

THE PHYSICISTS INTERVENE

For over 150 years American physicists have been making forays into elementary and high school science teaching. Their novel approaches have usually worked—but the results have always been short-lived.

Clifford Swartz

In 1826 Joseph Henry went down from Albany, New York, to visit the United States Military Academy at West Point. He observed¹ that

one article very necessary in teaching *chemestrys* is found in this room. VIZ. a blackboard on which the student is taught the atomic theory and all algebraic formula and chemistry. Indeed, it appears to be one of the principles of teaching in this institution that everything as far as practical should be demonstrated on the blackboard.

Henry, who was the preeminent physical scientist in the United States during the middle part of the 19th century, promptly had blackboards installed at the Albany Academy, where he taught at the time, and a few years later took the idea with him to the College of New Jersey, which later became Princeton University.

While we remember Henry primarily for his work in electromagnetism, he actually devoted a major part of his career to education at various levels. He was concerned with the practical details of pedagogy, including the use of the blackboard for diagrams and the use of demonstration apparatus instead of simply lecturing. He was also concerned with the theory of learning and the philosophy of education. Foreshadowing the works of Jean Piaget, Henry wrote that the “different faculties and powers of the mind are not simultaneously, but successively, developed, with some periods of life better suited to particular acquirements than others.” He warned against the “endeavor to invert the order of nature and the attempts to impart those things which cannot be taught at an early age, and neglect those which at this period of life the mind is well adapted to receive.” He charged that “by this mode we may indeed produce remarkably intelligent children

who will become remarkably feeble men.”

Henry’s opinions brought about very little change in the educational system for younger students. However, his insistence on using demonstrations did affect physics teaching at the university level, as did some of the apparatus that he devised.

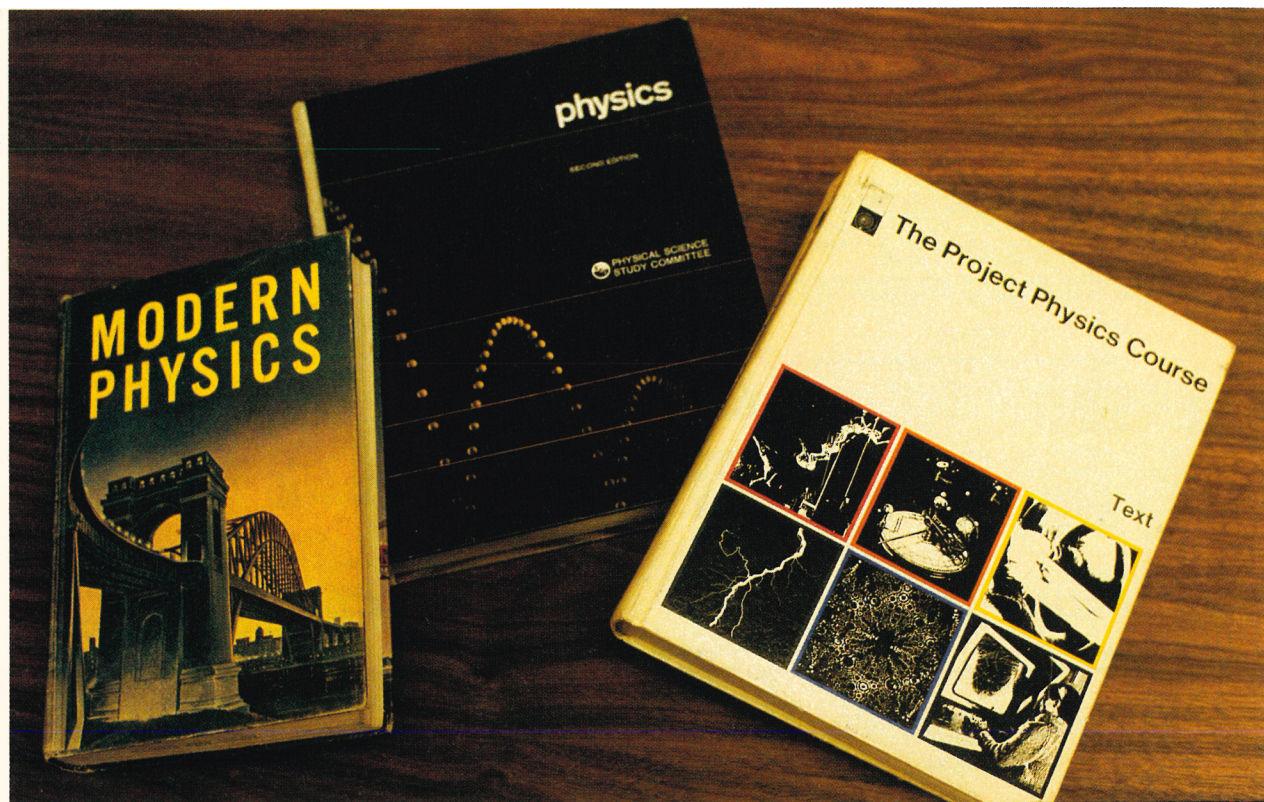
In almost every era, physicists have intervened in American schools. The intervention has always been relatively brief, and has encountered opposition from the educational establishment. As we will see, in each case major changes came about very rapidly and then gradually faded away or were merged into older practices.

