22 July 1955, Volume 122, Number 3160 SCIENCE

Improving Science Teaching

AAAS Cooperative Committee on the Teaching of Science and Mathematics

Only 249 men and women who had prepared to teach high-school physics graduated from colleges and universities in the United States this spring. And only half of these few graduates—if recent experience serves as a guide—will actually be teaching high-school classes next fall. The other half will have been diverted into other occupations by more attractive employment opportunities, will be in military service, or for other reasons will not be teaching.

One hundred twenty-five new physics teachers are clearly far too few to replace those lost through death, retirement, and resignation from the nation's 25,000 high schools and to teach the additional classes called for by an enrollment that is already well above the 6 million of 3 or 4 years ago and that is expected to reach 11 or 12 million by 1965.

The widening gap between supply and demand is only in part due to the decline in the size of college graduating classes since the peak of 434,000 in 1950. During the past 5 years the total number of graduates has declined 39 percent, but the number prepared to teach high-school physics has dropped 74 percent.

Although the pinch is most severe in physics, a similar situation prevails throughout science and mathematics; the supply of new high-school teachers has declined more rapidly than the total number of college graduates.

High-school principals, faced with an inadequate supply of science and mathematics teachers, have two courses of action open to them. They may use teachers who are inadequately prepared or they may drop courses that their students want and should have. Either action will mean that fewer students in the years ahead will enter college with a developing interest in science and mathematics.

Consequences of the Shortage

The shortage cannot help but affect unfavorably the rate of production of future scientists and the quality of their training; many students develop their interest in scientific careers at the high-school level. Also adversely affected will be the scientific knowledge and appreciation of the general public; many students are formally introduced to the sciences during their high-school years, and for a large number, high-school courses represent their only formal study of science.

The shortage of teachers of science and mathematics poses such serious consequences for scientific and technologic progress in the United States that an immediate, coordinated, large-scale attack on the underlying causes seems necessary. Since all branches of science will be affected, science as a whole has an important stake in the improvement of high-school teaching. The AAAS—first through the Cooperative Committee on the Teaching of Science and Mathematics and the Academy Conference (the composite organization of state and city academies of science), and then through the endorsement of the board of directors—has decided to do what it can toward improving the quality of science instruction and increasing the number of well-trained teachers. The program, *Science Teaching Improvement Program*, developed by the cooperative committee, will form the basic plan, and the Carnegie Corporation of New York has generously provided a grant of $300,000 to help finance these efforts. Additional funds will be necessary to carry out fully the proposed program.

Factors in the Current Situation

Of the factors responsible for the shortage of well-qualified teachers of science and mathematics and the deficiencies of much of the instruction given in these fields, four seem to be particularly important. Although some of these factors affect all high-school teachers, their combined effect has been greater on teachers of science and mathematics than it has on teachers of other subjects.

1) *Birth rate changes.* High-school enrollment is increasing and will continue to increase. The upsurge of births in the United States during World War II was followed by even higher birth rates in the postwar years; births in 1940 totaled a little more than 2 million; in 1954, 4 million. But the newly graduated teachers for the expanding high-school population must be drawn from the thin generation born during the 1930's when birth rates were low. Students currently graduating from college are wanted for many occupations other than teaching; the over-all shortage of new graduates affects teaching as well as other occupations.

2) *Lower salaries of teachers.* The salaries offered to high-school teachers are frequently lower than those offered to the same individuals by other prospective employers. Moreover, the salary increases and ultimate salary ceiling to which a teacher can look forward are lower than those in other professional fields.

