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HARVARD PROJECT PHYSICS—A COGENT APPROACH

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Diversity is a highly valued concept in American education. This certainly has been the earmark of the recent national secondary school curriculum improvement projects. Certainly, the curriculum studies in the fields of mathematics and science have provided some possible models for current and future curriculum projects. A good example of such an undertaking was the efforts of the Physical Science Study Committee formed in 1956 to develop an improved introductory physics course for the secondary schools.

After nearly four years of assiduous work, this group of physicists developed the necessary instructional materials for a new course in physics. The impact of this project is indicated by the fact that in 1961–1962 about a fifth of all students studying physics in high schools were taking the new course, and instruction for many others had been influenced in some degree by the new materials. In spite of the tremendous success of this project, several science educators still felt that more than one or two physics courses should be available for use by secondary schools.

A point of view, namely, that there is no single best way to organize a high school course in physics has often been expressed by science teachers, officials of the National Science Foundation, members of the PSSC group, and others. This conviction was primarily responsible for NSF scheduling a meeting in the fall of 1963 to explore the question, "Are there desirable approaches to the study of physical science in high schools other than those presently available?" Data available at that time clearly indicated that physics was the only science course with a declining percentage enrollment. It was acknowledged that a great deal had been accomplished by PSSC, but the exigency for additional nationally supported curriculum studies in physics was quite apparent. Physics teachers, like their counterparts in chemistry, biology, and mathematics, needed to develop additional models for use in the high school classrooms.

Perhaps the most important outcome of the NSF meeting was the impetus given to the development of additional courses in physics. As a direct result of this exploratory conference, a group of scientists with a strong engineering interest, formed, under the sponsorship of the Commission on Engineering Education, a project that is now known as the Engineering Concepts Curriculum Projects (ECCP). This group, as engineers, decided to develop an approach that would "tie the physical principles to the man-made world, tie them in with the study of systems, processes, and devices man has created to cope with nature. Automatically, this approach would place emphasis on the influence of technology in creating our modern environment."[1] Also under development was the Harvard Project Physics course which was attempting to produce a "model" built upon the concept of a historical and cultural approach to physics. The rationale and basic components of a humanistic approach to a high school physics course certainly could add a new dimension to the diversity of science courses. HPP's possible contribution to the learning of physics as a fundamental science is in need of elaboration and evaluation.

The Need for New Physics Courses

In addition to the seemingly basic concept of diversity in American education, there are other excellent reasons why the secondary schools should have available to them different kinds of physics courses. Such factors as the staid image of physics to a growing majority of students, teacher and student discontent with present courses, and the lack of success in presenting physics principles in their proper societal perspective, strongly suggest the need for complementary physics courses.

The enrollment data presented by Fletcher Watson indicate rather clearly that present course offerings are not commensurate with either societal or student needs since the percentage enrollments in physics have continued to decline.[2] This continual decline in enrollment, starting in 1948 and continuing to date, has occurred notwithstanding the tremendous contribution of the PSSC. It is rather disturbing to have this phenomenon occurring at the same time that physics continues to become increasingly more crucial in our society.

Gerald Holton, although concerned with the declining curve in enrollment data, feels that the really important factor is in the social mission of physicists and teachers interested in good education.[3] He indicates that the high school graduate who does not attend college will find it difficult to profit from on-the-job training, technical home study and other opportunities which lead to an adequate standard of living and a contributing member of our society. Holton is also concerned about the students who pursue the humanities and social sciences while avoiding physics courses in high school and college. He believes that these students must be reached before they get to college and says, "Precisely, these students should realize that what has been achieved in physics has sooner or later influenced man's whole life. To be ignorant of physics may leave them unprepared for their own time. They can be neither participants nor even intelligent spectators in one of the great adventures."[4]

A recent North Central Association study of innovative practices in 7,350 high schools across the nation indicated that PSSC Physics was one of the innovations with a high abandonment rate. Although 43.2 per cent of the schools had adopted PSSC materials, 3.2 per cent of the respondent schools had abandoned the materials. The predominant reason given for discontinuance was that the materials were considered most suitable for the high-ability college-bound student. Such comments as "PSSC Physics makes too many assumptions of background knowledge that are not true. . . . The result (in student achievement) did not justify the expense.", indicate some of the reasons for abandonment.[5] The survey results also identified the fact that the materials may have been indiscriminately adopted.

