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AUTHOR Brekke, Stewart E.
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ABSTRACT

This paper traces the history of physics education in America from the time of the revolution to the present. Various reform efforts, innovations, and movements fostering educational change are described. The evolution of high school physics from its inception in this country from no laboratory work for students to laboratory work and from simple laboratory work to a more sophisticated experience in the laboratory is outlined. The evolution of coursework and texts are also discussed. Contains 24 references. (JRH)

CHANGES IN THE AMERICAN PHYSICS CURRICULUM IN HIGH SCHOOLS FROM REVOLUTIONARY TIMES TO THE PRESENT

Stewart E. Brekke

Northern Illinois University

In America, universities did not allow students to perform laboratory experiments until after the 1850s. Another half century was to pass before high school students were granted the experience. England and France were very backward in this respect: as late as 1950 the best scientific work was being done in technical and special schools instead of universities in those countries (Atkinson and Malesda, 1962).

American education was first modeled upon the British system. In colonial times, there were very few secondary schools. The secondary schools that existed were called academies or grammar schools. These academies consisted mainly of preparing boys for college. The subjects taught were primarily Greek and Latin, with a small amount of grammar, rhetoric and practical arithmetic. In contrast, there were the so called "English Schools' which emphasized, in Revolutionary times, subjects such as navigation, surveying, bookkeeping, astronomy and sometimes modern languages (Nye, 1960). After the Revolution with the expansion of knowledge, the academies had changed their course offerings to include mathematics and science courses such as algebra, trigonometry, botany, geology, and physics (Nye, 1960).

In post-Revolutionary times, there was a famous teacher in the Albany Academy who taught electricity and magnetism to secondary students. This was Joseph Henry who taught there from 1826 to 1832 before going to teach at Princeton. Henry, who was very advanced for his time, was a firm believer of the learning by doing principle that was popularized by Dewey eighty years later. This method was done by Henry to: 1) spark student interest, and 2) to provide practical experience in applying principles to everyday life. In teaching science, he had to have students assist him in his experiments to supplement the lack of apparatus that characterized most schools of the period. Henry did provide demonstrations to his students and unlike many of his contemporaries, his methodology included visual aids during the lecture or demonstration. Henry, besides urging the trustees of the Albany Academy and Princeton to provide demonstration equipment such as gloves and good apparatus for his lectures, used the blackboards extensively. Not only were blackboard virtually nonexistent in the classrooms of the day, but there was little use of the blackboard itself in the course of instruction. Henry also felt that the core of his teaching involved experiments since that allowed the lecturer to "fix the attention of his audience."

Henry's contribution to science was in the field of inductance. Thus, the unit "the Henry" has been named after him as the unit of inductance. While he is chiefly remembered for his contributions to electricity and magnetism, he was a great innovator in high school teaching in post-Revolutionary times. It should be remembered that he was the exception because at the time, there were very few high schools, almost none of which offered courses in electricity and magnetism (Swartz, 1985).

As small high schools came into existence, coupled with the increased interest in sciences and technology, the capacity of public institutions to render proper instruction was outstripped. Small high schools loaded down their teachers with all kinds of courses in science - physiology, botany, chemistry, natural sciences (physics), and astronomy (Swartz, 1985). To illustrate, Massachusetts, in 1857, sparked a growing enthusiasm for science by requiring by law all high schools to teach natural philosophy, which was mainly physics, chemistry, and botany in towns of over 4,000 population (Swartz, 1985).

By the 1870s the laboratory method began to appear in high schools. However, it is difficult to determine how many students actually had laboratory work where they performed experiments individually, since: 1) the cost of providing apparatus was prohibitive for many school districts, and 2) teachers who were trained in laboratory methods were scarce according to an 1870s Commission of Education report (Rosen, 1985). In rural areas, instruction by textbook of physics was probably the sole method (Rosen, 1985).

The Harvard University Catalogue for 1870 advised the incoming student to pursue a course in elementary physics before entering. This course was mechanics. In 1872 a new option was designated for admission to the college, that of mathematics and physics. This marked the first acceptance of physics as an accredited secondary school subject by an American college. In 1876 all candidates for admission to the freshman class had to present one of the following combinations of science: a) botany; b) physics and chemistry; c) physics and descriptive astronomy. In 1886 physics itself was divided into a two-part subject: either 1) astronomy and physics, covering designated chapters in specified texts, or 2) "a course of experiments in the subjects of mechanics, sound, light, heat and electricity, not less than forty in number, actually performed by the pupil at school....the Faculty requests all teachers who can command the necessary apparatus to present their pupils in the second of these alternatives" (Rosen, 1985).

