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ABSTRACT

A review of the changes in physics education since 1930 includes the beginnings in very practical applied physics. Research-oriented physics received a major impetus from the technological explosion stimulated by World War II. Physical Science Study Committee (PSSC) physics is seen as an outgrowth of rigorous training for research followed by even more rigorous general physics courses in college. Two alternative curricula, R for research physicists and S for non-research students, are proposed. The author feels that no S curriculum now exists. The objectives of such a curriculum are described in terms of the four objectives of the National Assessment of Education Project. A discussion of college physics department priorities in curriculum is then presented at some length with the most vital need stated being the development of a continuously flexible, master plan for physics in education with emphasis on instruction at the various school levels. (TS)

TRENDS IN PHYSICS EDUCATION

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AAPT, New York, 4 February 1971

The chief focus of these remarks is on college level physics instruction since that sets the pattern and affects physics education at all other levels.

The changes in physics education since 1930 have been profound and should be reviewed since they control the direction in which changes will continue. At that time physicists in basic research were largely concentrated in the universities. Students in undergraduate physics courses were engineers or majors in other disciplines. A very small number of these turned to physics and an even smaller number went on to graduate work. Practically no student began as a freshman major in physics. A physics department at this time saw its function as primarily a service department to other disciplines and secondarily as a producer of future research physicists. The emphasis on service is apparent from courses like household physics, el[illegible]nics, acoustics for architects, geophysics, electrical measurement techniques, and photography, which were commonly offered by physics departments. The presentation in all courses was largely phenomenological. Only those physics students nearing graduate work had any significant experience with the great unifying theories of physics in their more comprehensive form. Most of the few students who majored in physics in that era went into a variety of industrial jobs, at the bachelors level as technicians and at the graduate level in engineering administration.

The technological explosion stimulated by World War II created an enormous new demand for research oriented physicists for direct use in product developmental programs and for the expansion of university departments to produce more physicists. Under this pressure, the physics undergraduate instruction gradually became oriented toward those students headed for graduate level research, with a termination of most of the service offerings. The reorientation stimulated a new series of texts which introduced the student as rapidly as possible into the most general and powerful forms of physical theories. To achieve the necessary skill in abstract symbol manipulation proved impossible in the normal four year program, even with mathematics and physics theory displacing practically all advanced laboratory work.

Attention began to be paid to the possibility of starting this rigorous training in secondary school and to the related problem of improving the preparation of secondary school teachers. At about this stage the PSSC physics project appeared as the first major attempt to strengthen secondary school physics. Reactions to this course varied enormously; largely, I think, due to a conflict between two contradictory and unstated goals for secondary school physics education. Although not specifically designed for the future Ph. D. in Physics, the PSSC course demands a dedication with a level of abstraction and symbol manipulative skill which is the characteristic trait of the Ph. D. physics program. To the secondary teachers and students alike the course was apparently not a part of the liberal education which every student should have. The continued decrease of enrollment in secondary school physics shows that this was the common opinion toward the new course.

For those students who planned to continue in physics, however, the PSSC has permitted a considerable strengthening of introductory college physics courses. At least three versions of new general physics courses have been introduced for the first two university years, the Feynman "Lectures on Physics," the Berkeley Physics, and the M. I. T. series. The last of these is not yet completely available in commercial form. These courses not only expect the equivalent of PSSC as a prerequisite but require some skill in the use of calculus and a concurrent study of higher mathematics. The pace and content of the new courses fitted the physics Ph. D. preparation program very well but was appropriate for practically no other students. During the evolution of the curriculum several national conferences assisted in clarifying the goals of the physics Ph. D. preparation, defining it with the name of the "R" curriculum.[1] In addition these conferences pointed out that departments should offer an "S" curriculum in physics for those students who did not want to become university research physicists. Development and use of the "R" curriculum proceeded very satisfactorily because meeting the shortage of research physicists was universally considered to be the first priority task of a department. Development of the alternate "S" curriculum has not proved to be easy. Even the departments who tried to design and initiate an "S" curriculum found few students interested in following the program.

Other indications of a widespread lack of interest, even a lack of understanding, of the role of physics in general education began to appear.

[1]Am. J. Phys. 31, 328 (1963)

Studies of the reasons seemed to indicate a variety of factors; among them were inadequate or inappropriate preparation of secondary physics and general science teachers, inappropriate physics content in the science courses for general education, the production of new scientific knowledge at such a rate that teacher preparation quickly became obsolete, and the difficulty of keeping text material current with scientific discovery.

In response to some of these factors a new secondary physics course is now available, the Harvard Project Physics. This course presents physics as a logical, historical evolution of an intellectual discipline in the same way one would present philosophy or any other discipline. It is definitely more appealing to the average student and yet it is only one step further toward the kind of instruction which is really needed.