Most of the individuals and groups involved in curriculum planning seem willing

[1] Engineering Concepts Curriculum Project, December, 1966. Commission on Engineering Education: Dr. Newman A. Hall, Executive Director, p. 4.

[2] Fletcher G. Watson. "Why Do We Need More Physics Courses?" *The Physics Teacher,* (May, 1967) 212–214.

[3] Gerald Holton. "Project Physics. A Report on Its Aims and Current Status." *The Physics Teacher,* (May, 1967) 198–211.

[4] Holton, *op. cit.,* p. 203.

[5] North Central Association of Colleges and Secondary Schools. *NCA Today.* North Central Association of Colleges and Secondary Schools, 5454 South Shore Drive, Chicago, Illinois, Special Issue, May, 1967, p. 4.

to assign a central role in curriculum decision making to the teachers, who in the final analysis are responsible for the actual classroom learning experiences. Teacher's concern for the appropriateness of present physics courses is exemplified by the interest shown in an NSF supported institute at Creighton University during the summer of 1967. The Institute, which was under the direction of this writer, was the first and only NSF supported summer institute designed specifically to correlate physics concepts with the evolving HPP materials. Although HPP has made a concentrated effort to remain as quiet as possible about their project, formal applications were received from 247 individuals. Additional applications were received from individuals not meeting the criteria for admission. If we take more than a cursory look at the backgrounds of the participants in this Institute, it becomes obvious that many experienced teachers are convinced of the inadequacy of present course offerings.

Thirty-five teachers were accepted for the Institute. In addition, permission was granted to one individual to come as an "observer" for four weeks of the six week period. It is interesting to note that five of the participants were not receiving any monetary reimbursement for attendance, with other applicants seeking the same privilege. Four of the participants, each with strong subject matter backgrounds, ask about the possibility of attending the Institute without formally enrolling as a graduate student and the commensurate granting of credit. As one participant wrote,

> "After almost 30 years of teaching, I am interested in neither the grade nor the credit for the course. . . . rather the type of program that could bring me and my school the maximum benefit." [6]

The participants had unusually strong academic backgrounds with an average of 41.9 semester hours of formal course work in physics, 16.7 of these hours being at the graduate level. In addition, these individuals were successful, experienced teachers having spent on the average 9.6 years teaching physics. These facts would lead one to conclude that their major concern was not one of being inadequately prepared in the content area, but rather a desire to learn about a philosophy of teaching and a series of instructional materials designed with sufficient flexibility to meet the varied goals and interest of students.

Although, originally, leadership was to be a factor used in determining the participants selected, operationally it did not become an important criterion in the screening process because many of the applicants were qualified in this category. Most of the participants held leadership roles in their school systems or educational agencies, and could be expected to have multiplier effects or to be considered as change agents. Three of the participants were to be instructors in pilot schools so designated by multi-system agencies, i.e. Educational Research Council of Greater Cleveland, State of Missouri. Incidentally, HPP materials have been recommended as one of the alternatives in the ERC Interim Science Program, a part of the tentative five year Greater Cleveland Science Program. Evidently there is considerable discontent at both the classroom and leadership levels with the present physics curricula.

Previously the problem of abandonment of the PSSC course was mentioned. Information obtained from the Institute participants and staff tends to provide supportive data for that phenomenon. The two laboratory instructors for the Institute were experienced high school teachers who previously had been involved with PSSC courses, having taught the course to high school students as well as serving as instructors for in-service institute programs. One of these instructors was attracted to the HPP materials because of his conviction that the history and philosophy of science should be an integral part of any high school physics course. However, after having used the HPP approach for three

[6] Letter to the writer from an Institute Participant. Dated March 19, 1967.

years he extolled the advantages of the laboratory activities and the availability of the physics readers. The other instructor had found the PSSC text too difficult for his students to read as well as being apprehensive about the emphasis in the course toward the science-prone student.

Of the thirty-five teachers accepted for the Institute, twenty-eight were currently using the PSSC materials, with two others having abandoned the PSSC approach. Written statements from all of the participants indicated their disenchantment with their present courses and a sincere desire to offer a course that would more closely meet the needs of their students.