Lab work versus book work

The most dramatic example of physicists’ intervention in the schools came almost 100 years ago, with the publication of Edwin Hall’s “*Harvard Descriptive List*.”² Hall had already discovered the electromagnetic effect that today bears his name and was trying to maintain his research activities. He thus responded with some reluctance when Harvard University’s president, Charles Eliot, directed him to prepare a list of high school physics experiments that students would have to have completed in order to seek admission to Harvard. Once into the activity, however, Hall not only drew up a list of 40 experiments but later expanded it and wrote detailed laboratory instructions. Up to that time, very few American secondary schools had offered a physics course with any laboratory work. That soon changed. Even though not many high schools sent students to Harvard, apparently every high school felt that it had to be good enough to do so. Within a decade most high schools offered a physics course with laboratory instruction, and equipment companies were busily manufacturing and selling complete sets of apparatus for Hall’s list of experiments.

By 1900, reaction to this emphasis on laboratory work and to the influence of university professors on secondary schools had set in. Psychologist and educator G. Stanley

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Textbooks. *Modern Physics* was the best-selling high school physics text throughout the 1930s, 1940s and 1950s. The cover of the 1955 edition is shown here. To illustrate “modern physics,” the book contained transparent overlays showing a steam shovel in a construction pit. (© 1955, renewed 1983, Holt, Reinhardt and Winston.) *Physics*, prepared by the Physical Science Study Committee, was first published in 1965. The cover epitomizes one major emphasis of the course, the recording and description of motion. (PSSC Series, 2nd edition, 1965, courtesy of D.C. Heath and Co. and Education Development Center Inc.) *The Project Physics Course*, created by Harvard Project Physics, was first published in 1970. The text was supplemented by handbooks, teacher resource books, readers, programmed instruction booklets, 8-mm film loops, transparencies, 16-mm films and laboratory materials. The course was characterized by an emphasis on the humanistic nature of science. (© 1970, Project Physics, courtesy of Gerald Holton.)

Hall wrote that “the trouble with physics is simply that it has failed to take account of the nature, needs, and interests of high school boys and girls.” In 1909 Charles Mann, another influential educator, complained that the laboratory approach had been perverted when “the college pressure was applied in 1886.” (As we shall see, many aspects of this scenario were to be repeated in the 1960s.)

We usually think of Nobel Prize winner Robert Millikan in terms of his research or as the administrator who established the power and influence of the California Institute of Technology. What is not so generally known is that Millikan devoted a great deal of time at the beginning of his career to teaching at the college level and to writing textbooks for the secondary schools.³ With a young colleague, Henry G. Gayle, Millikan coauthored a high school text that came out in two volumes in 1906: *A First Course in Physics* and *A Laboratory Course in Physics for Secondary Schools*. These books remained in print for almost 30 years. They were unlike standard college texts of the time, covering a different selection of topics better suited to the abilities and experiences of both teachers and students. Mindful of the limited equipment available in schools, Millikan adapted or devised many of the simple experiments and devices that remained standard in American schools until the 1960s.

During the 1920s and until after the Second World War, American physicists essentially abandoned their interest in the schools. A whole new profession emerged: that of the science educator. It was this profession that gradually took over the teaching of science in the schools during the 1920s, and it largely maintains its hold today. The usual requirement for a doctorate of education in science is a master's degree in science—most often general science or the life sciences—and further graduate work in learning theory or curriculum development. The profession has developed its own societies, journals, meetings and specialized language. In most universities with departments or colleges of education, the science educators and the scientists have essentially no interaction.

