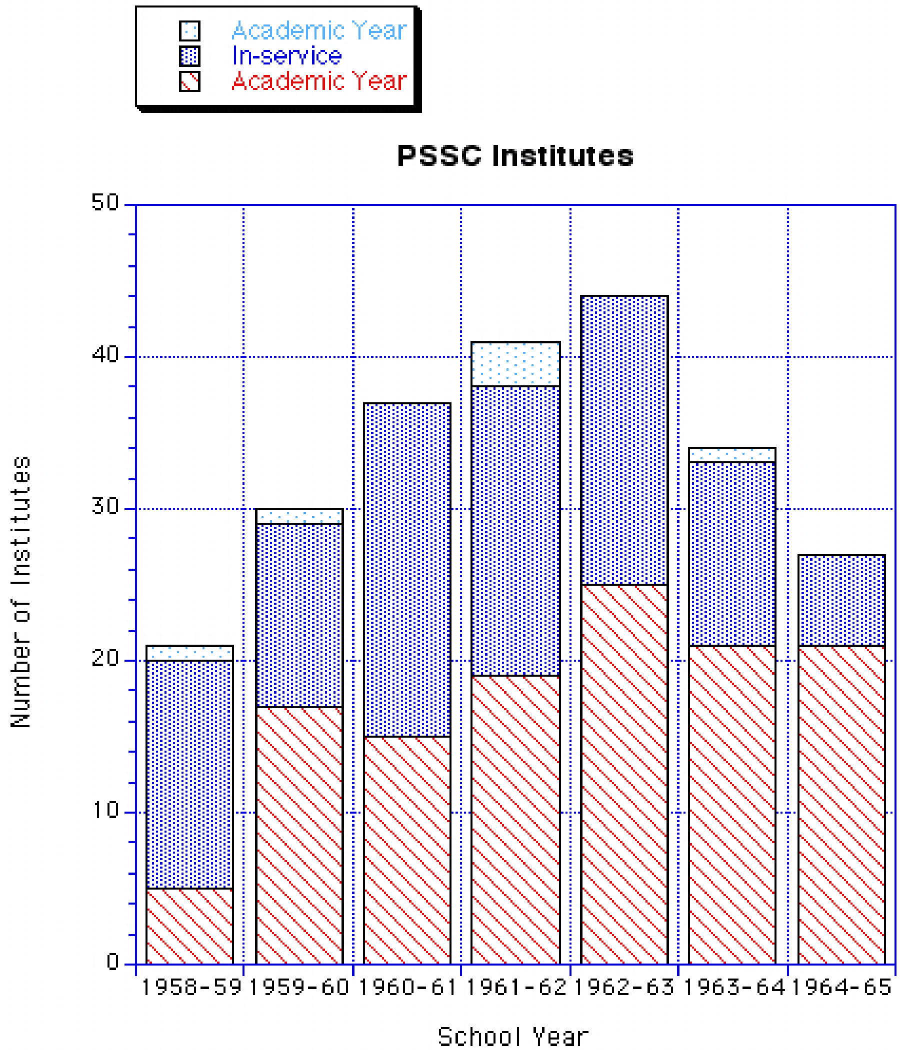

Fig. 2. PSSC Institutes. Summer Institutes met for 6 to 8 weeks and teachers could bring their families with them. In-service Institutes met evenings or Saturdays during the school year. In Academic Year Institutes teachers were enrolled as full-time students taking regular physics courses to strengthen their command of the field. (From Educational Services Incorporated (ESI) progress reports.)

