cations and possibilities of confusion. It is regrettable that Herschel conceived his plan in his own exuberant and slightly eccentric fashion and that he does not seem to have pressed the matter further.

Observing the Tides

Two other interests of the pair were meteorology and tidal observations. For Maclear these subjects formed part of his official instructions. For Herschel they were opportunities to exercise his somewhat wayward genius. In addition to the routine work, Herschel invented an instrument called the actinometer, which consisted of a thermometer with a large bulb filled with a dark-colored liquid. This was placed in the sun and the shade alternately, and the rate of rise of the liquid surface gave an opportunity of making rough measurements of the incident intensity of the solar radiation. Both men served on the local meteorological committee, and the correspondence is full of reiterated requests that Herschel's barometer be compared with that at the Observatory. Some of this concern was connected with the desire to ascertain the difference in height between the Observatory and Feldhausen. Herschel also devised the plan, already mentioned, for taking hourly observations throughout periods of 24 hours or more at the equinoxes and solstices. He went on to make experiments on the use of solar radiation for cooking and other purposes and records that a meal of mutton stew and potatoes was prepared in his solar cooker. His best systematic study was the detection of an annual fluctuation, and a daily fluctuation the magnitude of which varied with the seasons, in the barometric height.

The investigation of the tides was another subject which fell within the scope of Maclear's official instructions, and Maclear began the installation of a tide gauge in Table Bay in 1835. Thereafter this topic took an increasingly large share of his attention, for he took an interest not only in the tides in Table Bay but in those in Simon's Bay as well, and the apparatus employed became steadily more complicated. In the early days, Herschel, "assisted" by Bowler, would take the readings himself. Later on, a man who rejoiced in the profession of "tidewaiter" was employed, and Herschel devoted much time and thought to the problem of devising an apparatus to ring a bell when the tide was at midwater (either rising or falling) so that the tidewaiter might "take his cloak, lanthorn, key and pencil and go to the gage . . ." to take the readings. These tidal observations at the Cape were part of a widespread scheme, of which the moving spirit was Whewell, the Cambridge mathematician, for taking tidal observations at the same time all round the coasts of Europe and at other places where opportunity offered. Herschel and Maclear were anxious to secure a self-registering gauge, but this did not arrive until 1840, when it was installed first at Simon's Bay, where it remained for 20 years (a complete revolution of the moon's nodes), and later at Table Bay.

Herschel occupied himself to a great extent in the statistical and harmonic analysis of the results, demonstrating the presence of the terms due to change in the lunar and solar declinations, but the subject soon became a routine one, and Herschel turned to more varied fields.

Finally, in 1838, Herschel packed up his instruments, sold his house, and returned to England. It had been a lively time in South Africa, with many new interests and stimulating problems. For Herschel there was a dignified and unproductive middle age, full of honor and respect. For Maclear there was the memory of four years of moral support and intellectual stimulation, and, for him, there were many years more of productive scientific work. The memory of their time together remained with them both. Maclear, having ceded his pension to his wife, was financially embarrassed when she died before he did, and Herschel intervened in official quarters to adjust matters. Herschel died before Maclear, who wrote the former's obituary notice, and even then, though aged and beset with blindness, there came back to him warm memories of all that they had done together (*1*).

Note

1. Use has been made in the preparation of this article of the Maclear papers in the South African Archives, particularly the file of letters written to Maclear by Herschel. In addition, the following unpublished documents in the possession of the Royal Observatory at the Cape have been consulted: manuscript diary of Maclear and observing notebook of Maclear (both about 1835); correspondence referring to Bowler; fragments of the diary of Thomas Henderson. I am much indebted to my wife for assistance in the transcription of many of these documents.

What Kind of Science Teaching Program?

To interest high school and college students in science, begin when they are elementary school students.

Laetitia Bolton

Herbert Hoover's indictment of the American high-school system as "one of the major causes" of our failure to produce enough scientists and engineers is typical of one kind of widespread public reaction to Sputnik's assault on our national self-esteem. Scientific authorities and politicians have been telling us that we should not have been surprised by this revelation of the Russians' superiority in space science. In an atmosphere ringing with echoes of "We told you so," it is hard for any of us to escape a conviction that we have made a massive, collective blunder, and it is natural for us to cast reproach on the people we hold responsible for it. First on the list are the educators, who are now hard put to answer the accusing question, "Why aren't we producing more scientists?"

Before making a scapegoat of education we should recognize that, by and large, it is an instrument of national policy rather than a prime mover. Teachers who have been struggling to carry out the national mandate to educate all our children for a democratic way of life should not be held too strictly to account for a program dictated primarily by school boards, which are more or less

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responsive to students and their parents, and by the national economy.

Why Is Science Unpopular?