During the 1930s and 1940s science education in the elementary schools became nature study at best. In most schools it vanished completely. Junior high science became—and largely remains—an exercise in memorizing “science” vocabulary. Until 1950, high school physics texts described mostly pre-1900 science.

The best-selling high school physics text throughout the 1930s, 1940s and 1950s was called *Modern Physics*, published by Henry Holt and Company Inc. As were most school textbooks, it was a “publisher's text,” written by a variety of authors over the years. The 1955 edition was by

PHYSICS

Thursday, January 25, 1917—9.15 a. m. to 12.15 p. m., only

Write at top of first page of answer paper (a) name of school where you have studied, (b) number of weeks and recitations a week in physics, with the total number of laboratory periods and the length of such periods.

The minimum time requirement is five recitations a week for a school year. A double laboratory period counts in place of one recitation. Laboratory work equivalent to 30 double periods is required.

Answer 10 questions, selecting at least one question from group I, one from group II, two from group III and two from group IV.

Group I

Answer at least one question from this group.

1 On what characteristic of sound waves does *each* of the following depend: (a) pitch [4], (b) intensity [3], (c) timbre or quality [3]?

2 The air column in a resonance tube which gives a maximum reinforcement to the sound of a tuning fork is $12\frac{1}{4}$ inches; the tuning fork has 256 vibrations per second. Find (a) the wave length [5], (b) the velocity of the sound waves [5]. [Neglect correction for diameter of resonance tube.]

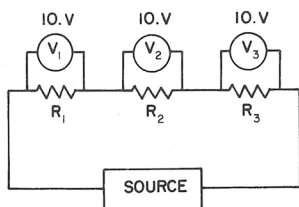
3 What is meant by the dew point [2]? How may the dew point be found in the laboratory [6]? Why does dew appear on the grass and not on the stones [2]?



Which resistor has the greatest resistance?

- (1) A (3) C
(2) B (4) D

35 In the circuit shown below, what is the potential difference of the source?



- (1) 3.3 V (3) 30. V
(2) 10. V (4) 1,000 V

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[5]

PHYSICS—concluded

Group III

Answer at least two questions from this group.

7 Describe the construction of an electromagnet [4]. Give *two* ways in which the strength of an electromagnet may be increased [2]. Mention *one* appliance in which an electromagnet is used [1]. Explain its use in that appliance [3].

8 Make a problem in which you are required to find the cost of running an electric heater on a 110 volt circuit [5]. Solve the problem [5].

9 Two dry cells, each having an electromotive force of 1.5 volts and an internal resistance of 0.1 ohm, are used to send a current through an electric bell that has a resistance of 4 ohms. Compute the current when the cells are connected in (a) series [3], (b) multiple (parallel) [3]. Illustrate by diagrams both a and b [4].

10 Describe with the aid of a labeled diagram the essential parts of an ammeter [3]. Draw a labeled diagram showing how the instruments should be connected in the circuit to find the resistance of a given wire by the voltmeter and ammeter method [5].

Group IV

Answer at least two questions from this group.

11 Define energy, work, power (activity), foot pound [8]. What is meant by the conservation of energy [2]?

Regents examinations from 1917 and 1990 reveal how the New York state physics curriculum has changed. The two highlighted questions are on the same topic but require radically different responses.

developing radar and persuading the Navy to use it during World War II when, with support from the newly established National Science Foundation, he gathered a committee to take a look at the teaching of physical science in high schools. (See Anthony P. French's article in *PHYSICS TODAY*, September 1986, page 30.) They decided that they would tackle only the problem of physics, leaving chemistry as a separate course to be renewed by chemists. They further decided that they would devise a course geared toward the top fifth of students academically, the same population then taking physics. They thus put off until some other time, or for some other group, the problem of physical science instruction for the majority of students. Both of these decisions were matters of tactics, based on considerations of time, money and the realities of school organization.

With characteristic chutzpah, Zacharias attracted a galaxy of distinguished scientists and brilliant younger physicists to the project. The list included Bruno Rossi, Philip Morrison, Ned Frank and Edward Purcell. It also included Francis Friedman, an associate professor at MIT, who became the editor and principal author of the lucid and gracefully written text.

