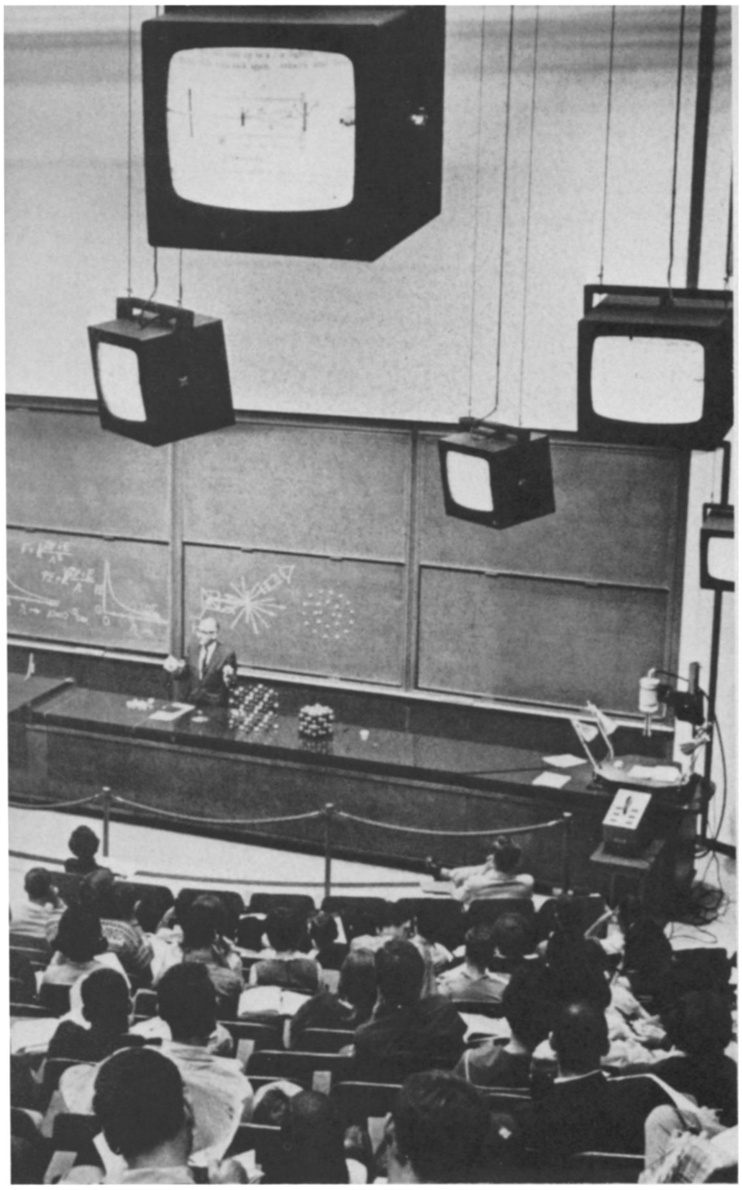

University of California

Science Education:

New theory, approaches and curricula in science education face old obstacles and new challenges . . .

by John H. Douglas

"In the first place God made idiots. This was for practice. Then He made school boards."—Mark Twain

After a decade of racing to produce more scientists than the Russians, educators are taking a long second look at science for the citizen, introducing healthy doses of literature and historical perspective into even the most rigorous disciplines and allowing the student to discover science for himself, as the "new humanity."

At the same time, a "Fourth Revolution" is taking place throughout the educational world, with sophisticated electronics beginning to replace the teacher in providing information, guidance and the inevitable testing to students.

Armed with new discoveries in educational psychology and the experience gained in 10 years' experimentation under abundant government funding, academic innovators are eager to apply the Fourth Revolution to science education. But they are already being challenged by declining financial support, decreasing science enrollment and competition from private industry.

How well are educational theorists, and school boards charged with implementing their innovations, facing these challenges? Fred Reif, a Berkeley physicist turned educator, is only a little kinder than Twain: New technology and curriculum changes, he says, can be beneficial, but "it's a matter of GIGO—Garbage In, Garbage Out. You put garbage into a computer, you get garbage out." Simply investing money into new ideas isn't enough.

Reif is one of an increasing number of scientists who have become disenchanted with what professional educators have done for the teaching of science, and have set about to make a contribution of their own. Following the launching of Sputnik in 1957—an event widely interpreted to show the United States lagging behind the Soviet Union in training scientists and engineers—Congress passed the National Defense Education Act, providing funds to improve science curriculum, encouraging scientists to help in this curriculum development, and offering lucrative scholarships to entice bright students to pursue scientific careers. Since then, total expenditures for public school education have more than tripled and the scientific community has taken effective leadership over science curriculum development.

First came the Physical Science Study Committee (PSSC) course in high school physics. Up-to-date, rigorous, emphasizing self-reliance on the part of the student, the course revolutionized physics teaching for a generation of scientists just now finishing their doctorates. In terms of speeding the process by which future physicists learned their trade, the course was a smashing success. As one Massachusetts Institute of Technology administrator put it, "We suddenly found ourselves boring the pants off our freshmen who had taken the course."