However, at the time the sciences generally were poorly organized and new texts were compiled that stressed abstract principles to the neglect of the concrete examples. The Committee of Ten, who besides urging that all college admissions requirements include a laboratory course in physics and chemistry (Rosen, 1985), advised in 1893, the high schools to teach fewer sciences and devote more time to each area. In this manner the sciences met the challenge of conservative educators to offer a substantial body of knowledge organized logically (Noble, 1954).

Natural philosophy was giving way to physics by the 1870s. Greater attention was directed toward the mathematical phases of physics, and pupils were being allowed to do more and more laboratory work. However, a statistical survey in 1880 indicated that in the public secondary schools short informational courses were common and the book, Steele's *Fourteen Weeks in Physics* was the most popular textbook. By 1900 the "science of common things" had been replaced by the logically organized subject of physics but the teaching of technical physics had little or no relation to the experience of the student. In such courses mathematics was a prerequisite, and physics was placed in the last year of high school so that they might receive ample instruction in mathematics before beginning the physics (Noble, 1954).

The secondary physics of the period had become highly theoretical, and the students who did laboratory work performed and "wrote up" a number of experiments. As in the chemistry courses of the times, the students memorized laws, hypotheses, theories, and gained a kind of knowledge that was criticized as not being relevant to their life's experiences. In fact, many of the high school texts of the period were written by college professors with little knowledge and understanding of the needs of secondary students. These texts were in reality college treatises that were abbreviated and simplified. As a consequence of this state of affairs the introductory courses were formal and unpractical. The reaction to the theoretical character of the courses and texts led to a curriculum of more practicality early in the new century.

By the late 1920s physics in the high schools had become more organized with a number of common areas. These areas were often mechanics, light, heat, sound and electricity and magnetism if the text used in the high schools are any indication of the content of the courses. It must be remembered, however, that the subject of physics still had not yet been specifically defined, (Bless, 1928) and even there was still areas that intersected with philosophy, according to one author, (Hagenow, 1928). There was some effort to try to teach high school physics as the study of energy relations, and to stress unifying principles of physics rather than treating the subject as a series of unrelated facts, (Bless, 1928). Further, in the late 1920s there was also some attempt to acquaint physics teachers with "Modern physics," or the study of X-rays, ionization of atoms, atomic theory and other new advances of the times, (Hagenow, 1928). However, there was still the identity crises in physics itself -- what did physics as a subject encompass, and how did it differ from other subjects such as chemistry (Krug, 1972)? It was also pointed out that physics developed by default since other subjects such as chemistry did not deal with mechanics, sound, heat or electricity, and thus, they were inherited by physics.

In a high school textbook commonly used nationwide it was pointed out in the preface that the book in the 1955 edition was basically the same as previous editions with the exception of some additions of modern technology such as electronics chapters, and revisions need to make the text more of a college predatory curse, However, the directness of presentation of the subject was the same as previous editions as well as the drawings. The text includes mechanics, fluid mechanics, heat, light, sound, and machines (Dull, 1955). Basically, the subject matter and method of presentation had been the same for a number of years.

From the 1930s to about 1957 little attention was given to the revision of the physics curriculum in the high schools. During the war there was some emphasis upon technical subject matter in military courses, but after the conflicts which engaged the United States there a few voices for examining the curriculum in high school physics. In the 1930s physics in high school was relegated to the background because apparently, the social problem of the depression pushed social studies to the foreground in the hope of solving these difficulties. One other factor was that physics was felt to be "too hard" and the new texts of the period were revised in order to make physics easier. Thus, in the 1940s the subject matter was toned down, and there were attempts to connect physics subject matter with the environment in some way. For example, in a newly revised high school text that was widely used, Modern Physics by Dull, Metcalfe and Brooks, a new chapter was added on the atmosphere and the weather as well as a chapter on radio and television in the 1955 edition. Further, there is a middle section set of acetate drawings in color on the power shovel as well as other sections of the book on machines (Dull, 1955). Apparently, there was some attempt to relate physics to "life" as illustrated by the examples from Modern Physics mentioned above, and this was done in part in order to acquaint the high school student with the need for taking physics courses. At the time many people had never even heard of physics let alone had even wanted to take the subject.