3) *Educational policies and attitudes.* During recent decades the high school has changed from an educational institution designed chiefly to train a few students for college admission to one designed to give terminal training to large

The AAAS Cooperative Committee on the Teaching of Science and Mathematics includes one member for each of the following: American Association of Physics Teachers; American Astronomical Society; American Chemical Society; American Institute of Physics; American Nature Study Society; American Society for Engineering Education; American Society of Zoologists; Botanical Society of America; Central Association of Science and Mathematics Teachers; Division of Chemical Education of the American Chemical Society; Board of Directors of the AAAS; American Geological Institute; Mathematical Association of America; National Association of Biology Teachers; National Association for Research in Science Teaching; National Council of Teachers of Mathematics; National Science Teachers Association; Section Q (Education) of the AAAS; and (by invitation) the Academy Conference.

numbers of students who are not going to college. Although this change has brought many advantages, it has also made it more difficult for most high schools to give rigorous, high-quality courses in the subjects that are most appropriate as college-preparatory work. Consequently instruction in science and mathematics has suffered.

4) *Attitudes of scientists.* Although many scientists criticize the high school, and many college teachers of science deplore the preparation their students bring from high school, scientists have not, on the whole, accepted responsibility for the training of high-school teachers. This responsibility has been left largely to departments of education. College departments of science have not seen to it that prospective teachers had a good background in subject matter; they have not provided—as have education departments—summer-school courses for teachers; they have not encouraged their students to become science teachers; they have not made science teachers feel themselves to be part of the total scientific community. The many individual exceptions to these generalizations are encouraging, but still leave it true that scientists themselves must accept part of the responsibility for the shortage of science teachers and the inadequate preparation of many who are teaching science courses.

The AAAS clearly cannot rectify all the defects, but it can help. It has selected the following seven programs or types of effort, and it hopes to make useful contributions to each. Although these seven projects have been selected as desirable lines of effort, it is likely that future conditions and decisions will modify many of the details outlined here, and that they may produce major changes in the projects currently planned.

Responsibility of Scientists

High-school science teachers should have reasonable knowledge of the subjects they teach. There is room for debate over what constitutes "reasonable knowledge," but there seems little question that many individuals now teaching science in the high schools are inadequately prepared in the subject matter of science.

Educators generally believe that all high-school teachers should have a reasonable background in the field of teaching. Again there is room for debate over the proper amount; most states require between 18 and 30 semester-hours in such areas as student teaching, child psychology, teaching methods, and the history of education. Scientists are by no means unanimous, but many agree that such courses constitute desirable preparation for the prospective teacher.

State certification requirements and departments of education usually see to it that beginning teachers meet the formal requirements in education. Over the country as a whole there is no comparable insistence upon adequate subject-matter preparation as it is defined by scientists. It is in this area that we think scientists can and should accept greater responsibility and exert greater influence.

In the typical college or university science department, attention has been concentrated on the preparation of students for graduate work and research careers or on the preparation of students for engineering, medical, or other applied science areas. Students with an interest in high-school teaching and with the necessary aptitudes in science and mathematics either have not been encouraged to prepare for teaching or have been discouraged from making such preparation.

How many individuals who might have become satisfactory teachers of high-school science and mathematics have been lost to teaching in this way cannot be calculated. Whatever the past losses, if the situation is to improve, collegiate science departments must actively encourage qualified and interested students to prepare for careers in teaching, both high-school and college, but especially high-school. Accordingly, the AAAS plans an organized effort to bring the facts concerning the critical shortage of high-school teachers of science to the attention of college and university departments of science and mathematics and to urge their more active participation in the recruitment, training, and encouragement of high-school teachers of science and mathematics.

What is appropriate on one campus may not be appropriate on another. The following list, therefore, includes what appear to be desirable activities, but the details must be expected to differ from one institution to another.

1) Collegiate departments of science can examine, and frequently improve, their undergraduate courses and major requirements from the standpoint of their appropriateness for future high-school teachers.

2) Working with departments of education and state school officials, they can revise certification requirements to place greater stress on subject-matter preparation of prospective teachers.

3) They can develop courses suitable for high-school teachers who return to the campus for summer work. In many states a teacher with graduate work or a master's degree qualifies for a salary increase. The undergraduate work of many teachers who would like to get such increase is not adequate, however, for enrollment in the traditional graduate courses in science and mathematics. Turned away by departments of science, they concentrate in education, in which they can receive graduate credit. This situation creates a problem for science departments: they do not wish to water down their advanced courses; neither do they wish to give graduate credit for their elementary courses. Yet unless they make some adjustment, they are missing an opportunity to raise the level of high-school teaching and improve the preparation of future students in their own fields.