Such data provides inexorable evidence that present course offerings are not commensurate with societal needs. Materials are beginning to emerge from curriculum project offices and find their way into selected classrooms that deserve the serious consideration of science educators. Perhaps now that the schools are beginning to accept the notion that thinking is associated with learning, programs will be judged in terms of their inquiry quotient. This writer's association with the physics course being developed by Harvard Project Physics has led him to conclude that many of the inadequacies associated with the present physics courses can be alleviated as the HPP materials are utilized in additional classrooms.

The Harvard Project Physics Course

The philosophy of HPP, which is one of diversity and variation, permeates the content and materials produced as well as being responsible for the flexibility of instructional materials. This point of view strongly suggests that the classroom teacher is to assume the responsibility for structuring the course he teaches. Rutherford has stated that practical considerations such as the diversity among students, teachers, and schools, as well as educational and psychological theory have provided the basis for HPP's decision to develop a course which would promote variation in instruction.[7]

> The teacher (or his students, if the teacher wishes) will be able to select a significant portion of the physics course (up to about one-third); he will have available a large variety of integrated instructional materials from the various media; and he will be able to adapt the course to his preferred mode of instruction even—especially—if his preference is for a highly individualized, student centered approach." [8]

HPP has produced for each of its six basic units student guides (texts), laboratory and demonstration equipment, laboratory manuals, tests, books of readings, films, loops, transparencies, programmed instruction booklets and teacher guides, with the course progressively moving away from the idea that a text must be the major source of information for the student. Topics that might have been viewed as being inappropriate in a physics course are included as well as being cast in a mode that facilitates an inductive approach. Varying amounts of time are required for each of the units.

One of the precepts of Project Physics is that history of science is to be used occasionally as a pedagogic aid and not that a historical order or sequence is essential in the course. A perusal of the course might lead one to conclude that too much emphasis has been placed on the historical aspects. This deduction, although unwarranted, stems from the fact that other introductory courses usually exclude most of the history of science. The May, 1967, issue of *The Physics Teacher* delineates in some detail the course content of the student guides, physics readers, and laboratory exercises. Consequently, only a terse summary of the units is provided here.

Unit I is entitled, *Concepts of Motion* and provides unusual opportunities to read Galileo's own words and repeat his experiments, using his techniques. The use of an inexpensive air track, the computation

[7] F. James Rutherford. "Flexibility and Variety in Physics." *The Physics Teacher*, (May, 1967) 215–221.

[8] Rutherford, *op. cit.*, p. 215.

of lunar periods, and the opportunity to discuss the authenticity of Galileo's reports leads to an understanding of the way in which ideas develop. Unit II, *Motion in the Heavens* deals with the dynamics of the planetary system and provides unique opportunities to plot the orbit of Mars by the use of photographs of Mars and prepared transparencies. This unit is definitely set in a historic context and facilitates the exploration of methodological questions on the evaluation of competing theories.

Unit III, *Energy,* not only deals with such concepts as the laws of conservation of mass and momentum, kinetic theory, thermodynamics and mechanical waves but also includes discussions on the Industrial Revolution and its social and cultural effects. The historical excerpts which are woven into the *Student Guide* (text) and supplemented by such selections from the Unit III *Reader* as "James Watts Account of the Steam Engine" and the "Arrow of Time" do much to signify the social and cultural consequences of scientific developments.

The progression from and the inadequacies of the mechanistic view provide the central theme for Unit IV on *Fields and Waves.* This unit deals with electricity, magnetism, and light. As one might suspect, considerable emphasis is given to the contributions of Maxwell, Faraday, Michelsen and others. Once again the historical information included enhances the significance of the discoveries described. However, one definitely should not conclude that physics concepts are neglected or omitted. The contents of the Unit IV *Physics Reader* certainly are appropos and attest to the brilliance of Maxwell and Michelsen.

A problem that had bothered people for many centuries, namely, the nature of matter, is the central theme of Unit V, *Models of the Atom.* Such concepts as the chemical basis of atomic theory and the quantum —theoretical model of the atom are studied and related in their proper historical perspective. Unit V helps the student discover that new experimental methods and data are essential if cogent information about the nucleus is to be obtained.