Another problem facing physics in the high schools was not only the difficulty of the subject since most courses required a strong mathematics background, but also decreasing enrollments. In order to combat decreasing enrollments there were calls for reassessing the typical high school physics curriculum in order to avoid having physics become replaced by high school physical science (Kelly, 1955). In fact there were some published articles which predicted that physics would indeed lose out to physical science because the frequent need to revamp high school physics curriculums had been largely ignore. The author of one article started in 1955 that in order to avoid losing the place of physics in the high schools altogether more effort must be made to increase enrollments through a variety of methods such as making courses responsive to the "differential treatment of pupils according to their ability and interest," and that there was need to change the admissions policies of colleges and graduation policies of high schools to require physics as a subject. He also stated that there was a need to revise and scrutinize the present physics curriculum inasmuch as it had grown not through design but accretion (Kelly, 1955).

Innovation in physics courses, that was also incorporated into many other science programs at the time in the early 1950s, was the use of the "discovery method" pioneered by Dr. Zacharias at M.I.T. in 1956. It had been pointed out by psychologist Jerome Bruner that "any subject can be taught effectively in some intellectually honest form to any child at any stage of development." Dr. Zacharias put his theory into reality by devising a new high school physics course based on the notion that it was more fun, and more instructive, to understand the principles of physics by performing experiments rather than by memorizing a body of facts and rarely testing them in the laboratory. This system, called the "discovery method," quickly spread to other science curricula as university scholars and high school teachers organized to make new high school science curricula (Time, Jan. 29, 1965).

Although some scholars, teachers and scientists had been active in curricular work, such as Dr. Zacharias, their efforts had not been accepted as meritorious work for the scholar. It took the successful orbiting of Sputnik 1, in October 1957, to bring the American consciousness to the teaching of science. Besides attacks from persons seeking to blame the schools for the Russian success, the event of Sputnik 1 had a good effect on American science education. The citizenry became more attentive to the needs of the schools, and students have become more attentive to the needs of the schools, and students have become more aware of the importance of academic achievement. Many students in the aftermath of Sputnik 1 became interested in science and engineering, sometimes with the encouragement of the high school faculty and administration. Further, one of the most significant results derived from the Russian first was the stimulation of interest in public school science on the part of some professional scientists (Anderson, 1964).

As the high school and elementary science curricula were scrutinized it became clear that:

1. Factual description choked out the investigatory nature of science.

2. The textbooks were quite standardized, bulky, and not very interesting.

3. A workbook accompanied many texts: pupils were often required to copy material from the book to the workbook.

4. Laboratories had limited equipment, some very expensive and rarely used. Time allotted for labs was inadequate.

5. The purposes of the laboratory work and demonstrations alike were to verify facts stated in the text, or to illustrate some principle.

It was not that these activities were bad in themselves, but the experimental and investigatory nature of science did not permeate the then current teaching of science (Anderson, 1964).

Scientists, some of whom were outstanding researchers, and educational personnel set out to obtain grants to reform science teaching. Besides forming new curricular committees, such as the Physical Science Study committee in physics, some scientists had begun to show interest in the public schools illustrated by their willingness as individuals or groups to aid teachers, local schools, and regional districts as advisors on projects, guest speakers, sponsors of activities, and judges in science fairs, to name a few of the things which benefited from their involvement (Anderson, 1964).

A national effort to update the physics curriculum was implemented in 1959 with the National Science Foundation giving a grant to the Physical Science Study Committee, now remembered as the PSSC. This committee brought together very able physicists, teachers, school administrators, professors of education and human learning to create a new high school course in physics.

After examining the current curriculum, textbooks and courses of study of American high school physics, it was found that there had been no real change in the high school basic physics course since 1910. In these high school courses there was no adequate representation of Modern Physics, and the committee reported that the courses were out moded, and that the content and objectives of present day physics had changed. Thus, it was determined that a new basic high school physics course was needed. It was at this point that the Physical Science Study Group began a pioneering effort in building a new physics course for the American high school student (Anderson, 1964).