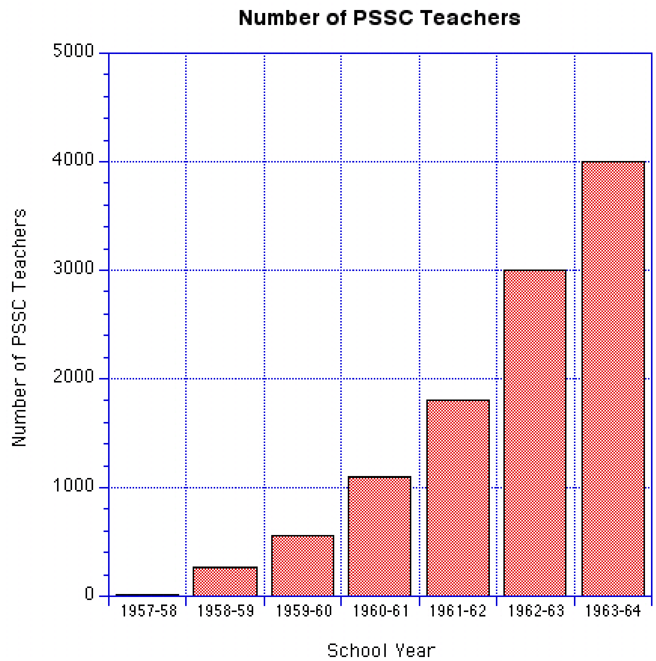

Fig. 3. Number of trained *PSSC* teachers. (From ESI progress reports.)

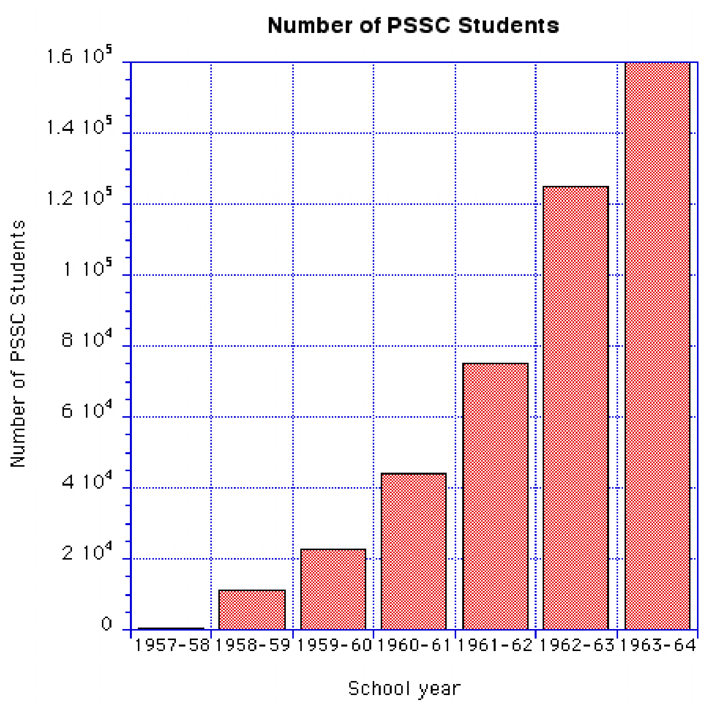

Fig. 4. Number of *PSSC* students. (From ESI progress reports.)

The Later Editions

The publication of the First Edition in 1960 did not bring an end to the project. Feedback continued to come in, and it became increasingly clear that some fundamental problems remained unsolved. In particular:

1) Although many traditional topics, such as statics and alternating current had been excluded, the course was still too long. Many classes never made it beyond the beginning of Part 4, “Electricity and Atomic Structure.” Yet, for schools that wanted to offer a second year of physics, there was not enough material.
2) Part 1 posed serious teaching problems. Although Part 1 contained a number of simple experiments on the measurement of times, lengths, and masses, it was, for the most part, assertive. Of course, the idea was that Part 1 would serve to set the stage for most of the year, but it was very difficult for teachers and students to “go lightly” over Part 1, as was intended, and thus allow more time for Parts 2–4. The schedule suggested in the *Teacher’s Guide* was just not realistic.

