JOURNAL OF RESEARCH IN SCIENCE TEACHING VOL. 10, NO. 4, PP. 365-378(1973)

REVIEW OF THE RESEARCH AND EVALUATION PROGRAM OF HARVARD PROJECT PHYSICS

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Introduction

During the 1960's, a number of national curriculum development projects were supported by the federal government. Although the greater share of effort was directed toward developmental activities, a few projects were involved with active programs of research and evaluation. One of these was Harvard Project Physics, a humanistic approach to the study of physics at the secondary school level. With considerable financial support from the U.S. Office of Education and the National Science Foundation, an extensive program of research and evaluation was conducted during the last half of the decade. As a result of that activity, nearly 60 articles, monographs, and dissertations were produced. It is the purpose of this paper to summarize the major findings of the Harvard Project Physics research and evaluation activity to make available to interested science educators, the design, implementation, and results of a major curriculum evaluation effort. It is hoped that bringing together in one place a glimpse of a multifaceted research and evaluation program will help to reduce the communication gap that all too often exists between the researcher and the practitioner.

Background

The group given the responsibility of evaluating Project Physics was guided by three beliefs: (1) Evaluation can be used during the development of a course to help improve the course; (2) Evaluation can be applied to the final course materials and provide data upon which school personnel can base decisions concerning adoption and use of the courses; (3) A national project funded by the U.S. Office of Education has an obligation to conduct research on the evaluative process itself, and to investigate some of the basic problems in teaching and learning.

As a result of these three beliefs, an evaluation strategy evolved during the four-year formal evaluation of Harvard Project Physics (HPP). As implied by the statements above, the elements of this strategy include: (1) *Formative* evaluation to be used for course improvement; (2) *Summative* evaluation for consideration by potential users of the course; and (3) *Research* on the evaluation methodology and the factors that may affect teaching and learning. These three goals were stressed sequentially in HPP, as Table I shows.

Pursuance of these three goals by a staff supported by the Project resulted in a number of publications describing the research and evaluation findings. These publications are the basis of this review.

An analysis of the studies suggested several categories in which to group findings. These are somewhat analogous to categories suggested by the general goal of the HPP research to

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TABLE I

Time Line of Activities

Goal	Year			
	1965-66	1966-67	1967-68	1968-69
1. Course Improvement	————	———→	- - - - - -	- - - - - -
2. User Information		- - - - - - —	————	————→
3. Educational Research		————	———→	

determine "What happens to different kinds of students working with different kinds of teachers in the Project Physics course?"

The rubrics under which the various research and evaluation findings are grouped are listed below:

A. Methodology.
B. Teachers.
C. Students.
D. Learning Environments.

Articles that are primarily concerned with each of these four topics are reviewed as a group. In addition, a section is included (Section E) that summarizes the results of the final year, the major evaluation effort.

Summary of Findings

Methodology

A general overview of the Project Physics evaluation strategy is described by Welch and Walberg[1]. In addition, the various data gathering techniques are listed and referenced in their article.

In brief, the four-year evaluation plan was as follows:

Year 1. Develop instruments and refine overall plan.
Year 2. Pilot test evaluation design and instruments on a selected sample.
Year 3. Implement the evaluation plan on a national random sample of physics teachers.
Year 4. Analyze and disseminate results.

Three elements of the HPP design make it somewhat unique among science curriculum development groups. First, various cognitive, affective, and behavioral measures were used as criteria. Second, a true experimental design was employed. Third, the elements of the evaluation plan were trial-tested prior to its final implementation. While these components do not, of themselves, insure a successful program, they do point out the attempt to follow the tenets of experimental design.

Many of the studies of students, teachers, and learning environments were conducted as complements to the evaluation plan mentioned above. For example, as the group of selected teachers was pilot testing the evaluation design in Year 2, research studies involving the teachers were being conducted simultaneously to ascertain their unique personality characteristics.

Several important techniques were used in the evaluation of Harvard Project Physics. A system of randomized data collection[2] was developed to reduce the total testing time required of any one student. A national random sample of physics teachers with random assignment to experimental and control groups was employed[3]. Also, there was the development of several new measuring instruments to assess the many goals of the course. These instruments are described by Geis[4], Ahlgren[5], and Anderson[6].

Geis[4] presented a thorough review of the literature on the semantic differential test as a means for measuring attitudes. He pointed out the problems in using the semantic differential to measure attitudes in an absolute sense, but made a valid argument for its value in assessing attitude change. Ahlgren[5] described a technique of confidence testing as a means of assessing pupil achievement. Confidence testing permits the student to indicate his degree of confidence in the correctness of his response. Such a technique increases test reliability and is a good predictor of long-term retention.

Another measuring technique that was developed by the HPP staff was the Learning Environment Inventory (LEI). This instrument was an important part of the research program of the project. Because it was not feasible to visit a national population of physics classes, a paper and pencil alternative was devised to determine students' perceptions of the classroom climate. Anderson[6] described the rationale of the LEI and presented validity and reliability evidence. Scores on the LEI were used as a criterion for evaluating the course and as a means to describe what was occurring in the many physics classes. Further discussion of the LEI is found in a later section in this review.

A model for research on instruction in connection with an evaluation effort was developed by Walberg[7]. He described the need to consider student learning in terms of aptitude, instruction, environment, and the interaction of these variables. This model was applied to the HPP program using the criterion of physics achievement.

A final methodological problem that grew out of the evaluation program was explored by Welch and Walberg[8]. Their research indicated no pretest sensitization effects for either cognitive or affective measures when the interval between testings was seven months and test taking was part of the normal class activity.