One of the approaches of the PSSC was to make significant education possible in spite of the massive amount of material accumulating in all fields, let alone in physics. What the PSSC did was to organize the new high school physics course in a way that can be understood by the student and used by him effectively. The PSSC course utilized only a relatively small number of concepts such as energy, time and motion. Actually, only thirty-four concepts were emphasized, and it is around these that the whole high school PSSC course was built. If the young high school student could master these specific concepts, and the facts relating to them, the youngster could then explain most of the physical phenomena he encounters, according to its designers (Tyler, 1967).

In 1964 the Harvard Project Physics Course was granted major funding from the U.S. Office of Education and the NSF. Starting with a high school physics teacher, a university physicist, and a professor of science education, the project grew into a major undertaking, with national participation for over four years. The Project Physics Handbook begins with a quotation from I. I. Rabi, a famous physicist. The quote states that science should be taught in the humanistic way, "with certain historical understanding, with a certain philosophical understanding, and a human understanding, in the sense of the biography of the people who made this construction, the triumphs, the trials, the tribulations."

In the Harvard Project Physics Course there was an attempt to reduce the traditional student dependence upon the text through the use of educational media. Thus, an extensive array of materials and guides had been developed. There were instruction books, and six books of selected readings. Fifty laboratory experiments and demonstrations had been prepared with newly developed equipment. Further, for the teacher each unit had about 10 transparencies to be used in lectures and demonstrations.

This course was made so that it could be finished in one year in any school. It was made so that an average high school student could take the course and finish it. In above average classes the students can finish the six basic units in six to eight months leaving one to three months for enrichment. The philosophy of the course is to deal with the diversity in high school students exploiting individual differences.

The PSSC physics course was supposed to be the archetype of curricular reform in the 1950-60s. Underlying the effort of the PSSC, and other science curricular committees, was the idea of Jerome Bruner that "the schoolboy learning physics is a physicist, and it is easier for him to learn physics like a physicist than doing something else." This premise served as a key doctrine for the new high school physics, the PSSC course (Tanner, 1971). It should be noted also that there were attempts to advance subject matter to lower levels of students and to apply the mode of inquiry discovery to the high school physics course of the PSSC as well as the Harvard Project Physics.

However, the PSSC course in which many millions of dollars of federal funding were pumped, did not live up to expectations. In retrospect almost all the testimonials of advantages from the PSSC course turned out to be from the project staff and certain teachers who used the course materials and not from any kind of objective studies. It was soon found that many high school students who took conventional physics courses scored high on standardized achievement tests than did the PSSC students. On some tests the PSSC students did the same as students in conventional courses once the PSSC material had been included as part of the test (Tanner, 1971).

Also, it was realized that the student does not have to be a discoverer in everything he learns. After all, the basis of culture is that fundamental knowledge need not be rediscovered by each new generation. Finally, it remains to be shown that it is easier for a young schoolboy to learn physics like a physicist than by other means (Tanner, 1971).

The Harvard Project Physics course did not attract new students into high school physics courses and thus, there is still a crisis in high school physics enrollments (Layman, (183). The Harvard Project Physics course was not strong enough to stand by itself as a producer of capable high school physics students; the students did not get as deep a grounding in basic physics. Thus, this course failed too. At this time a survey by the Educational Testing Service, which used a small but national sample, found that about 9% of all U. S. high schools offered PSSC physics, 8% offered Project Physics, and 54% offered the conventional course using Modern Physics by Williams, Trinklein and Metcalfe (Pallrand and Lindenfeld, 1985).

However, the effects of PSSC and the Harvard Project Physics can be noticed in the development of the standard course used most widely, Modern Physics by Williams, Trinklein and Metcalfe. This text had been used in various editions and forms since 1922. It can be said that the ideals of the PSSC and the Harvard Project Physics were slowly implemented in the changing editions of Modern Physics since the 160s, below are some of the changes made in new editions, from 1955 to 1076. Also, there are some other effects on some lab manual such as more inquiry discovery and more Modern Physics experiments for high school students.

The changes in the texts from the 1955 edition of Modern Physics to the 1972 edition is probably in large measure due to the national attention devoted to the physics curriculum because of the orbiting of Sputnik. One can see the level of the subject presented in each edition, 1955, 1964, and 1972 is successively higher. Further, more attention is given in each edition to atomic, nuclear, and subatomic physics. The influence of the PSSC on shaping these texts can be seen in 1) the attempt to unify the subject through the concept of energy, 2) the increasingly high level of presentation, and, 3) the devotion of larger and larger sections of the textbook to Modern Physics such as atomic, nuclear and particle physics (Modern Physics. 1955-1972).