Of course it is shocking that only about one-fourth of all our high-school students study physics, only a third take chemistry or geometry, and only two-fifths take intermediate algebra. Yet we cannot agree with Mr. Hoover that the failure of students to go in for science or mathematics stems primarily from their wish to escape hard work. Science is unpopular partly because of cultural pressures, because of our heritage of anti-intellectualism, which makes young people suspect that a scientist is a queer duck, not quite human and probably not very happy. Science also fails to attract many students for the simple reason that they have had little opportunity to become interested in the subject. At the elementary level, for the most part, science is either not taught at all or is presented in a way that discourages enthusiasm.

Children who are exposed to a stimulating science experience are much less subject to adverse cultural pressures. They are not so likely to be frightened by what they hear about the destructive aspects of science, and they are less awed by popular misconceptions of what scientists are like. Those who have experienced personally the joys of search and discovery that are the scientist's rewards are far better able to appreciate his achievements and enter into his world. Because they have found science exciting, they are eager to continue studying it.

Should We Copy the Russians?

Most intelligent Americans would agree with Wernher von Braun that science education in the United States needs the kind of "powerful boost" he hopes that Sputnik may provide. But where should the pressure be applied? Is more required science in high school the answer, as Mr. Hoover suggests? Or should we adopt a crash program modeled on Russian methods, impose a rigid "ten-year schedule" on carefully selected children in order to assure the production of an aristocracy of scientists and technologists? Responsible American educators, and most scientists working in this country, do not believe that this kind of program would be either workable or desirable for us. Whatever course we adopt must be contained within the democratic structure of our society.

Moreover, the kind of science teaching we provide must be different from the Russians', and differently motivated, because our over-all aims are not the same. Here is where the educators come in. It is their responsibility not merely to train more scientists but to foster understanding of science. They must undertake to create more enlightened citizens, capable of integrating knowledge and appreciation of scientific aims and achievements into our general culture. As Edward Teller said in his appearance on "See It Now" last December, "we need more science fans." James R. Killian has pointed out that "the liberal arts of our time cannot be liberal if they reject or disdain science and technology," and that, conversely, "science and technology cannot fulfill their responsibilities if our scientists and engineers lack the humanistic quality which has been ascribed to the Athenians—the art of making gentle the life of mankind." This integration, which should be basic to our whole science education program, cannot be carried out successfully if it is left until college or even high-school age. We must start by making science intelligible and interesting to children while they are still young enough to incorporate it into their scheme of values as well as their core of knowledge.

Successful Teaching Produces Results

The Ethical Culture Schools of New York City, where science is introduced in nursery school, afford an excellent example of the fact that children who enjoy a satisfactory science experience at an early age are likely to acquire a lasting interest in the subject and a sympathetic attitude towards scientific problems (*1*). Most of the students attending the Fieldston School—the Ethical Culture high school—come from the two elementary schools in this group, the Midtown School and the Fieldston Lower School, which offer well-planned science programs. The science faculty believes that this preparation accounts for the fact that about 70 percent of Fieldston students, boys and girls, choose to take more science than is required for graduation or for college entrance. Over the past five years, half the boys and about 6 percent of the girls have taken all three sciences—chemistry, physics, and biology—offered in the upper school. These subjects are elected by the students from a rich curriculum, which includes classical and modern languages, many arts courses, and a full athletic program for all students, in addition to other basic subjects commonly offered in high schools (*2*).

About one-fifth of all Fieldston students choose an accelerated mathematics program leading to a year of college mathematics in their senior year. A high proportion of graduates also qualify for advanced placement in college chemistry and physics. This outstanding record is not due to pushing or cramming. Every effort is made to avoid overloading students or increasing tensions caused by anxiety over college admissions. For each student the science or mathematics course is kept to what he can absorb and enjoy.

Conservation, also introduced in the elementary schools, is taught at the high-school level as an integral part of social studies and biology. An extensive, laboratory-based science program in the seventh and eighth grades makes unnecessary the conventional ninth-grade "general science" course.

This interest is reflected in the fact that, in a recent survey of Fieldston graduates, more than a fourth of the careers reported were in the fields of science, medicine, or science teaching. This is a significant number for a school which offers a general college preparatory course with no special emphasis on any one area of learning.

What Kind of Program?

To produce this degree of voluntary involvement, an elementary program must be based on the premise that every child is a potential scientist. The small child's natural, unbounded curiosity about his world—about animals and plants, wind and weather, sunrise and sunset—is the most powerful tool he and his teacher can use to investigate this world and its forces. Anyone who has watched children absorbed by the wonders of Chicago's Museum of Science and Industry, New York's Museum of Natural History, the Hayden Planetarium, or "Mr. Wizard's" television program on NBC, can see with what delight children latch onto this kind of presentation. But their introduction to science need not be even so formal as this and is more effective if it is an integral part of their daily life at school. A science program for children should grow out of their constantly expanding interests, should satisfy their curiosity and stimulate it to further discovery.