But while these budding scientists were accelerating their race to the Ph.D., larger numbers of students were racing to get out of physics altogether. In the decade after PSSC was introduced, proportional enrollment in high school physics dropped steadily to the point that the percentage of students studying physics in 1970 was a third less than the percentage in 1960. The significance of this decline is disputed, with some educators blaming the rigors of PSSC for discouraging students and others saying the decline was inevitable, coming as a result of many factors. At the same time, a scarcity of scientists changed into a seeming surplus in some fields (see accompanying article), and the rationale of science education came under new scrutiny. "The course was just too traditional," Jerrold Zacharias, one of the original leaders of the PSSC, says. "It was geared too much for people who might become physicists."

PSSC physics reached only about 20 percent of high school physics students during the sixties, according to Laurence Binder, head of the materials and instruction development section of the National Science Foundation. The comparable NSF-sponsored chemistry and biology courses fared somewhat better and the Foundation believes its projects succeeded in helping produce first-rate professional scientists during a period of national need. "The experi-

The New Humanity?

ence was encouraging," Binder told SCIENCE NEWS, "for we did what we started out to do."

Now, however, emphasis has changed, with NSF funding and major academic concern aimed not so much at producing trained professionals, but at increasing scientific awareness and sophistication in all students, especially women and racial minorities, who were previously seldom encouraged to study technical fields.

One of the first high school courses developed specifically to attract the total spectrum of students was Harvard Project Physics. Begun in the mid-sixties as a course option, additional to PSSC, Project Physics presents its material in a historical context, emphasizing the social conditions and individual personalities of scientists involved with particular discoveries, the effect of discoveries on society, and the practical aspects of knowing how things work. Its organizers say they found that in many schools where the course was offered, enrollment in physics increased markedly, with girls often making up half the classes. A four-year follow-up they conducted showed their students enjoyed science more than those in a control group, while not suffering academically for having taken the "softer" course. Project Physics was first implemented on a large scale in 1970 and has grown rapidly. It now reaches some 165,000 students in the United States and 20 adaptations are in preparation abroad.

To encourage students to study science earlier, several elementary science programs have been developed. The Elementary Science Study program developed at the Educational Development Center of Newton, Mass., today offers over 3 million elementary school children a variety of multimedia materials to guide them in discovering scientific principles from experiments they help design themselves. A similar program developed in Berkeley, the Science Curriculum Improvement Study (SCIS), emphasizes environmental and ecological studies, also taught by the "discovery method" of creative experimentation. The "Science: A Process Approach" of the American Association for the Advancement of Science is more traditional, a "behaviorist" course giving students programmed training through a more highly structured set of learning objectives and tests.

These various elementary school science programs reflect the deep rift between educational psychologists over the most fundamental questions about how children learn (see accompanying article). The "discoverist" school owes much to the Swiss psychologist Jean Piaget who said that a child's capacity to learn increasingly complex tasks must develop at its own speed over a period of time. He emphasized the need for exploration and organizing activities on the part of the student. The "behaviorist" school follows the theories of B. F. Skinner and Robert Gagne who advocate carefully defined goals and conditioned-response techniques for reinforcing these goals. The behaviorists argue that their method is more efficient; the discoverists, that their method better prepares the child to handle future problems that fall outside the neat confines of stated objectives. "When a consumer looks at both groups," says Herbert Thier of SCIS, "he finds one saying 'We can prove he learned a thing,' and the other saying 'Gee, I wonder what the kid will need when he grows up?' "

. . . revolution of teaching technology, a changing job market, new threats from creationists, and shrinking funds.

Florida State University

The George Washington University

Scientists trying to improve teaching at the university level might well wish for such controversy, for college science education remains largely unchanged, and efforts to modify it languish unsupported and uncoordinated. The fault, according to MIT's Zacharias, lies with the "Robber Barons," department chairpeople too interested in defending their own territories to bother with reform or to hire new professors for their teaching ability. "A man maintains independence by being salable horseflesh," he says. "Neither teaching nor educational reform is regarded as a salable skill in the university."

The picture of academic inertia presented at the turn of the century by the British scholar Francis Cornford has changed little: "Every public action which is not customary, either is wrong, or, if it is right, is a dangerous precedent. It follows that nothing should ever be done for the first time."

National Education Association

As a result of this inertia, Zacharias told SCIENCE NEWS, he is resigning as chairman of MIT's Education Research Center, one of the leading institutes for trying to encourage changes in university teaching.

The MIT administration, meanwhile, is setting up an education division of the university to conduct interdisciplinary research on higher education and offer a variety of courses to students.