The Physical Science Study Committee realized that much more was needed than simply a new text. The whole approach to teaching had to be different. For one thing, the course was developed around a theme combining everyday phenomena with philosophy and the nature of physics investigation. Completely new laboratory experiments were designed to be the backbone of the course. First-rate experimental physicists went to MIT or to PSSC headquarters in Watertown, Massachusetts, to spend weeks or months during the summer designing apparatus to meet the peculiar constraints of school laboratories. To supplement the text for students who wanted to investigate further, the committee commissioned a whole library

Charles E. Dull, H. Clark Metcalfe and William O. Brooks. Advertisements for that book proclaimed that it made use of a great new instructional tool: built-in transparent overlays. It turned out that there was only one such arrangement in the book. It showed a picture of a steam shovel in a pit. If you folded back the two transparent overlays, you could look in and see some of the gears. That was modern physics in 1955!

One way to analyze the nature of high school physics courses is to look at the exam questions. In New York, statewide exams have been given in major high school subjects since 1878. The figure on this page shows two questions on the same topic, one from a 1917 Regents exam and the other from the 1990 exam. The two questions require radically different responses and surely reflect radically different courses.

Physical Science Study Committee

In 1957 the physicists came roaring back into American education. Jerrold R. Zacharias of MIT had already had a successful career in molecular beams and a second one

of monographs. These were written and carefully edited at such a level as to make them attractive to bright high school students. Their authors were top scientists such as George Gamow, Victor Weisskopf, Robert Wilson, Hermann Bondi, René Dubos, Francis Bitter and Edward Andrade. Zacharias also produced a series of half-hour films that dealt with major segments of the whole course. Many of the films display phenomena not easily reproduced in classrooms, always with attention to the details of measurement and quantitative analysis associated with the investigation.

But the committee realized that a new text and new materials were not enough. With support from NSF, the PSSC proceeded to organize an elaborate series of summer and in-service workshops for the nation's high school physics teachers. Because there were only about 4000 full-time high school physics teachers in the United States (the same number as today), reaching many of them was a feasible task. And indeed, a large fraction—probably over half—of these teachers attended PSSC workshops. In many sections of the country continuing sessions were organized for monthly get-togethers of teachers and local university physicists. At these meetings the teachers learned more physics, exchanged teaching tips and bolstered one another's confidence.

The history of education is filled with factual uncertainties. It is difficult to ascertain even such basic facts as the number of textbooks sold (because it is a matter of proprietary interest) or the number of students who have taken a particular course. During the 1960s, teachers of introductory university physics frequently polled their students to see who had taken the new PSSC course. Many students were not sure whether they had or not. And even students who used the text may not have had well-trained teachers who understood the new material. But it is probably safe to say that for about two decades, over one-fifth of the American students studying high school physics used the text and laboratory materials designed by the PSSC. Because there are about half a million students who study high school physics each year, that means that PSSC directly affected at least two million students during its first 20 years.

It is also hard to know exactly how much money was spent on the development of the materials and the teacher training that followed. The total was probably under \$5 million. Even with these conservative estimates, it appears that the Federal government provided a modern, intellectually respectable physics course for less than \$3 per student.

The new course's influence extended well beyond its own use in American high schools. Most subsequent commercial texts borrowed freely from PSSC, particularly for laboratory work. The text was translated into 16 other languages. The films and laboratory apparatus made their way into the introductory courses of many universities and colleges. The seventh edition of the PSSC text, about to be published, will command a small but viable part of the high school market.

To be sure, the PSSC course did not take over the whole high school market, nor was that the intent. The last thing that Zacharias and company wanted was to create a new dogma. Now, a generation later, critics of the curriculum reform movement of the 1960s claim that PSSC did not increase the number of students taking physics and that it and other new projects were started by

scientists who had little knowledge of school realities and created curriculums that faded away. Such criticism reflects a lack of knowledge of the facts or a misreading of history. From the beginning, schoolteachers were involved in all aspects of PSSC, as they were with most of the other curriculum projects that followed. There was no reason to expect that the original text and materials would dominate the market or could continue to be used for many years without change. There was never any intention of increasing the number of students taking high school physics. That mission was considered to be yet another project.

Harvard Project Physics

Several years after the PSSC project started, Gerald Holton, F. James Rutherford and Fletcher G. Watson developed a new type of high school physics approach.⁴ One of its major aims was to appeal to teachers and students who were not using the PSSC approach. Because only one-fifth of physics students were studying PSSC, they reasoned there should be adequate customers for another type of course. Furthermore, because only one-fifth of high school students were taking *any* kind of physics course, there was even more room for a course with wider appeal. These originators of Project Physics (frequently called Harvard Project Physics) thought that they could reach this larger audience of students who would not make a career of science or indeed might not go to college at all.