Then, in Unit VI the problem of the constitution of matter is pursued by studying more deeply the atomic nucleus. Nuclear physics is approached by using radioactivity as the basis for additional discoveries and the development of methods for understanding the composition of the nucleus. This particular unit highlights the recency of the historical development and the close relationship of nuclear physics to modern technology.

It should be emphasized that HPP feels that the topics in each of the six units are to be studied by all students. Flexibility and diversity occur through varying degrees of depth in the topics via the various media available, i.e. laboratory activities, programmed texts, loops, physics reader, etc. In addition, supplemental units will be available for inclusion.

An important characteristic of HPP is its emphasis on flexibility, both in content and approach. An excellent illustration of this viewpoint is the multi-media instructional system (MMS) currently being designed and field tested. Basically, this system involves developing sequenced units which integrates the laboratories, films, texts, programmed texts and other media for which materials have been produced by Project Physics. Although much has been written and said about media, this is one of the first attempts to explore how the various media interact with each other and/or with individual differences in students. The emphasis in the classroom shifts from a place in which teachers present information to a largely passive audience to a milieu in which students learn through active involvement with a variety of instructional media. Teachers help students reach conclusions in harmony with the information at their disposal. Undoubtedly, this will demand new teaching strategies as well as changing the role of the teacher and his subsequent relationships with the students. Recent reports from research and development centers indicate that teachers need assistance in developing appropriate teaching behaviors for this new role.

Evaluation of Project Physics

Usually one of the first questions asked about a new curriculum project concerns the effectiveness of the course materials. Inherent in this germane question is a query about the comparability of the experimental course materials to those presently being used. Unfortunately, the criterion of comparability is simply whether or not the students using the "new" materials score as highly on the conventional standardized tests as do students who are exposed to the conventional course materials. Although most science educators are cognizant of the inappropriateness of using the same evaluative criteria for courses with different objectives, their penchant for evaluation leads them to condone and encourage questionable criteria. Certainly, evaluation is imperative, only the evaluative components are debatable. Holton states it this way:

> We have also learned a lot in ten years about the limits of effectiveness of the hopes and dreams of curriculum makers, and one aspect of that is a new realization that a detailed scholarly evaluation of the achievement and failure of any curriculum development in the various circumstances of real life is a prime responsibility of the curriculum group, if not of an independent agency.[9]

He also indicates that HPP is indebted to such groups as BSCS, CHEMS, PSSC for their pioneer efforts in evaluation and curriculum revision. Since Project Physics is the first of the new second-generation science curriculum developments for senior high schools, it has definite responsibilities for helping to provide new guidelines in models for curriculum development. In this respect the Project is primarily concerned with two aspects, namely, redefining the role of the teacher and including sufficient flexibility to cope with diversity of content and student needs. The best example of this effort is the multi-media integrated system.

A recent copy of the HPP Newsletter describes in some detail the evaluation phase of Project Physics.[10] The Project has developed a series of instruments to measure the achievement, attitudes and interests of the people involved in both the teaching and learning of physics via the HPP materials. It is anticipated that after four years of testing and developing all of the materials will be released to the general public in final tested form in 1969. Over 6,000 students and approximately 100 physics teachers in diverse kinds of school settings will have used the preliminary versions and have participated in the feedback. During 1969 HPP will publish a comprehensive research report of its evaluation components. This report should include data and the accompanying inferences resulting from the large scale evaluation program involving randomly selected teachers with randomly assigned control and experimental groups, as well as summarizing data obtained and the continual feedback from teachers, students and HPP staff involved throughout the Project's existence.

Although most of the data being obtained by Project Physics has not been completely analyzed, certain tentative conclusions and trends are in evidence.[11] The HPP students have shown significant gains on measures of physics achievement. Students, who had not previously indicated a desire to take a physics course, but were "recruited" into the HPP course were in general satisfied with their experience to the extent that they would recommend the course to their friends. In the nine schools

[9] Gerald Holton. Project "Physics. A Report on Its Aims and Current Status." *The Physics Teacher*, (May, 1967) 209.

[10] Harvard Project Physics. *Newsletter 6*. (Fall, 1967) Harvard University, Cambridge, Massachusetts.