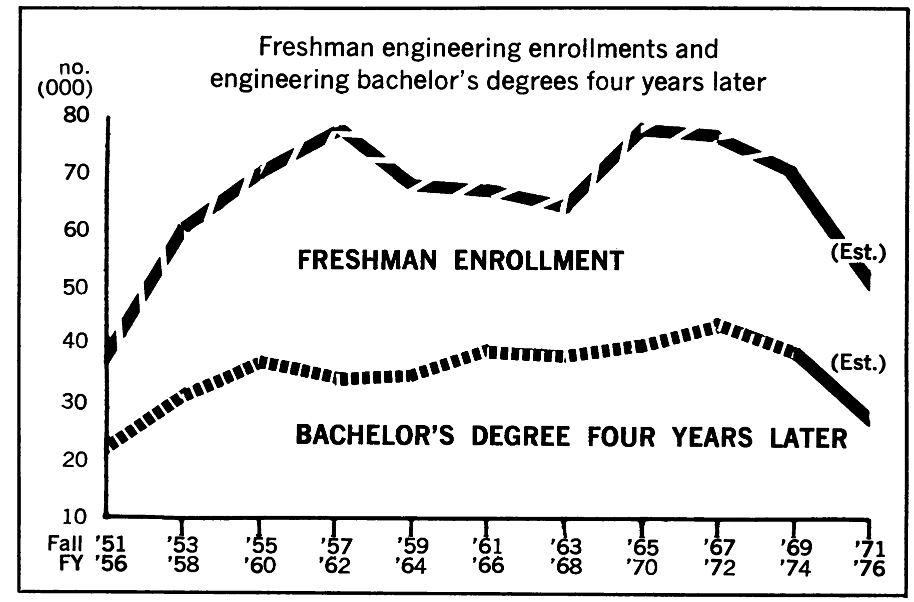
Reif agrees that much college science education is still a "cottage industry" based on a lecture model that "dates from the Middle Ages," but he hopes eventually to create a market for good college teaching through his SESAME doctoral program for university science teachers, at Berkeley. The program takes talented science graduates at the master's degree level and trains them in science curriculum research and development. Reif emphasizes the word *talented*. Just introducing new curriculum or setting up more efficient ways to broadcast the material will not make better education, he says. "You must take the very best talent and get it into intimate contact with the consumer. Education is not doing this." Specifically, he worries about who will be chosen to carry out the innovations of the Fourth Revolution, which, he says, could become "effective in the distribution of mediocrity on a grand scale."

In a paper written in 1967, the British biologist-educator Sir Eric Ashby identified four revolutions in education: shift of responsibility for education from the parent to a teacher, adoption of the written word, invention of printing, and now, the introduction of television, tape recorders, radio and computerized instruction into schools.

According to a report entitled "The Fourth Revolution," by the Carnegie Commission on Higher Education, electronic education will lessen routine for faculties and offer a richer variety of

Turning from science: Shortages ahead

by John H. Douglas



Davida Daemon/Scientific Manpower Commission

Students by the droves are turning away from majoring in science, raising the specter of short manpower supply in some professional fields in as little as three years. They apparently have been misled by isolated unemployment statistics and been given insufficient encouragement by Government and society to go into science.

The first crunch will come in engineering. According to Betty Vetter, executive director of the Scientific Manpower Commission, freshman engineering enrollment has fallen 30 percent in two years. This means that by 1976, when an estimated 43,000 new engineering graduates will be needed, only 29,000 will be produced. Students have apparently read of layoffs in the profession and mistakenly believe no jobs await them if they pursue engineering majors.

Just the opposite is true, Vetter says. Layoffs have mainly affected older engineers whose specialized talents are no longer needed or are out of date, and who cannot adapt. Especially hard hit are the non-degree engineers who were hired during the last technical manpower shortage and trained only in one speciality. "We're setting the stage for repeating this tragedy," she says.

The percentage of students obtaining undergraduate degrees in science has steadily decreased for two decades. Science and engineering students formed 21 percent of the 1950-51 graduating class, 17 percent in 1960-61 and only 11 percent in 1970-71. Next to engineering, physics enrollment has decreased the fastest, to the point that a shortage of physicists is expected by the middle of the decade. Meanwhile, students rushing headlong into premedical or environmental majors will probably soon form a substantial oversupply of life scientists, unless medical schools that now accept only one applicant in three greatly increase their capacity.

Even before the recent elimination of most graduate National Science Foundation fellowships and traineeships, the number of first-year, full-time science graduate students was declining rapidly, falling by 2.2 percent in 1969-71 and 5 percent in 1970-71. The decline hit the "top 20" graduate schools hardest, with an 8 percent drop in 1970-71. These institutions are expected to experience the severest effects of continuing decline with sharp cuts in specific departments and increased difficulty in attracting the best faculty.