A number of colleges and universities are meeting this problem by developing special courses, usually offered in the summer term, that are open only to teachers. Thus these courses do not interfere with the usual sequence for students with other interests but are valuable for high-school science teachers. On some campuses these courses carry graduate credit in science; in others they are counted as education credit, even though they are planned and taught by science departments.

Other adjustments are also possible: a master's degree in science teaching can be given without interference with the usual master's degree in science. Efforts can be made to have school regulations amended to allow salary increases for appropriate additional college work, even though a good portion of the work is at the undergraduate level.

4) College and university departments of science and mathematics may assist high-school teachers in other ways, for example, by providing a departmental staff member to a neighboring high school to offer advanced instruction in science for a selected group of students. Sponsorship and support of meetings and conferences at which college and high-school teachers may exchange information is still another avenue through which college scientists can assist in improving high-school science teaching. Representatives of college and university staffs might also be made available for consultative and lecture services to high schools.

Emergency Measures

A large potential source of high-school teachers of science and mathematics consists of individuals who have had college work in these fields, who may be interested in teaching, but who lack the required courses in education. Such individuals are found among seniors in liberal arts, engineering, premedical, predental, and other curriculums; some of the students who started to specialize in these other fields later developed an interest in teaching, but made that change too late in their college careers to take the usual sequence of courses in education without unduly lengthening their college programs. Similarly, among col-

lege graduates with substantial amounts of work in the sciences and mathematics may be found some who would like to teach.

Special accelerated programs in education should be arranged for senior undergraduate students who wish to qualify for teaching positions before the beginning of the next academic year. For students in independent liberal arts colleges without departments of education, cooperative arrangements with departments of education in nearby institutions may need to be worked out. In any case, institutions of higher education should take the initiative in setting up such accelerated programs and in bringing them to the attention of interested students.

Many states provide for emergency teaching certificates that make it possible for a partially qualified individual to obtain immediate teaching employment and to satisfy the requirements for a standard teaching certificate while employed. In some cases accelerated programs in education leading to emergency certification may be possible; in others, especially those found among college graduates out of school for some years, supplementary or refresher work in science may be more appropriate. Colleges and universities, in cooperation with certification authorities, can take the initiative in establishing such programs and in bringing them to the attention of interested individuals in the regions that they serve.

The AAAS plans to study the effectiveness of tapping these resources of potential science and mathematics teachers, to collect information on what is already being done toward that end by individual institutions, and to hold a series of state conferences of scientists, educators, and state certifying officials to stimulate additional efforts toward the development of emergency programs for the training of science and mathematics teachers.

Recruitment for the Future

The efforts described in the preceding section are required to meet the pressing current shortage of science and mathematics teachers. To satisfy expanding requirements for the future, vigorous measures will be necessary to interest a considerably larger number of potentially qualified students in preparing for teaching careers.

Many steps may be taken toward the accomplishment of this objective. Among these are (i) the preparation and dissemination of appropriate guidance materials on mathematics and science teaching; (ii) the promotion of vocational guidance programs through assemblies, radio, and television; (iii) the utilization of scientists and engineers as counselors of students with scientific interests; and (iv) the encouragement of high-school science clubs, science fairs, and junior academies of science.

An important element in the development of a recruiting effort is knowledge of what it is that people find attractive and unattractive in the field for which one is recruiting. Some of these factors are already known insofar as they concern the field of teaching, but current and better information is desirable. Consequently the AAAS plans to make a study both of the factors that attract people into teaching, and of the factors that are important in influencing teachers to turn to other kinds of work. The information from the study can be used, not only in guidance and recruiting, but also, to some extent, in suggesting changes in school policies and arrangements that would make teaching more attractive.