In 1964 the National Assessment of Education Project, now carried out under the Education Commission of the States[2], began an evaluation of general education in the United States. A major initial task of this Project was to establish the objectives of education by means of which progress in education can be measured. The objectives they have stated represent the integrated opinions of probably the largest number of educators that have ever collaborated to establish such objectives. Physicists should pay particular attention to the objectives of science education since they represent the minimum goals for any science curriculum. The four basic objectives as currently stated by NAEP are:

[2] E. C. S., 822 Lincoln Tower, 1860 Lincoln Street, Denver, Colorado 80203.

1. Know fundamental facts and principles of science;
2. Possess the abilities and skills needed to engage in the processes of science;
3. Understand the investigative nature of science;
4. Have attitudes about and appreciations of scientists, science and the consequences of science that stem from adequate understandings.[3]

You may disagree with these objectives--in fact, the NAEP is not convinced that this is the ideal formulation. However, they can be used as a starting point and frame of reference in a discussion of the current situation in physics education.

In the prevalent curriculum (the Ph.D. in physics curriculum) the pre-college, freshman, sophomore, junior, senior, and first graduate year are almost exclusively devoted to objectives 1 and 2. In these years the student is presented established theories and drilled in the use of these theories at such a rate that he has no time to speculate on alternate theories or to gain skill in devising theories to fit observations. After the first graduate year, however, the emphasis shifts completely to objectives 3 and 4. The doctoral candidate begins making observations which no one has made previously and is himself responsible for an interpretation, model or theory, of his observations. This aspect of his work directly satisfies objective 3. In his research, he participates in seminars with his research supervisors and with other graduate students to achieve objective 4 except perhaps for sufficient understanding of the consequences of science. If there were greater emphasis on the applications

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[3]"Science Objectives", NAEP, Room 201A Huron Towers, 2222 Fuller Road, Ann Arbor, Michigan 48105.

and consequences of science, physics graduates would not insist on careers as university professors and would welcome the opportunity to use their talents and training in other careers--such as, for example, government work supervising environmental studies, international education, secondary school teaching, or a wide variety of jobs in industry. Using the NAEP objectives as criteria, the complete "R" curriculum seems fairly satisfactory for education in physics. No subsection, however, as an undergraduate major or minor is satisfactory.

One might think that an "S" curriculum satisfying the service functions could exist at a strictly undergraduate school. It does not, for the following reason. A student who becomes interested in physics at such a school usually transfers at the junior level to the nearest university offering the complete Ph.D. program. His four year college teachers want him to compete successfully with those who went through the first two years of the university's "R" curriculum. This pressure forces the first two years to be identical in both kinds of institution and in both kinds of curriculum.

Departments also offer, not a complete curriculum, but two additional and alternate introductory physics courses. One is intended for liberal arts majors; it usually meets in large sections with minimal problem solving and laboratory. This course is usually directed at objective 4 but can not succeed because the students lack the prerequisite "based on an understanding of science" as stated in the objective. The second course is intended for biologists, pre-medical and similar students; it differs from the "R" curriculum course only by not using calculus. It therefore satisfies only objective 1 and to some extent objective 2.

The extreme emphasis in undergraduate physics on objectives 1 and 2, to know facts and to learn skills, has had a deep and harmful effect on the preparation in science of those few primary and secondary school teachers who have certificates for physics teaching. With rare exceptions, these teachers have been thoroughly conditioned to present physics as an orthodox system to be learned and not questioned. The more qualified such a teacher is--in semester hours of "R" curriculum physics--the more conditioned he is likely to be. The teacher who is qualified in this way cannot present secondary physics in a manner to achieve objective 3, to understand the investigative nature of science, even if he has inquiry oriented teaching materials! He cannot resist teaching as he was taught and so defeats the inquiry approach by telling the students what they should observe and even what they should infer from those observations.

It is the primary and secondary teachers who control the general public's attitude on physics since eighty percent of the population has no physical science training past grade nine.

Thus we come to the first of the major tasks facing the physics department, appropriate training in physics for future primary and secondary teachers. A corollary is the extensive remedial treatment needed for teachers already in service. A second corollary could be the development of instructional materials in physics for primary schools, secondary schools, and for the university teacher preparation curriculum.

The second major task facing physics departments is the reorientation of at least a part of the "R" curriculum. From discussions being conducted at this meeting and elsewhere it is clear that at least some future physics graduates should have more experience with the applications of physics in other scientific disciplines and in work outside the academic world. A corollary of this problem is that the present type of "R" curriculum has existed long enough that departments are staffed by people with the same preparation deficiency and will thus find it difficult to recognize the deficiency and possible solutions.