The budget cuts and falling off of science enrollment could hardly come at a worse time, with the biggest batch of post-war babies just hitting college and with women and minorities beginning to make headway in their fight to join the science fraternity. By 1990 the United States is expected to have up to one-third more people than now, but by then college enrollment will have tapered off because of lower birth rates, and the shortage of trained technical personal could be critical. Women and racial minorities now find acceptance into science fields easier, but just at a time that money is becoming scarce. (The average woman Ph.D. today makes only 65 percent of the salary of her male counterpart.) Still, the average bachelor's level scientist earns a beginning monthly salary of $828 to $954, compared with $708 for a humanities graduate.

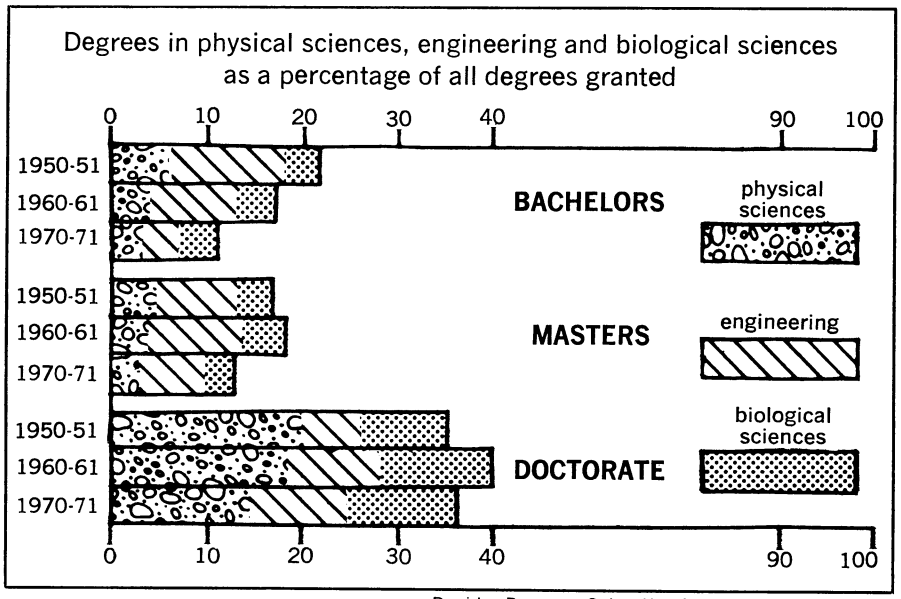
"We desperately need to study the future demands for scientists," says courses and increased opportunity for independent study for students within a few years. It will have a centralizing effect, requiring cooperation between campuses in producing new materials and a new role for libraries as "education centers" where students will use the materials. The commission says Government funds will be needed to facilitate these developments and specifically recommends creation of seven regional cooperative learning-technology centers for sharing costs and facilities in the development of television programs and computer instruction software.

Other countries have made more progress than the United States in utilizing many of the new educational technologies. Britain's Open University offers a model of how television can be used to provide education to a broad public not reached through traditional teaching methods, and it now serves 30,000 adult students, more than twice the enrollment of Oxford and Sussex Universities combined. Most students are employed full time and receive their university education by watching a series of television programs, completing assignments in home study kits obtained by mail, utilizing local study centers equipped with computer terminals and participating in occasional tutorial sessions with a teacher. Sweden, Germany and Japan have similar programs and Canada is contemplating the establishment of an Open University on the British model.

In the United States, development has been haphazard, but two projects may show the way of the future. The first is PLATO, the computer instruction network of the University of Illinois. Operating from one large computer complex in Urbana, the system offers telephone access to users with terminals throughout the world. The project started in 1959 and began offering computer-taught courses for credit the following year. By this fall, 40 to 50 courses will be available and some 400 teachers are actively preparing material for the system. Terminals consist of a glass plate that stores a display sent out from the central computer. The display may be words, graphs or diagrams; color pictures from microfiche slides can be superimposed over the display. Some 250 terminals are now in use, from California to Paris, and the project director, Donald Bitzer, told SCIENCE NEWS he hopes to have 4,000 terminals in operation within two years, at an operating cost of less than 50 cents per student per hour—a figure that would indicate computer instruction is ready to compete economically with classroom education.

The other project is being conducted by the Mitre Corporation. Mitre, a suburban Washington, D.C., thinktank, has installed a two-way cable TV system in Reston, Va., to provide customers with the ability to use their "touch-tone" telephone to communicate with a computer, whose readout is then displayed on the user's TV set. Beyond simply providing a new outlet for educational material the project promises a variety of community services, including auctions, games, information retrieval and a community forum. To develop the educational software for eventual use on such community systems, Mitre is working with Brigham Young University to write computerized English and mathematics courses for students at two junior colleges. The Educational Testing Service will evaluate the program.