[11] Harvard Project Physics. *op. cit.*, pp. 3–6.

that have been using the Project materials for the third year, subsequent enrollments in physics have almost doubled.

Some of the more important and unusual evaluative components of HPP include readability and time allocation studies, assessment of a multi-media approach, and the effect of the course on student enrollment. Project Physics is also vitally interested in the kind of teacher that is successful with the course as well as the methods and media to be used in developing teaching behaviors to facilitate maximum effectiveness of HPP materials.

A correlation study between the time a teacher spent last year on a particular unit, beyond a reasonable minimum, and student achievement as measured by the unit tests indicated very little relationship. This would seem to indicate that the recommended time schedule serves as a valuable guideline. The problem of readability has always been a serious one in science textbooks.[12, 13] Project Physics conducted a readability study during both of the last two development years and as a consequence have made the text shorter (210,000 words versus the average of 300,000 words for the other three currently most popular texts) and also easier to read.

HPP pilot studies of MMS as an integrated system have yielded encouraging results.[14] Preliminary information seems to indicate that the multi-media teachers come to know their students better and become more concerned with assessing individual progress and making provisions for the differentiation of learning. Comparative achievement tests scores suggest that the students respond well to the approach. Data as to the student's evaluation of the effectiveness of the various media indicate that laboratory exercises, lectures and demonstrations are the most effective with programmed instruction, film loops and chapter problems receiving the lowest ratings. The textbook was ranked fifth out of the ten kinds of media rated.

Data obtained during and subsequent to the Institute at Creighton provide another dimension for evaluating HPP. The Institute participants were given experience in utilizing the multi-media system. We anticipated some negative response from the participants because it meant changing their teaching style from that of being the dominant person in the classroom to that of being a resource person. He no longer was the dispenser of information standing at the front of the classroom. At the outset, many of the participants were apprehensive about relinquishing their status leadership position, but eventually most of them felt that this approach had considerable merit for at least three of the units. However, only about one-half of the participants indicated an intent to use the MMS for a portion of the course.

One would need to assume that the participants in the institute were seeking ways in which they could modify the physics courses they had been teaching. Responses obtained from the Institute enrollees revealed that 60 per cent planned to use the HPP course as soon as the materials were available. An additional 29 per cent decided to modify the HPP course and combine it with their present course. Only one of the participants indicated that he did not plan to use the HPP course materials. Feedback from the Institute enrollees who are now teaching HPP indicates a high degree of satisfaction with the HPP course and materials. They predict increased enrollments in the courses, with at least two of the school systems increasing the number of sections of HPP as well as additional schools within the systems adopting the HPP course.

[12] Bernard Belden and Wayne Lee. "Textbook Readability and Reading Ability of Science Students." *The Science Teacher,* (April, 1962) 20–21.

[13] Arnold J. Moore. "Science Instructional Materials for the Low-Ability Junior High School Student." *School Science and Mathematics,* (November, 1962) 556–563.

[14] Daniel Smith, Herbert J. Walberg, Morton Schagrin, and Eugene Poorman. "Affective Response to Different Media In a Multi-Media System," *Science Education* 52:16–22, February, 1968.

A unique feature of the Institute was the use of two 1967 high school graduates as laboratory assistants. Since they had just completed the HPP course as high school students, it was possible to obtain feedback and candid reactions to the course materials during the laboratory discussion sessions. One of these students, who was planning to pursue mathematics and the physical sciences in college, felt the course was sufficiently challenging with adequate utilization of mathematics. The other boy, a Merit Scholarship winner, felt the opportunity to pursue in depth selected concepts an important feature of the materials. He was especially intrigued by the use of Polaroid photography as a laboratory technique which increased the accuracy of the data and added realism to many of the laboratory experiences. This same student found the loop films to be extremely valuable. However, comments from these students clearly indicated the existence of disquietude during the first units of the course. This uneasiness seemed to be due to the fact that their role as a student had been changed from that of accepting passively the authoritative pronouncements of a teacher to one in which they were encouraged to question, to search, to reflect and to perceive relationships.