Higher Salaries

At the root of much of the difficulty of attracting and retaining competent teachers are the prevailing low salary scales and the deterioration in the relative economic position of teachers with respect to other occupational groups. Although all teachers are affected by these economic factors, the problem arises most acutely in the recruitment and retention of science and mathematics teachers. Industry and government compete more aggressively for persons with training in science and mathematics than they do for prospective teachers in other fields.

We support the principle that beginning salaries, rates of salary advance, and salary ceilings for teachers should be comparable to those available to other professional personnel of equivalent training. Obviously the AAAS cannot bring about such a sweeping change; this can be accomplished only by widespread local action at the community level. What the AAAS can do is to enlist the aid of state academies of science and other state and local scientific groups in bringing to clearer public attention the need for higher salaries for teachers and the special problems that exist in the fields of science and mathematics. Moreover, its 50,000 members and the members of its 260 affiliated and associated societies could lend their influence to these efforts in their own communities.

The salaries of teachers of science and mathematics are usually controlled by general salary schedules. It is doubtful that salaries of science and mathematics teachers could be raised above general levels, and debatable whether they should be. Efforts to increase the total income of science teachers are, however, being made by methods other than salary increases. Therefore a study is also contemplated of the various ways in which science teaching can be made more attractive financially by such devices as year-round employment, summer employment in science-related industries, or additional pay for directing student research projects, science clubs, science fairs, and other activities. Most salary schedules at present do not provide for increases on a merit basis. Although it is recognized that such differential scales are debatable, consideration of this problem by scientists might lead to a more satisfactory solution.

Better Working Conditions

To a considerable extent, the large size of classes, heavy teaching loads, and lack of adequate laboratory facilities and instructional equipment discourage competent students of science and mathematics from looking forward to careers as teachers. These same factors contribute to the high rate at which teachers of science and mathematics leave teaching for other occupational fields.

The AAAS, both as an association and through its individual members, can bring to the attention of appropriate groups the need for improving the conditions under which science teachers work. It will investigate the effectiveness of the use of teaching assistants and of such instructional aids as motion pictures, radio, and television in increasing teaching efficiency and providing the teacher with more attractive working conditions. It will give special attention to the adjustment of teaching load, so that a more effective job may be done, particularly in connection with laboratory instruction.

Believing that closer affiliation with organized science and the resultant enhancement of professional *esprit* would benefit teachers, the AAAS plans to encourage the attendance of teachers at scientific meetings and will support the provision of time off and reimbursement of travel expenses to encourage such attendance.

Awards for Distinguished Teachers

In recent years the secondary-school teacher has not enjoyed high prestige, not by any means, we think, as high as his contribution to society merits. The public recognition of exceptionally able teachers of science and mathematics represents one means of enhancing their prestige. The AAAS therefore plans to institute an annual program of awards to outstanding teachers. The teachers to be honored will be those who, over a period of years, have been recognized in their schools and communities as exceptionally effective, whose knowledge of

science or mathematics approximates that of the master's degree level, and who have, through writing or other means, been of substantial help to their fellow-teachers. Such teachers are good "professionals" and merit higher prestige than is accorded to teachers generally. We propose to honor them with citations as Distinguished Service Teachers. Since these citations are intended not only to reward excellence but also to call public attention to the importance of good teaching, the citations will be awarded in the teachers' own schools.

If financial backing can be secured, even more might be done. For example, the teachers selected for citation might be given monetary awards; or the expenses might be underwritten for each year's group to attend the annual meeting of the AAAS.

The scope of these plans is flexible. The number selected each year should be small enough to make the citation a real honor, yet large enough to make the motivation and prestige values as widely effective as possible. Perhaps 100 Distinguished Service Teachers a year would be a good starting level.

Intelligently administered, rank and honors are not only an award to those who receive them but an inspiration to those who aspire to them. For many individuals, and particularly those who are sincerely attracted by the opportunity to guide the intellectual development of young people, the respect accorded the teacher may provide the best measure of the value that society places on teaching.