Some commercial developers are not so scrupulous. Hoping to cash in on the lucrative educational products market, particularly in the field of science with its expensive equipment, several private corporations have jumped into textbook publishing, laboratory supplies distribution and electronic software development. "It's very dangerous and there's no way to prevent it," says Gerald Holton of Harvard Project Physics. "Some companies claim to sell apparatus as if it were authorized Project Physics equipment, which has nothing to do with the course. If he is not careful to use authorized equipment a teacher can wind up with a shelf full of stuff that is not designed to go with the course." Reif agrees. "The danger is tremendous," he says. Inadequately planned commercial ventures can discredit a good idea before it has a chance to develop. "Commercial companies jump in, with no talent, and produce junk. . . . It's frightening for



Davida Daemon/Scientific Manpower Commission

Vetter. "First we need to decide what to do about science—the role of science in American life, in foreign policy, and so forth—*then* ask how much money to allocate. Now it's all so haphazard."

In theory, cutting fellowships and traineeships in favor of putting more money into goal-oriented scientific projects will put enrollment into what the Administration calls free market economics, in which students will naturally gravitate toward the subsidized specific areas, resulting in direct attacks against the nation's technological problems. But critics point out that such an approach militates against flexibility and serendipity.

Says Philip Handler, president of the National Academy of Sciences: "We have embarked upon the painful transition from a society where almost all judgments were made in a market economy to a society which is learning to make its major decisions in the public sector, where the Government must learn to weigh hazard against benefit. . . . Meanwhile the manner of directing attention to [the nation's] problems has turned both our decision-makers and our youth against science. This nation may yet pay a dreadful price for such public behavior." □

% Change In First-Year, Full-Time Graduate Enrollment

	69-70	70-71
All Sciences	−2.2	−5.0
Engineering	+4.7	−4.7
Physical Sciences	−9.4	−6.5
Mathematics	−2.9	−9.4
Life Sciences	−2.5	−2.8
Psychology	−3.4	+0.2
Social Sciences	−3.4	−6.1

Science enrollments are dropping.

Georgetown University

anyone who undertakes innovation."

But more immediate problems threaten science education innovators. With the decline of government funding, the Science Education Improvement Activities of the NSF have had to be curtailed. This year the Activities have had $30 million of Congressionally appropriated funds impounded, leaving $47 million. Next year, a "restructured" NSF science education program will emphasize "problem-oriented" projects, teacher training and "science literacy," while reducing or eliminating such items as graduate student support and the Institutional Science Programs. Or, as one official put it, "Goodies now; to hell with tomorrow."

Thier agrees. "The biggest disaster is the lack of long-term planning and commitment. Research and development don't start from ground zero—you need staff and personnel; you need a training and indoctrination period. Short-term projects are very expensive,

Training doctors: Shortcuts, change, and a fund-cut 'disaster'

by Joan Arehart-Treichel

As a branch of science education, medical education is faced with its own peculiar problems. For one, the heat has been on medical schools for some years now to meet a much-publicized physician shortage.

Several years ago the Association of American Medical Colleges conducted a study to determine how many physicians the nation needs per 100,000 people. They arrived at 175, then estimated how much medical school enrollment should be increased to meet the need by 1976. The enrollment goal was 15,000. At that time enrollment was about 8,500. It is now around 13,000. Medical schools have also increased in number during the past decade, from 80 to 113. So it looks as if the nation's over-all physician shortage is being slowly alleviated.

Yet there is another, pressing problem . . . getting newly graduated physicians into the areas where they are needed most—inner cities and poor rural areas. So far, efforts in this direction haven't been very successful. For example, medical students in Kansas have long been required to work with a general practitioner in a rural area for six months. But when the students graduate, a Kansas G.P. notes, "they promptly move to California." Since 1963 the Federal Government has offered loans to medical students that have forgiveness provisions if the students practice for a while after graduation in inner cities or rural areas. This effort has not had much impact on the dearth of physicians in those areas. Two years ago Congress set up the National Health Service Corps to put physicians into needy communities. So far the corps has allocated only several hundred physicians, largely for lack of funds, and also because many interns and residents have preferred to not participate in it.

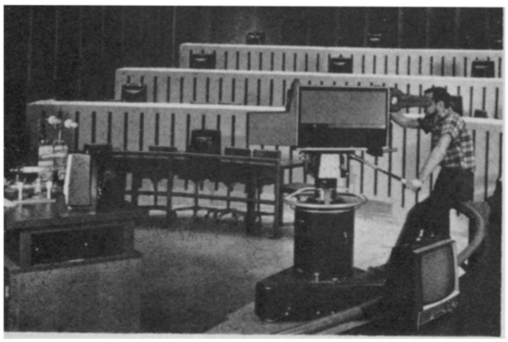
A number of persons believe that if medical schools trained more black physicians, the physician shortage in at least the inner cities might be filled. But medical schools are training more blacks now, and so far the thrust has done little to change health care in inner cities. Says August Swanson, a neurologist and director of academic affairs for the AAMC, "I think it is unrealistic to expect that the man trying to escape the ghetto is going to go back to the ghetto and stay any longer than it takes to acquire the necessary wealth to get out of it."