The Planning Committee for the project decided to embark on two projects: extending the *PSSC* course both upward and downward in terms of the target population. Work in the upward direction concentrated on developing additional material on key topics that had to be left out of the one-year course. These included angular momentum and its conservation; statistical thermodynamics leading to the Second Law of thermodynamics; relativistic kinematics and the extension of conservation laws of energy and momentum to the relativistic domain; and quantum systems beyond the hydrogen atom. After several years of piloting, this material appeared as the “Advanced Topics Supplement.” (It was a paperback with a violet cover, symbolically continuing the spectrum of the red, yellow, green, and blue paperbacks of the *PSSC* preliminary edition.) Actually, it was recommended that teachers wishing to use the additional material either combine it with the end of the course into a second-year program or intersperse it at the appropriate places to create a three- or four-semester course.

The downward extension addressed the original central theme of *PSSC*, namely, the evidence for the existence of atoms. Known in-house as the “junior-high project,” it was later renamed *Introductory Physical Science (IPS)*. It was clear from the start that this could be done with mathematical tools limited to arithmetic and simple graphing. It was also established that most of the relevant experiments could be done with very simple equipment in any classroom with flat tables and one sink. The approach to atomicity was strongly influenced by Part 1 of *PSSC*.

The educational objectives of *IPS* were quite close to the original objectives of *PSSC*. Looking at the combination of the two courses from the point of view of the learner, the time spent on Part 1 of *PSSC* could be used more effectively on other topics.

By the time the third edition of *PSSC* was published (1971), *IPS* was already so widely spread in the 9^{th} and 8^{th} grades across the country that Part 1 could be eliminated without harming the main objectives of the course. In the third and fourth editions, the course started with optics. In the many schools that used both programs, there was now more time to do a thorough job with *PSSC*. By bringing its program into the junior-high school, PSSC also reached a larger segment of the student population than any 12^{th} -grade course in physics and, possibly, all physics courses combined.

The third and later editions were no longer produced with NSF support and were no longer supervised by the PSSC Planning Committee, which disbanded. NSF ruled that the original material be available to any “U.S. Person” under free license. My co-authors and I were the only ones who took up the challenge. The millionth copy of *PSSC Physics* was sold when the book was in its fourth edition (Figs. 5 and 6).

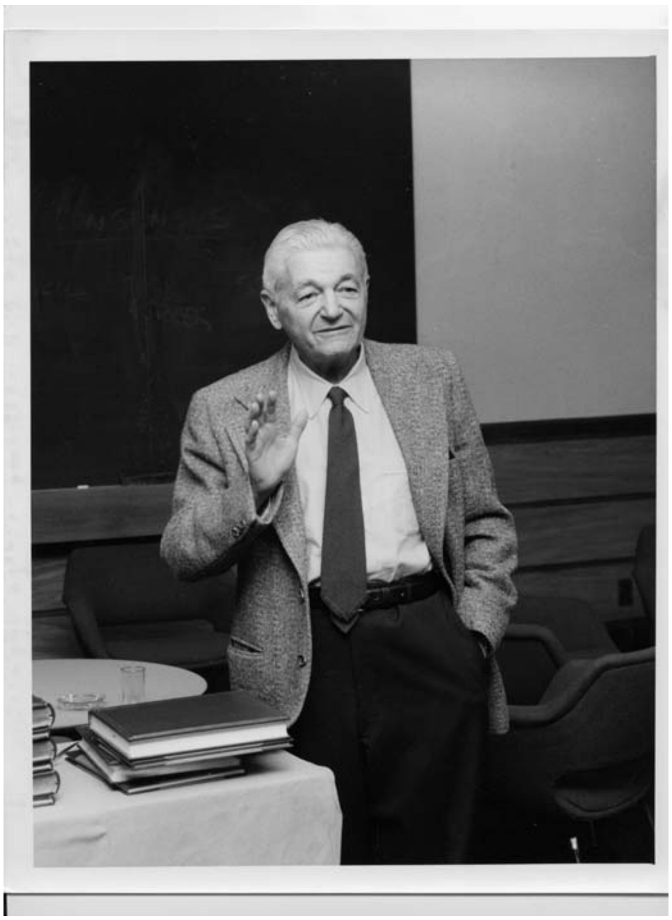

Fig. 5. Jerrold Zacharias speaking at the reception in honor of the millionth copy of *PSSC Physics* sold.