How Young Can They Start?

It is interesting to note that even advocates of elementary science education do not always realize at what an early age science can become a part of children's lives. Senator Margaret Chase Smith, in a recent plea for teaching science in grade school, said: "Obviously we can't start teaching science to 6- and 7-year-olds in the first grade." Yet schools which gear their teaching to the experience and interests of children themselves find that even in nursery school children can acquire some understanding of and appreciation for science. At the Fieldston Lower School, for example, last winter's first snowfall triggered off a month-long investigation of the effects of temperature by a group of five-year-olds who wanted to know why the snow melted when they brought it indoors. They tried refreezing it and went on to find out something about how snow differs from ice and how refrigerators work. To discover some of the effects of heat, they baked cakes in an oven, checking time and temperature. This is a typical example of how an imaginative teacher can utilize the common experiences of everyday life to introduce young children to the joys of scientific discovery and the fundamentals of research.

Last February, Governor Harriman signed a bill making science teaching mandatory in New York State from the first grade through the eighth, beginning in September 1958. The state's recommended curriculum, already adopted by many New York elementary schools, is built around ten topics: "kinds of living things, keeping healthy, using electricity, common chemical and physical changes, lifting and moving things, energy from the sun, the atmosphere, earth and sky, rocks and soil, survival of living things."

This is an interesting list which should prove suggestive to teachers, but much of the success of the new program will depend on how these topics are approached. Cornelius Denslow, science teacher at the Midtown School, has pointed out, for example, that "information per se is not understood or retained unless the child is ready to receive it. Only when it satisfies a genuine curiosity is it truly assimilated" (*3*). Let us hope that in our zeal for science education we do not make the mistake of trying to "cover" prescribed subject matter at the cost of discouraging real interest in young people. "Science is not a mere matter of information," says Randolph Smith, director of the Little Red School House in New York City. "Keeping children's natural curiosities alive and fostering the essence of the scientist's avid search for knowing in every nook and cranny of his world is the nub of the job." There are all sorts of ways in which this can be done. At the Little Red School House, as at the Ethical Culture Schools, the earliest science experience is often focused on the care of animals and their young. A rabbit, a snake, a mouse, or a skunk may be not only a treasured classroom pet but also, for city children especially, an open-sesame to a new world of living things. This leads by degrees into a study of biology and human physiology.

A seven-year-old group at the City and Country School, another independent elementary school in New York City, recently did some research on hydraulics in order to install a water system for their building-block reconstruction of Manhattan. When an over-enthusiastic "engineer" poured too much water in the sand-pile reservoir, the class began investigating the effects of soil erosion.

At the Little Red School House, a dying jack-o'-lantern that developed mold once inspired a month-long exploration of molds (including penicillin)—where they come from, how they grow, and what they are good for.

Science experiences often grow out of other classroom work or school activities. The eight-year-olds who run the school post office at the City and Country School recently solved a complicated electrical problem when they found that the "special delivery bell" they had installed, to be operated from the school office, did not work. With the help of the science teacher they did some careful testing and found that the steel wire they had used provided too much resistance to carry electricity from their small battery source. In copper wire they found the answer to their problem.

With no sacrifice of its importance, science may be closely integrated with social studies. For example, the nine-year-olds who run the school supply store at the City and Country School study the products they sell. This usually involves a visit to a paper factory, with an introduction to chemistry through the process of making their own paper in the science laboratory.

The city itself becomes a laboratory as children investigate how fires are extinguished and how garbage is disposed of. In the course of constructing and lighting a model of their city, students at the Little Red School House discover the underworld of subways, cables, and conduits that lie beneath its streets. They find out how power is produced, how pumps work, how gravity and friction affect the operation of all these utilities.

An unusual workshop-laboratory such as that which the Walden School maintains for nine,- ten-, eleven-, and twelve-year-olds may help to provide, for city children, a substitute for the kind of opportunity offered by a rural attic or suburban junk-pile—a chance to take things apart and put them together; to handle, feel, discover for themselves how things work. From old radio parts, old telephones, clocks, or vacuum cleaners these youngsters sometimes derive as much scientific understanding as from the more formal laboratory equipment which the school also supplies. One boy, for example, made out of three old radio rheostats an apparatus to regulate the lighting for a school play. An old motor was repaired and used to spin colored disks, which led to a study of light and color by children of different age groups working together.

In all these schools, photography serves as an exciting introduction to chemistry and physics, as children learn to develop and print their own pictures. A child who is fascinated by glass blowing may go on to make his own thermometer or hourglass. At the Midtown School, more formal instruction may include carefully supervised chemistry experiments—making ink, freeing oxygen, crystallizing chemicals from solutions, separating mercury from mercurous oxide. At Walden, children do some dissecting of earthworms, crayfish, frogs, fish, and chickens. An eighth-grade study of ecology climaxes the science course at the City and Country School.