So how can physicians be placed in unpopular geographic areas? Swanson foresees states eventually licensing physicians by town or community, so that when the more desirable locations have enough physicians, doctors will be forced to practice in the less desirable ones.

To educate medical students more quickly while trying to maintain quality, medical schools have introduced some drastic changes in curricula. Many schools now allow students to earn an M.D. degree within six years after high school. If a student is strong in certain science areas, he may be able to skip courses. More and more students are able to progress at their own speed and to pursue the courses that interest them most. A number of specialties no longer require an internship. The problem is that many states still require a physician to have an internship before they will grant him a license.

Some physicians see these curriculum changes as beneficial. Others, such as George L. Engel of Rochester, N.Y., fear that curriculum changes, especially the trend toward shortening undergraduate experience and abolishing the internship, may create a crisis in medical education that will compound the so-called crisis in health care. He contends, for example, "that psychiatrists, neurologists, radiologists, pathologists, ophthalmologists and others are being hurried into their specialties without having experienced broad clinical responsibilities for patients in other areas." Marvin Cornblath, director of pediatrics at the University of Maryland School of Medicine, is concerned that medical students' cry for "relevant" science courses may persuade instructors to ignore basic science that will be more relevant a decade from now. After all, Cornblath points out, it takes about a decade for a physician to complete his education. Medicine is one, perhaps, the only profession, where a person receives his degree halfway through his training. In fact, 90 percent of all graduating doctors today go on to pursue a residency in one of 23 specialties. The AAMC would like to see medical education become a continuum rather than have arbitrary breakdowns into medical school, internship and residency. But Swanson admits, "There are a lot of problems working that out after such a long, historical development of a graduate program."

It is hard to pinpoint changes likely to take place in medical education during the next several years, but one thing does loom large—a cutback in Federal funds for medical education. The Health Manpower Act of 1971 (SN: 12/25/71, p. 421) was supposed to make money available for the construction of more medical schools. So far no money has been released. The Administration is also eliminating, starting in fiscal 1974, special scholarships and loans for medical students as well as training grants for young physicians who are going into medical research. The AAMC is now querying medical schools to find what effects these cuts are liable to have on the quantity and quality of medical education. The preliminary feedback is that the cuts will be "disastrous." Rep. Paul Rogers (D–Fla.), chairman of the House Subcommittee on Public Health, told SCIENCE NEWS, "The President's proposed cutback on traineeships, scholarships and grants may well be the most ill-conceived portion of the entire health budget . . . I don't think the President realizes the impact this would have on medical education."



University of California

intellectually and financially. It's a complete disaster because you'll eventually be spending more Government money to do the same job."

Even as new science curricula and delivery systems are reaching the schools, old arguments have suddenly revived to compound the science educator's other problems. Under heavy pressure from fundamentalists, the California State Board of Education included in its guidelines to textbook publishers a statement that new science texts should reflect a "dualism" (i.e., between creation and evolution) in their treatment of the origins of man. Later, a committee with no biologist member was set up to review the texts and make appropriate changes. After narrowly defeating a motion to include discussion of divine creation in science books directly, the board unanimously decided to put the discussion in social science texts instead.

Discoverists vs. behaviorists: Muddle of contrasting theories

by Robert J. Trotter

For centuries teachers stood in front of classrooms and dispensed their words of wisdom. Students flunked or graduated depending on how much of this knowledge was retained. This method worked to a certain extent and is still widely used. But experiments in developmental and educational psychology have shown that more efficient methods of teaching can be devised.

One theory of education, for instance, is based in part on the work of the Swiss psychologist Jean Piaget. For the past 40 years Piaget has been investigating intellectual development. Experiments with children have led him to conclude that intelligence develops through various stages, stemming from active interaction with the environment. In the first or sensori-motor stage a child learns basic concepts of the physical world by being exposed to a variety of tangible and visible objects. This and other intermediate stages are necessary, says Piaget, before a child or student can build up to more difficult, abstract modes of thinking.

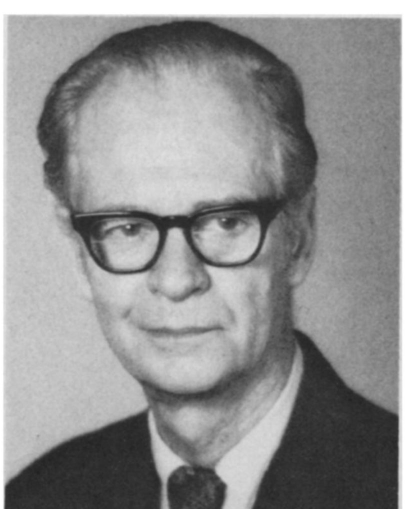
In a traditional chemistry course, for instance, students memorize formulas and perform classic experiments that confirm foregone conclusions. According to Piaget this can be damaging to lively minds. Instead, his theory says, students should learn the basic principles of chemistry by being allowed to develop their own experimental projects. Discovery through doing, says Piaget, not only teaches but can awaken original thinking.