The theme of Project Physics was to be humanistic. Holton had already written a splendid introductory college text that interwove good physics with good history of science. In many respects, Project Physics became an elaboration of that book at a lower level. Besides the textbook, there were short monographs on many interesting topics, new laboratory experiments and lab guides, 16-mm films and 8-mm film loops, programmed instruction materials, teacher aids and a variety of tests. The entire package could serve as the nucleus for an introductory course in college as well as in high school. It was a major contribution to our library of curriculum material.

The ancillary materials for Project Physics are now out of print. In spite of the fact that science educators and teachers were included among the developers from the beginning and the fact that the project had been carefully devised after an extensive analysis of the realities of high school education, the course did not succeed in expanding the audience of potential high school physics students. The explanation for this failure is complex, but one simple reason may be that the materials required students who could and would read. Apparently that is the same group to whom the PSSC materials appealed. Perhaps only a small fraction of high school students have the maturity and the combination of talents and interests to respond to an intellectual challenge.

Junior high school

At the junior high level, physicists were involved in the 1960s with the production of three new courses, only one of which still exists in a form similar to the original: Introductory Physical Science. In a way, IPS is a descendant of PSSC. Uri Haber-Schaim, who was in charge of developing the PSSC laboratory, was the team leader for IPS. The course, which is designed to prepare 9th-grade students for the new high school science courses,



Robert Karplus working with children. In 1961 Karplus left a very successful career as a theoretical physicist to form the Science Curriculum Improvement Study. His project attempted to create an elementary school science syllabus paced by the stages of students' intellectual development.

depends on sequential development of logical arguments and classroom laboratory experiences. To a scientist the course appears to be exciting and valuable. Because of its dependence on laboratory work, however, it requires a well-trained teacher. Though more than three million books have been sold, very few schools are now using the course.

Another descendant of PSSC was a course designed for 8th graders called Time, Space, and Matter, also known as the Princeton Project. Its theme was Earth science and it contained ingenious experimental work in geology and astronomy. The course required time for individual student activity. Even though it seemed to be accessible to students with a wide range of academic ability, it failed to propagate after the trial years and is no longer available.

The third and largest of the junior high curriculum projects was Intermediate Science Curriculum Study. It was started in 1966 by Ernest Burkman and other science educators from Florida State University. From the beginning they brought in scientists and school teachers and included them at every level of the organization. ISCS was a coordinated 7th-, 8th- and 9th-grade course sequence designed for individualized study. It covered physical science in the 7th and 8th grades and allowed a choice by the teacher of biological and Earth science topics at the 9th-grade level. It sought to develop science skills and methods, including not only manual abilities but also such processes as model building and testing. During the 1970s, almost one-fourth of the junior high students in the United States used this curriculum. The materials are still available commercially, but few schools continue to use them. The individualized study and the almost continuous laboratory work made life difficult for the teacher and the school system.

Elementary school

Each of the high school and junior high school curriculum development projects found that students had not been adequately prepared at the earlier levels. Clearly the

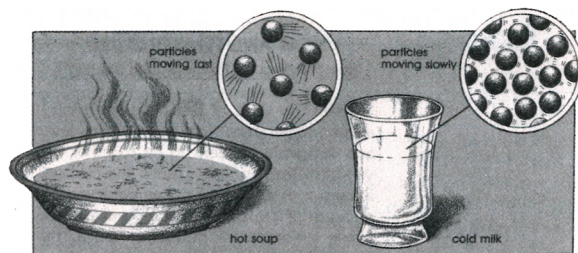
place to start curriculum revision was in elementary schools.

In 1961 Robert Karplus formed the Science Curriculum Improvement Study. Karplus left a very successful career as a theoretical physicist to study learning theory. The elementary school science syllabus he created matched his views of how students develop intellectually. These views were strongly influenced by Piaget's theories of sequential concept development. The SCIS curriculum materials made use of many new laboratory devices, and their study required sequential development from one grade level to the next. The program required teachers to undergo extensive training, so that they would understand both the science and the principles and techniques of the teaching program.