The implications of these two tasks which immediately confront physics departments are far reaching enouch that we do not need to look for others. A really adequate plan will necessarily be general enough so that other deficiencies will be easily recognized and their solutions incorporated.

To develop such a comprehensive plan, physics departments must collaborate with the total physics community, professional educators and all others concerned with science education in a study of instruction in physics at all levels and for every type of educational program, e.g. for technicians, for the general public, for adult continuing education, for teacher preparation refreshment, and for the many college level major programs. The comprehensive plan should include several parallel tracks of instruction in physics with different emphases. At many levels the physics instruction should be in combination with that from other fields. The complete plan should specify the objectives at each stage so that each component track stresses all four NAEP objectives properly. Two factors will tend to reduce the number of tracks; first, the desire to permit selection of a major career as late as possible in the individual's education, and second, economic reasons. Nevertheless, any contraction of the number of tracks should be done from a complete plan with conscious and explicit compromises being made in the contraction. The complete plan should specify (1) which types of institutions carry out each part of the instruction, (2) preparation programs for teachers at each stage of the plan, and (3) mechanisms for continuous interaction of all units participating in the plan.

A comprehensive program on this scale must not be a static plan. At first it will need to contain many remedial elements to counteract prior training deficiencies, and these elements should gradually be eliminated. It must be responsive to the changing needs of society. Probably the only way to design and maintain such a flexible plan is to form a group who can represent all interests, and who will continuously review and revise the plan for education in physics.

The formulation of such a program is a long range goal, yet there are developments underway which can be included logically as parts of the plan. The newly formed Council on Physics in Education of the AAPT could serve as the nucleus for formation of the general review group to design and monitor the physics education plan.

Some examples of components of new curricula needed under a comprehensive program are becoming available. At the elementary level three should be mentioned, the AAAS program, the SCIS program at Berkeley, and the programs at The University of Minnesota. These are providing instructional materials which facilitate a greater emphasis on objective 3, "to understand the investigative nature of science, " by stressing the laboratory inquiry approach method.

At the secondary level should be mentioned the IPS I & II (Introductory Physical Science) for grades nine and ten, the ECC (Engineering

Concepts Curriculum) for several grades, QPS (Quantitative Physical Science) for grades eight or nine, the PSSC (Physical Science Study Committee) grade twelve physics course and the Project Physics course for grade twelve. All of these in one way or another are attempting to reduce the former exclusive concentration on objective 1, "to know facts and principles," and strengthen various of the other objectives.

At the college level some of the most promising changes have been in large part stimulated directly or indirectly by the Commission on College Physics. Among the new courses are the PSNS (Physical Science for Non-Scientists), a college IPS (Introductory Physical Science), and CGSP (Concepts in Physical Science). These courses attempt to change the character of the introductory physics course serving non-physics majors by attempting to introduce more of the investigative aspects of science.

In addition many new texts are available for use in introductory college level courses which stress the investigative nature of science or which present applications and consequences of science.

All of these efforts and many others not mentioned must be commended as much needed improvements.

Nevertheless, I think their success will be limited by the fact that we lack a comprehensive program based on educational objectives for instruction in physics and that the improvements so far have not been designed as a part of a complete plan. At the moment physics departments are restudying their function as a direct result of the changing manpower market for research physicists. It is difficult to see how the teaching responsibilities of a department can be adequately defined without a general description of all physics education from which a selection of priorities can be made.

Some areas which need special attention are (1) the training of high level technicians, (2) the training of teachers of technicians, (3) the preparation of physics education specialists, (4) appropriate preparation in physics for elementary and secondary teachers, (5) appropriate preparation in physics for the general public, and (6) continuing education in physics for adults. To repeat, however, the most vital need is for a continously flexible, master plan for physics in education to serve as a resource and reference for people planning curriculum development.

If physics departments assume this larger role, and I am confident that they will, then an appreciable fraction of the department staff will have to be redirected from research in physics into research in physics education. Such a redirection is not a trivial effort and will not occur unless departments plan for the change and reward those in physics education research on a par with those remaining in physics research.

As the most difficult part of the complete plan, the interaction mechanisms between levels of instruction in varying kinds of institutions must be designed and made effective. The experience of the Institutes program of the National Science Foundation has shown how difficult it is to bridge the gap between secondary school and college scientists. The recently initiated NSF Cooperative College School Science program, CCSS, has, however, indicated one effective type of interaction which could serve as a model.

The needs which have just been pointed out have been with us for some time and as we have seen there have been efforts at solutions to parts of the problem. That these have not been more successful has been in part due to physics departments' strong emphasis on doctoral physicist production. That emphasis is now being questioned severely and there is reason to hope for significant changes, even a renaissance of interest in physics by the general public. I believe that physics departments, as they take on much more diversified functions, will play a most significant part in the new developments.