Fig. 6. Uri Haber-Schaim receiving from the president and the science editor of D. C. Heath, publisher of the first six editions, a specially bound copy of *PSSC Physics* to commemorate the millionth copy sold.

Lessons for the Future

What are the most important conclusions that future developers of physics programs can draw from the *PSSC* experience? Is the present educational climate conducive to such enterprises? With respect to the first question, I would make the following two suggestions.

The first step should be to define a set of general objectives and then to work down to specific content and methodologies, ending up with a curriculum. Starting from a syllabus, i.e., a list of topics, and then leaving it to the schools to decide what to do with the topics leads to an overcrowded syllabus with little opportunity of reaching any worthwhile long-term objectives. Unfortunately, the National Science Standards did just that, and so did individual states. The reckless addition of topics to existing syllabi is largely responsible for the ever-increasing size of textbooks and the decreasing amount of time spent on each topic.

The inclusion of such topics as “understanding the nature of science” by itself does not produce the desired result. It will at most produce a test question like “How many steps are in the scientific method?”

Second, a curriculum project has to be led by imaginative people with a deep understanding of the subject matter. Otherwise, the developers will follow the natural inclination of continuing along the beaten path.

As one of the examples of the validity of this statement, we need only look at the introduction of waves in the *PSSC* program. Mathematically, a pure sinusoidal wave is simpler than a pulse. This is probably the reason why for many years the study of waves started with sinusoidal waves. From the point of view of the physics, pulses are much simpler. This was the path taken in the *PSSC* program.

Another example is the teaching of kinematics before dynamics. The chapter on kinematics was the most rewritten chapter in the textbook. Yet only in the seventh edition did we realize that it is much better to introduce acceleration after students have experimented with motion under the influence of forces rather than the other way around.

In the case of topics that had not been taught before at the high-school level, there is the danger of simply opting for a watered-down version of what is taught at the university level. Again, there is no substitute for a thorough command of the material when sound ways for an elementary presentation of new topics are needed. This point is particularly relevant in the context of introducing contemporary physics into introductory courses.

When PSSC was started, the implicit assumption was that whatever science students learned, they learned in class. No one bothered to find out what ideas about nature students brought to their first science class. Today, we know that most students have some deeply rooted ideas about the world around them. These ideas are sometimes based on the student’s own experience, and sometimes they are the result of the use of the daily language. Often they are at variance with the “correct” ideas. Future curriculum projects should take this knowledge seriously. If they do, it will have a profound effect on the outcome. (A simple example: The widely spread reflex to Aristotelian reasoning in qualitative questions in mechanics cannot be overcome by assigning more plug-in drill on a computer screen. However, it can be overcome with more demonstrating, more experimenting, and more qualitative thinking. All of this takes time, and thus something else will have to be left out.)

The system approach, which was so important in the development of *PSSC*, must be extended. The last 30 years have clearly demonstrated the severe limitations of independent course-by-course reforms. What is called for is primarily coordination, not integration, among courses in the natural sciences themselves, and courses in mathematics and in the social sciences. Defining academic subjects in terms of independent one-year courses is strictly an American practice. In this framework the issues of the interrelationships of science, technology, and society can be given at best some lip service in the physics class. In most countries of the world, physics and chemistry are taught over several years. Structured sequences will have to come to the U.S. too if we want to reverse the trend of replacing the study of science by a mere memorization of vocabulary.

I mentioned earlier that at the beginning of the *PSSC* project, ETS provided a special test of *PSSC* students. Without that arrangement few parents would have allowed their children to take the course. Today few public schools will even look at any science program that does not correlate exactly with the state standards because their students will have to take state-mandated tests. These tests, as bad as they are, have become the masters of science education. It is imperative that the tight grip of state standards be loosened for good innovation to flourish.