Finally, the 1976 edition of Modern Physics is still different. One can see the same forces at work stemming from the work of the PSSC shaping this 1976 Modern Physics. As stated in the preface of Modern Physics, 1976, this new edition attempts to "strike a realistic balance between physics theory and practical applications." In the 1955 edition of Modern Physics there was a great deal of emphasis upon applications such as motors, steam shovels, and practical electricity. In comparison there are fewer problems for the students to solve and fewer questions to answer in the 1976 edition. In the 1976 edition the MSS system of units is used throughout the text exclusively as compared to previous editions in which the English system was used alone such as in the 1955 edition. There are introductory pages on energy in the 1976 edition . Motion is dealt within the 1976 edition in 30 pages. It was dealt within 50 pages in the 1972 edition. Wave motion, emphasized in the Project Physics curriculum, is given more space in the 1976 edition of Modern Physics. There is more advanced character to the 1976 edition as compared to previous editions, and it appears that the course has been more logically organized. It is also pointed out in the preface that there are many sections in the texts so that the book can appeal to different student's interests rather than handing down of the subject to the students without accounting for individual differences and interests. In the 1955 edition the Modern Physics had many problems and questions and these were graded into questions and problems for all students and the second section, section B, was for the more advanced student. Student interests were not considered in the text. Further, there are historical sections in the 1976 text probably reflecting the Project Physics and its humanistic approach to the subject.

The older type of laboratory manual such as the Physics Workbook printed to accompany some earlier editions of Modern Physics in 1964 had many experiments in which laboratory equipment was used but not much thinking was required. The student collected data in the laboratory and filed them into neatly arranged data tables that were preprinted. While the student received practice and familiarity with the equipment, there was criticism that the student basically did not know what he was doing. This type of manual for the course in the high schools also had some places for the student to answer according to multiple choice questions and answers as well. This was not what the PSSC had in mind for an ideal Modern Physics course. Another workbook and laboratory manual still in print by AMSCO utilizes the older approaching which the student mechanically performs the experiments. The workbook section still has the fill-in type questions in which work from the text is copied into the blank spaces . However, in keeping with the Modern trend AMSCO has put out a PSSC oriented laboratory manual that is designed to fit into any high school introductory physics course. It points out that high school physics courses have become harder and this manual, although keeping the ready-made data table and the blank spaces for answers to be copied from the text, tries to give the student an overview of the experiment by using "strategy" sections. Also included is a section on what a student needs to know before doing the experiment. The goal, according to the author, is to provide easier understanding of the experiments, and the format of each experiment goes back to the type of experiment of pre-PSSC and pre-Project Physics. Modern physics is accounted for, however, because there are experiments on finding Planck's Constant Spectra, and the typical Radioactivity experiments (Walker, 1973).

In the 1980s standards were being set by the AAPT for not only student achievement but also for recommended teacher preparation. Large numbers of workshops for upgrading teaching skills and knowledge were an integral part of the teaching scene. Further, in the universities courses were continuing to be upgraded and requirements for teaching certificates in physics and other fields have been increased by the colleges and universities. Textbooks continue to be upgraded as educational psychology is applied to the creation of these texts. In my opinion one of the more significant developments in high school physics texts was the high school text for physics by Merrill publishers in which drill and practice, a basic teaching strategy, is used in problem solving for the various topics in high school physics. The text and its successors also show the effects of the PSSC and Project Physics by having many sections on Modern Physics and references to the historical background of the topics in the book. Also, there was the continuing problem of enrollments in which physics from its earliest times in the high schools repeatedly suffers.

In conclusion one can see an evolution of high school physics from its inception in this country from no laboratory work for students to laboratorv work and from simple laboratory work to a more sophisticated experience in the laboratory in which more thinking is done by the student. Also, there are now more Modern physics laboratory experiences. Coursework has gone from virtually none at all to a higher and higher level and some of the work previously reserved for the introductory college course is now regularly taught in high school. Further, texts now have substantial sections on modern physics, an area ignored at first, but now in the high school an integral part of the course.

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