Another elementary school project founded largely by physicists was Elementary Science Study. In a way, ESS was another child of PSSC. (Its headquarters were in the same building PSSC had used.) The materials produced by this group were unique in that they did not form a course sequence in the usual sense. The project leaders thought that elementary school students should handle materials and explore phenomena in a loosely structured way. The unofficial description of student activity in ESS was "just messing around in science." A large number of unrelated units were prepared, each consisting of a teacher's guide and a student kit. Most physicists would be delighted to have their own children explore these units—or to mess around with them themselves. The teachers who took part in the development of the materials were fiercely enthusiastic about this method of teaching science to children. In practice, however, principals and school boards do not want children "just messing around." Like all the other elementary school projects, ESS is little used now in its original form.

There is one strange example at the elementary school level of how not to attempt a curriculum revision. The project was called Science: A Process Approach, and was an effort by a large organization—the American

Fourth-grade elementary school textbook in the elementary school series *Science* (Silver Burdett, Morristown, N. J., 1985) has a section dealing with heat, which includes the page shown at right. Note that fourth-graders are supposed to learn about atoms. (© Silver Burdett and Ginn. Used with permission. All rights reserved.)



All matter is made up of tiny moving particles. The more heat energy that matter has, the faster the particles move. For example, hot soup has a lot of heat energy. The particles that make up hot soup move fast. Cold milk has little heat energy. The particles in cold milk move slowly.

Heat energy is measured by the effect it has on matter. Heat affects matter by raising the temperature of matter. Think of two cups filled with the same amount of water at 0°C. One cup is heated to 10°C. The other cup is heated to 20°C. Which cup has received the most heat energy?

Heat energy is measured in a unit called a calorie (kal'ər ē). Adding calories of heat to matter will raise the temperature of matter. The water heated to 20°C needs two times more calories than water heated to 10°C.

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Association for the Advancement of Science—to become involved in the schools. SAPA's originators were strongly influenced by the psychological theories of Robert Gagné, who emphasized the hierarchical development of the skills underlying science processes.

According to Gagné, these processes are observing, classifying, measuring, interpreting data, inferring, communicating, controlling variables, developing models and predicting. Most physicists are surprised to learn that their work consists of these particular processes. Gagné maintained that these processes should be taught sequentially, frequently without much emphasis on any particular subject matter. SAPA provided no student texts; the materials consisted of laboratory supplies and elaborate instructions for the teacher. Unfortunately, the teachers usually spent more time trying to learn the instructional protocols than they did learning new science. Although SAPA was one of the most expensive projects, it was the least used and the least influential.

One smaller project that never got out of the development and trial stage was called Conceptually Oriented Program Elementary Science. COPES, the creation of Morris Shamos, emphasized the concepts of science, such as energy conservation. Another small-scale project, Elementary School Science by a Quantitative Approach, had measurement and quantitative analysis as its theme. All natural sciences topics were dealt with in this way, including botany, physiology, Earth science, chemistry and physics. One of the fundamental guidelines of this program was that the materials should be designed so that classroom teachers could administer them without any special or extra preparation in science. This turned out to be a practical and feasible goal. The materials were available for some years in the form of the *Measure and Find Out* books, published by Scott, Foresman. They went out of print when their publisher temporarily stopped issuing school science texts.

Persistence needed

During the 1960s scientists, and physicists in particular, actively intervened in the teaching of school science. They produced texts and laboratory materials that were new, exciting (both to adults and to children) and scientifically

accurate. Thinking that they had accomplished their goals, the scientists left the scene. Some went back to their laboratories; some simply grew old and no young scientists came forward to take their places. As the nation's interest in science education waned at the end of the 1960s, the standard career pattern for scientists in the universities left no time for excursions into nontraditional fields. It was as if the scientists had been shaking a huge bedspring; once they got it into oscillation they turned their backs and went their way. Should anyone be surprised that the bedspring soon stopped shaking? The educational system is vast and complex, with inertia and energy-dissipating mechanisms at every turn. Furthermore, there are territorial problems: The administration of the system is fragmented, not only by loose state control, but also into local district jurisdiction, further subdivided, in most cases, into control by the principals of individual schools.

Some effects of the high school curriculum projects are still visible. Many high school physics teachers remember with fondness their PSSC and Project Physics workshops. These, however, are the older teachers. The last of the workshops was held almost 20 years ago. While there are about 4000 full-time high school physics teachers in the United States (and perhaps another 4000 who occasionally teach a course), there are about one million elementary school teachers, with an annual turnover rate of almost 15%. These figures militate against any long-term effect of short-term solutions. Due to both economic factors and the academic backgrounds of most of the people in the teaching profession, it is essentially impossible to retrain the nation's elementary school teachers in science or science teaching.