This author has conducted informal interviews with selected students enrolled in two HPP pilot schools. These two schools were diverse in nature, size and location, with one enrolling 2500 students in a metropolitan area, the other school was in a rural unified school district with an enrollment of about 500 students. Responses from these students indicate that the students were well satisfied with the HPP course and materials. They were especially impressed by the flexibility and inquiry approach. An interesting student reaction revealed their almost disbelief, or at least amazement, of the interrelationships that exist between the humanities and the principles of physics. These students were interested in the historical aspects and made special mention of the milieu in which Galileo functioned. They also indicated that the magnitude and significance of a scientist's contribution becomes more apparent if the student is fully cognizant of the environmental conditions existing at the time of the discovery.

These two pilot schools were not only experiencing a total enrollment increase in their physics classes, but a marked increase in the number of girls enrolling. Over one-third of the students taking physics in one of these schools were girls.

The problems of preparing teachers to use the HPP materials are similar to those associated with any curriculum change, namely, the teachers have to accept and learn to implement new educational objectives and materials. In addition to the NSF sponsored institute previously mentioned, HPP has held two teacher training sessions. The first six-week briefing session for 34 high school teachers was held at Pomona College in the summer of 1966, which thirty-six different teachers attended, the session held at Wellesley during the summer of 1967. Additional NSF Summer Institutes are scheduled for 1968, with this writer directing one at Kansas State University. HPP has also announced receipt of a grant to film a series of 32 teacher-training sessions for Project Physics. These films will eventually be available for pre-service and in-service teacher training.

There is little doubt that the eventual success of HPP is dependent to a considerable degree upon the ways in which the materials are used in classrooms. Most of the previous national curriculum projects have experienced significant difficulty in having teachers use the course materials in the appropriate ways. This fact is one of the major reasons that the Mid-Continent Regional Laboratory at Kansas City has selected as its focus the problem of discovering ways in which teacher behavior can be modified so that the new teaching strategies will foster self-directed learning on the part of the students. It would seem that those of us associated with HPP, or any other curriculum revisions, should be earnestly concerned about the procedures to be used in preparing teachers to implement the new curricula. Unless we concentrate on this phase of curriculum development, many of the objectives included in any curriculum model will not be achieved.

The information presently available from activities associated with HPP certainly is tantalizing. This project, capitalizing on the pioneer efforts of other groups and an extremely competent central staff, is definitely about to make a major contribution to science education. It should serve as a very valuable model for any curriculum project.

AN IN-SERVICE INSTITUTE IN RETROSPECT

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During the 1965–1966 academic year the author directed a National Science Foundation supported In-Service Institute in Biological Science Curriculum Study (BSCS) biology for secondary school biology teachers. Since the introduction of BSCS materials on the commercial market in September 1963, many schools have adopted them. It is expected that within the next few years, this number will continue to increase tremendously. Teachers who plan to make use of the BSCS program need preparation in order to make best use of it. It was the purpose of this Institute to assist in this task. More specifically, the objectives of the Institute were as follows:

1. To develop an understanding of the BSCS philosophy and approach to teaching high school biology.
2. To enable teachers to become familiar with BSCS curricular materials.
3. To strengthen the background of participants in selected subject matter areas correlated with the BSCS Yellow Version approach.

In looking at this Institute, its planning, its operation and its outcomes in retrospect, many points became obvious to me which facilitated effective organization and operation of the Institute. It is hoped that this article might accomplish the same for others.

Regardless of the background level the Institute is designed to serve, I deem it essential that an academically homogeneous group be selected. This was carefully attempted and successfully accomplished in the following manner. When announcements introducing the Institute were made, eighty teachers applied for admission. Of these, only twenty-four were selected to participate. In addition to National Science Foundation application forms, letters of recommendation from science supervisors were submitted for evaluation. These letters and recommendations obtained over the phone proved most valuable and valid. We learned that science courses taken by participants and recorded on their applications did not always reflect the students' actual understanding of a particular field of study.

In order to best accomplish the objectives of the Institute, the program was divided into two aspects. The first aspect was lecture-discussions on biological topics that were correlated with those in the BSCS Yellow Version textbook. It was during this time that subject material was dealt with in depth. Six professors of biology and one professor of chemistry served as lecturers for topics related to their field of specialization.

The second aspect of the program was laboratory, discussion, and activity periods dealing with the teaching of BSCS biology to high school students. Laboratory les-