Consultants to Teachers

The plans described here are designed to retain experienced science teachers in the classroom and to increase the number of young people who prepare to teach science. Even if these goals are achieved, the greatly increased high-school enrollment of the next few years will in all probability necessitate the use of many science teachers with less than adequate preparation. It is proposed, therefore, to undertake a pilot study of a method for "upgrading" the work of relatively inexperienced and inadequately prepared teachers.

The plan provides for the employment in each of several geographic regions of two competent science or mathematics teaching counselors—expert consultants —who will tutor, assist, and serve as a source of information and help to the less-experienced and less-competent science teachers of the region. These consultant teachers would have no administrative supervision over their colleagues and would be employed only in regions in which supervisory help in science and mathematics is not already available within the school system.

If one such consultant were made available to each group of 20 to 25 teachers, the increase in staff would amount to only 4 or 5 percent. The number of teachers will increase anyway; perhaps this type of increase would be more effective than others. It seems worth while to test the hypothesis that the total effectiveness of instruction will be greater with such consultants than if the same individuals simply taught classes all day.

If this hypothesis is borne out, it is hoped that the demonstration will encourage school systems, state departments of education, and colleges and universities to assume permanent responsibility for providing continuing consultant services in science and mathematics to nearby high-school teachers of those subjects.

Role of the AAAS

It should be obvious that the AAAS can work more effectively on some of the foregoing proposals than it can on others. On the one hand, the AAAS has strategic opportunity to work toward the assumption on the part of scientists of greater responsibility for the training of science teachers. On the other hand, there is nothing unique that the AAAS can do on the problem of raising teachers' salaries.

There are so many facets to the problem of bringing about a sizable increase in the supply of well-prepared high-school teachers of science and mathematics, and of improving high-school teaching in these fields, that the AAAS cannot hope to achieve any large measure of success without the concurrent efforts of many other groups and organizations. Although it will supplement and sometimes cooperate with other programs looking toward the same ends, the AAAS will concentrate its major effort on the projects that it is particularly well qualified to carry out by virtue of its broad representation of scientists and science teachers in all the sciences at all levels.

Biological Effect of Atomic Bomb Gamma Radiation

Eugene P. Cronkite, Victor P. Bond, W. H. Chapman, R. H. Lee

The gamma radiation from the atomic bomb has been appropriately divided into the prompt gamma radiation associated with the fission process and the delayed gamma radiation. The delayed gamma radiation has been subdivided into the initial gamma radiation that extends through the first minute after detonation and the gamma radiation that is associated with contamination by fission products. With the air-burst, the latter is unimportant. The prompt gamma rays are of relatively little importance, because they are filtered out by the materials surrounding the bomb (*1*).

The high dose rate and the reported high effective energy of the initial gamma radiation had led to speculation about the relative biological effect (RBE) of this nuclear radiation as compared with the usual laboratory x-rays and gamma rays. Estimates of the relative biological effect by various competent individuals varied considerably, and a value of 1.0 was considered unlikely. The relative effect and species differences in effect of radiations on mortality was studied extensively by Boche and Bishop (*2*).

Field determination of the gamma-ray relative biological effect, using mortality in mice as the criterion, was undertaken by the Naval Medical Research Institute, Bethesda, Md., and the Naval Radiological Defense Laboratory, San Francisco, Calif.; extensive control studies of x-ray mortality on mice were conducted, both in the United States and at the Pacific Proving Ground (*3*).

The control studies consisted of exposing first-generation hybrid LAf_1 mice to laboratory sources of x-rays of several energies and with different conditions of scatter. Approximately 10,000 mice were exposed in various control studies (*4*).

Commander Cronkite, Lieutenant Chapman, and Commander Lee were stationed at the Naval Medical Research Institute, Bethesda, Md. Lieutenant Bond was at the U.S. Naval Radiological Defense Laboratory, San Francisco, Calif. Dr. Bond and Dr. Cronkite are now at Brookhaven National Laboratory, Upton, L.I., N.Y.