Nor has there been any great improvement during the last 30 years in teaching science methods to future elementary school teachers. Methods courses in schools of education are usually taught by people who have no personal experience with scientific research. Methods courses in science departments are usually taught by

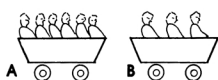
CHALLENGE / CRITICAL THINKINGUNIT TWO
Chapter 6

Use after pages 117–125.

Have you ever been on a roller coaster? Roller-coaster cars do not have a motor. They are usually pulled up a long hill at the beginning of the ride by a chain. From then on, the cars go up and down hills without any outside help.

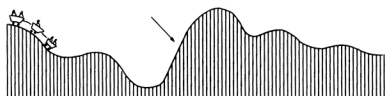
1. Use the terms "potential energy" and "kinetic energy" to explain how a roller coaster works. As a roller-coaster car is pulled up the first hill, its potential energy increases. This potential energy changes to kinetic energy as the car moves along the track.

2. A roller-coaster car with a great amount of kinetic energy will travel faster than a roller-coaster car with little kinetic energy. Which of these roller-coaster cars will take less time to get to the end of the ride? Why?



Car A. This car has more mass, and therefore it has more kinetic energy. It will travel faster than the other car, and therefore it will take less time to get to the end of the ride.

3. Draw an arrow to show where a chain will be needed to pull the cars in this roller-coaster ride.



Workbook sheet for elementary school students. This page is from the teacher's edition of the workbook, and so answers are provided. Note that answer 2 is incorrect. Fortunately, students do not remember much of what they are told. (From the Silver Burdett series *Science*. © Silver Burdett and Ginn. Used with permission. All rights reserved.)

a scientist may be welcomed into a classroom as an occasional entertainment, neither teachers nor school officials have time for long-term interference by laymen. The professional educators must fulfill their prescribed agenda.

One possible way for the physics profession to influence what is taught in the schools is to spell out what students should know about physical science at various levels. Until recently, the US has prided itself on not having uniform standards in education. But our traditional fear of central control has amounted in effect to a preference for anarchy. The situation now seems to be changing. Various groups, including political leaders, are talking about setting up national norms or goals, presumably defined by tests. Project 2061 of the AAAS has defined such goals in very general terms. The National Council of Teachers of Mathematics has just published a much more specific list of grade-by-grade goals for mathematics learning. If physicists, or all physical scientists working together, do not set such goals, the science educators will do it for us.

Physicists have a long tradition of intervening in the schools. Many of the interventions produced effects that lasted a school generation or more and influenced somewhat the curriculums that succeeded them. Now that the effects from the 1960s have largely faded away, it's time that we started shaking the educational bed-spring again. When we stop, it stops.

References

1. The quotes from Henry's writings are from B. M. Swartz, *Phys. Teach.* **16**, 348 (1978).
2. A. E. Moyer, *Phys. Teach.* **14**, 96 (1976).
3. A. Romer, *Phys. Teach.* **16**, 78 (1978).
4. G. Holton, *Phys. Teach.* **5**, 198 (1967); this issue has four other articles describing Project Physics. ■

people who have no experience with the realities of elementary schools. And while virtually everyone in the field espouses the need for hands-on science learning in grade school, teachers colleges themselves seldom provide such instruction.

What has happened to science education in the elementary schools can be seen by a casual examination of commercial textbooks. A few publishers dominate the field, and their books look very much alike. They also look very much like the textbooks of 40 years ago, except that the modern ones have more four-color pictures. The publishers claim that they are producing materials desired by and approved by science educators and school systems. But there is a degree of circularity to their reasoning. For example, most school science exams, whether produced by commercial publishers or state and national organizations, consist of tests of vocabulary memorization. The texts generally promote this by containing chapter-end glossaries of the science words to be learned.

Any scientist dealing with the schools should become familiar with social, psychological and political problems very different from those at the universities or in research. First of all, there is the problem of learning about the nature and capabilities of children at different ages. There is an enormous amount of literature on this subject, much of it in obvious contradiction to the actual practices in the schools. Second, the scientist will find that the PhD is not the union card for easy acceptance into the power structure of the schools; the EdD is preferred. Third, while