At the same time this discoverist approach was being developed and expanded, a behaviorist or stimulus-response approach to education was gaining acceptance among educators. Harvard psychologist B. F. Skinner has been an influential theorist in this school of thought. Experimenting with animals instead of humans, Skinner developed a method of teaching that is much more structured and controlled than that of Piaget.

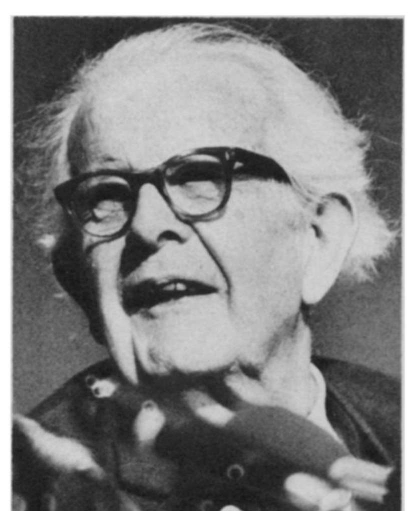
Using operant conditioning (rewarding desired responses), Skinner has been able to teach pigeons to play Ping-Pong. Because both pigeons and humans are organisms, Skinner says that operant conditioning and a mechanical treatment of stimuli and responses can be used in the classroom. The desired response is a correct answer. The rewarding reinforcement is approval from the teacher or (in the case of a teaching machine) permission to go on to the next problem. In a chemistry course hundreds of formulas and reactions can be learned in this way. By designing precise contingencies, Skinner says, very subtle discriminations can be taught. Discoverists would say such learning is merely mechanical mastery of skills and leaves no room for original or insightful thought. Behaviorists would answer that insight is nothing more than the proper use of previously conditioned responses.

The discoverist and behaviorist approaches are not diametrically opposed and they are not mutually exclusive. But putting either of them into operation requires trained teachers, special texts and specially designed equipment and environments. The discoverist teacher needs texts that are based on Piaget's stages of development, a variety of stimulating objects and equipment and an open type of classroom. The behaviorist teacher, on the other hand, needs a whole different set of texts (programmed instruction sets and even teaching machines) and a highly structured environment.

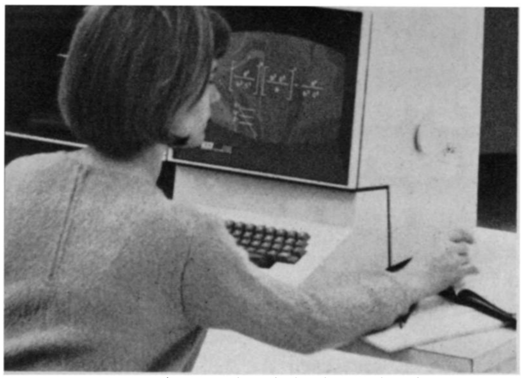
One teacher or group of teachers might decide on a particular teaching methodology only to find that the materials are not available. In this case it is the book publishers, not the educators, who are making decisions on teaching theory. Even when the materials are available, a student might move from one teacher and theory in the morning to a completely different approach in the afternoon. A specific theory or approach is necessary if a teacher is to do more than impart information on a hit-or-miss basis, but the superimposition of theories, subtheories and neotheories on older theories leads to a muddled education system. It is this muddle that is at the root of much of the criticism leveled at the education system.



Skinner: The structured approach.



Piaget: Self-discovery in science.



International Business Machines Corp.

Similar controversies are springing up in other states. At the end of the last legislative session, the Michigan House Education Committee unanimously adopted a measure to assure "reasonable amount of time" to the Biblical explanation of creation in any course containing references to evolution. The measure is expected to come up again this year. The Judiciary Committee of the Colorado General Assembly defeated a bill to provide "equal time, space and tax money expended" for creation and evolution, but backers are expected to gather signatures to put the measure on the next general election ballot. Still awaiting Federal court action is a suit brought by Washington Star-News religion columnist William Willoughby against the NSF, asking an equal amount of money to that spent for development of the NSF-sponsored biology text series for "promulgation of the creation theory."

"The situation is analogous to what we experienced in the 1920's," Jerry

Portrait of a successful community-wide science program

To academic innovators, the last decade of science curriculum development has brought unparalleled opportunity for intellectual challenge and discovery. But to local educators charged with applying the new ideas at the school level, the changes have more often brought a challenge to patience, ingenuity and budget.

Each new curriculum seems to require its own new equipment that lasts, with luck, about two years in many school systems. Elementary school teachers, in particular, often found open classroom experimentation contradicting accustomed pedagogy and threatening their skimpy scientific background with instant exposure. But when school boards, administrators and teachers fully commit themselves to making the innovations work, the results can be spectacular.