Technique and Equipment

In all these schools children become familiar with equipment and learn to handle it efficiently and safely. All except the Little Red School House have a full-time science teacher and a well-equipped science room which is used by the older children for classes and "free period" science work. These are important assets, but the equipment for an elementary school laboratory need not be elaborate or costly.

Techniques, Denslow feels, are best taught in response to "children's natural desire to learn better ways of doing things." Katharine Reichenbach of the

Walden School finds that techniques often improve when a child becomes so fascinated by an experiment that he does it over and over again.

Must We Scrap Democracy?

I have suggested only a few of the ways in which early science experience can be made a vital part of every child's education. I hope that these examples may suggest the kind of elementary science teaching which should be an important part of our answer to sputnik. One of the immediate reactions to its launching was to lay the blame for our tardiness on democratic society. "Too much gabbing has been going on these days," Max Ascoli wrote in *The Reporter* last fall, "about the prospects—if not, indeed, the actual evidence—of the superior capacity a slave society has over a free one in getting things done." John R. Dunning, dean of Columbia University's School of Engineering, reminded us in an excellent article in the *New York Times Magazine* that "we should not be deluded into thinking that dictatorship is necessarily more efficient than liberty. . . . The voluntary principle is the very thing we are defending in the cold war."

If we reject, as most of us do, the notion of drafting scientists, we must find some better means of increasing our supply. Most of the current clamor for reform has been aimed at the upper levels of education. But high schools complain that students are not interested in science; colleges find them ill prepared. The widespread introduction in American schools of science teaching, democratically motivated by the interest and curiosity of younger children, would seem a made-to-order method for raising the level not only of our science education but of our culture as well.

Notes

1. An issue of the Ethical Culture Schools' publication, *School and Home*, for March 1930 reveals that at that time science had long been an important subject at all levels in these schools.
2. The students' choice does not appear to be motivated by parental interests, since Fieldston families represent a wide range of occupations and cultural backgrounds. Since a majority of the students are admitted in the primary or preprimary grades, where no intelligence tests are made, the factor of exceptionally high IQ ratings does not apply.
3. *Sci. Teacher* (December 1956).

Popularizing Science

Can it be done? One opinion is that very little of what scientists know can ever reach the public.

M. W. Thistle

"It is often said that the presentation of scientific results to the general public in assimilable form is an important task for our age, and so it is; but the best way of doing it is perhaps yet to be found."—Charles E. Whitmore [*Sci. Monthly* **71**, 337 (Nov. 1950)].

What scientists do, it seems to me, is to try to find out what is going on—either inside us, or outside us, or both. Scientists, then, are definitely set to eradicate mystery. Yet nonscientists, including some members of the popular press, tend to believe that there is something mysterious about science; that in consequence it is appropriate to regard scientists with awe, to praise them unmercifully, to laugh at them, to be afraid of them, or to consult them on questions that are not always framed in clear and answerable terms.

Nonscientists tend to believe that a scientific institution is swarming with eye-popping discoveries every Tuesday, most of which the scientists conceal because they are overcautious. Laymen cannot bring themselves to believe that most science is singularly undramatic; it is difficult to convince them that science is not a continuing series of spectacular advances, on all fronts at once.

Scientists, on the other hand, are very much aware that hundreds of scientists and thousands of engineers worked for a significant fraction of a century on the problem of nuclear fission. They feel that laymen must learn not to expect the same sort of spectacular success every week, in time for the rotogravure section; must learn that the progress of science is a slow creep, consisting of thousands of small successes; must learn that only now and then is a result achieved that is both dramatic and obviously meaningful to the multitude.

How did this situation come about? How is it that men who patiently try to remove as much mystery as possible, no matter how long it may take, are regarded as mysterious figures, crackling with sudden and frequent revelations of further mystery? Can it be that the task of talking about science to a lay audience is particularly difficult?

I have arranged a diagram of barriers to illustrate the situation (Fig. 1). The first barrier is a single one—man directing questions to the universe—but all of the other barriers are double: barriers inside the communicator plus barriers inside the communicatee.

I shall discuss first the possibility of giving detailed and accurate accounts and then the possibility of transmitting scientific attitudes.

First Barrier: Words versus Things

Here the problem is to record new information about what is going on in the universe, somehow in terms of human symbols. This relation between things-going-on and human symbology has fascinated me for years. In the present context, it is enough to note that this problem does exist and to remark that even the wisest words serve as rather poor maps of what is really going on.

Second Barrier: Language and Sophistication

Everyone is aware of the language barrier; most people are also aware that some few persons are much better than others at talking about science to laymen, and so they pin their hopes on these unusual people and trust that all will be well.

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