One such happy combination is in Fairfax County, Virginia, a suburban Washington, D.C., community of half a million population that has the nation's 15th largest school system. There, science coordinator Douglas Lapp and his staff work with 2,000 teachers in 130 elementary schools to bring some 60,000 young students benefits of the Elementary Science Study program through a do-it-yourself approach to equipment building and in-service teacher training.

Beginning in January 1970, with the encouragement of then Superintendent of Schools Lawrence Watts, Lapp began to work in a converted elementary school with school principals and supervisors to form a nucleus for teacher training. Equipment construction began, using the services of community women and student workers. In April the first workshops for teachers were held, and through the summer young people from the Neighborhood Youth Corps (NYC) and the Fairfax Community Action Program built basic equipment for the next year's course work, under sponsorship of the Office of Economic Opportunity.

By the opening of school that fall, 1,000 teachers had attended summer training workshops and began to use the homemade equipment in their classrooms. For a unit called "small things" 11,000 microscopes made from blocks of wood and a tiny lens—all costing 26 cents—went to schools on a rotating basis. Some 10,000 caterpillars were air-freighted from California in four shifts in time for students to watch them spin cocoons and emerge as mature butterflies. A staff of 10 part-time workers from the community and students working after school kept the equipment in good condition and constantly rotating among the various schools of the district.

Teachers usually taught four experimental units a year using the kits. Even counting the costs of local labor, the kits cost substantially less than those commercially available. Lapp estimates, for example, that a "small things" kit for a class of 32 would cost $68 to prepare, compared with $202 for the cheapest commercial substitute.

Lapp cites the teacher workshops and cooperation of the principals as keys to the project's success. "There's a lot of wheel-spinning in education," he says, "too much distance between curriculum and practice." To narrow the gap, workshops concentrated on what Lapp calls a "frontal attack on teacher attitudes toward children." Teachers were encouraged to act not so much as lecturers as instigators, who would challenge students to try their own ideas in performing experiments and then describe their observations. Teachers were not to keep interrupting the class to give advice but instead to wait for children to raise questions when they had difficulty and generally to "relax and enjoy the experience."

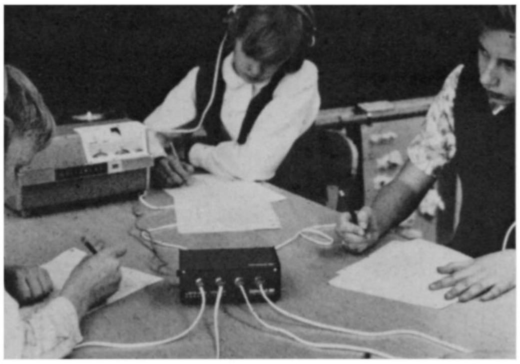
Though participation in the project is voluntary, no materials are sent to teachers who do not take the workshops. As a result, 95 percent of the teachers have received four days of workshop training with generally enthusiastic results.

Before, says Lapp, "Nobody asked the kids what they thought." Now the students get a chance not only to say what they think, but also to gain confidence and experience in performing experiments to develop the ideas they express. □

—*John H. Douglas*

School children in Fairfax County use locally made equipment to perform their experiments.

Douglas Lapp



3M Company

Lightner, executive secretary of the National Association of Biology Teachers, told SCIENCE NEWS. "There's a resurgence of isolationism, turning inward, Jesus Freaks . . . maybe a Scopes trial."

Controversy also arises when discussion of sex or venereal disease is included in science courses. "Where have these people been the last 25 years?" says Thier. "It's illogical to discuss the matter. They're trying to prepare kids for a world that doesn't exist."

Still, changes are coming. The Carnegie Commission estimates that the new electronic educational technology will be generally introduced into higher education before the turn of the century, and quotes figures showing that the technologists themselves expect "routine use" by 1990. And more curriculum changes are being developed. Zacharias has proposed a fundamental new attack on mathematics teaching, observing, "The 'new math' is very constipating to the intellect. But then mathematics education always has been." He leafs through his copy of the 1771 Encyclopedia Britannica to show a reporter the section in algebra. "See" he gloats, "just like 1972!" Instead of a traditional, abstract presentation, Zacharias is developing a more concrete approach, heavy with everyday examples and practical problems designed to encourage a student to "rummage around in his intellectual attic for solutions." Talking of future curriculum revisions, Holton says they should emphasize flexibility, teacher preparation and variety, exploiting the student's pervasive desire to "know how the world works."

Despite uncertainty of funds and disagreements over specific methods and objectives, the problem most often discussed in various ways by science educators is that of communication—communication between government and the education profession, between scientists and teachers, and ultimately between the scientists of today and those of tomorrow. Zacharias illustrates the problem with a parable:

"Colleges today are in trouble because they have become the new Tower of Babel. Everybody in the tower speaks the same language—broken English—but God created Departments, which keep people from talking to each other. The chemists can't talk to the physicists, who—God help us—can't talk to the humanists."

Once these barriers of communication start to fall, science education may indeed become, in Thier's phrase, "the new humanity." □