Teachers

A second major category of studies focused on teachers; physics teachers in this instance. It is possible to separate the studies into two groups: (1) those concerned with the characteristics of physics teachers and (2) those describing various effects of participation in the program.

During the pilot test of the evaluation design, a select group of teachers was used because of the need to obtain feedback on course materials. One source of concern in prior curriculum evaluation studies was the effect of using volunteers during a course evaluation. To provide some understanding of this problem, a study[9] compared 36 volunteer physics teachers with national norms and with data collected from teachers attending summer institutes. The select teachers scored significantly higher on measures of theoretical and aesthetic values than other high school teachers, but lower on measures of economic, religious, and political values. The innovative teachers scored much higher on test of physics achievement. While they were close to the norm group on teaching attitudes, they had a lower need for affiliation than did the norm group. On the Edwards Personal Preference Schedule, the select group scored lower on the need for abasement and affiliation, but higher on the need for autonomy and heterosexuality. It was tentatively concluded that volunteer teachers were in fact markedly different from typical teachers. These results motivated in part the decision to select experimental teachers on a random basis the following year.

During the main evaluation year, the participating physics teachers were selected randomly from the 17,000 physics teachers in the nation[3]. The randomly selected teachers differed from their volunteer counterparts in training in mathematics and science. The volunteer teachers had an average of 40 semester credits in physics while the average for the random sample was 23 semester hours[9,10]. Also, the volunteer group scored significantly higher on a test of physics achievement and the Test on Understanding Science[11].

A study of 162 physics teachers by Welch and Walberg[12] indicated that two-thirds were using traditional physics texts while 29% were using the PSSC text. Sixty percent were teaching only one or two classes of physics and the average number of physics students per teacher was slightly less than 50. This group expressed strong agreement with the philosophy that physics is needed by all students, not just the academically elite.

To determine the impact of possible HPP teacher training mechanisms, Welch and Walberg[13] assessed the effect of NSF summer institute programs. One of the institutes was an HPP institute while three others were designed for physics teachers in general. Significant gains on a physics achievement test were found at all four institutes. In addition, three of the four programs showed significant gains on two different measures of scientific processes. The apparent success of the summer institutes for preparing physics teachers led the project staff to insist on similar training for all new HPP teachers.

Rothman[10,14] conducted two studies to assess the relative impact on teachers of teaching a course and of attending a summer institute. Using the semantic differential as a measure of interest, he found that teachers became favorably disposed towards the content and activities of physics in teaching the HPP course. By comparison, the change in attitude effected by summer institute attendance was minimal.

Students

A large share of the Project Physics research and evaluation studies was concerned with students; their characteristics, factors affecting learning, and enrollments in physics. During the early years of the Project, it was important to identify traits of the typical high school physics student[15]. This information was helpful to curriculum developers because it described one of their target audiences. As the Project neared completion, it became more important to determine the impact of the course on student achievement and attitudes[11]. Articles concerned with both of these components are reviewed in this section. In addition, several studies of physics enrollments are discussed because of the Project's general objective to increase secondary level physics enrollments.

Characteristics. In a survey conducted in 1968, Welch[15] found the average physics student was a bright senior planning on college, having strong mathematical and science interests and placing high value on the pursuit of truth. Girls were found to differ even more from their comparison norm groups on measures of science interest and achievement. Several questions were raised in this study about the lack of appeal physics has even among the rather elite group of young men and women who normally elect physics. In an interesting set of studies, Walberg contrasted characteristics of boys and girls in science[16,17] and examined several nonscience aspects of students in physics[18,19]. Primary motivation for these studies was the desire to present to course developers an accurate image of the select group of students who enroll in physics. Student responses to biographic items on reading and study habits were tabulated[19]. Evidence of a low interest in reading (e.g., 25 % did not read nonfiction) was found as well as a general dislike of school (e.g., 75% reported difficulty in concentrating on their studies).

In recent years, a number of writers have described the growing alienation of artists and humanists from the science and technology of our times. Because the staff of Project Physics was trying to develop a course suitable for a broader group of students than potential scientists, it seemed worthwhile studying the other side of the "two cultures." Comparisons were made among three groups of students on items of the Biographic Inventory[18]. The groups were those winning awards in science, in the arts, and no awards at all. The first two groups were called "scientists" and "artists" respectively. The third group was called "nonwinners."

The three groups differed significantly on many of the items, for example, on measures of creativeness, imagination, curiosity, role expectation, and school satisfaction. Walberg[18] recommended, on the basis of this study, the need for a multifaceted physics course, that is, a course with a broad range of elements that would help meet the diverse needs and interests of the students in physics.

Another group of students that caught the research interests of the Project Physics staff was girls enrolled in science courses. Because there are relatively few girls who enroll in physics and also so few women in science who attain eminence, it was considered important to assess possible inherent tensions between scientific and feminine roles. Samples of boys and girls in the group of students studied by the Project Physics staff were contrasted on selected cognitive, attitudinal, and personality measures. Differences between boys and girls in the physics sample were compared to a list of thirteen traits, compiled by Taylor and Behren, that distinguished creative scientists from noncreative scientists. On these thirteen traits, there was considerable variation between boys and girls, with boys showing the characteristics that were closely aligned with characteristics of creative scientists. These included such things as a high degree of autonomy, self-sufficiency and self-direction, a preference for mental manipulations involving things rather than people, a high degree of personal dominance, and a marked independence of judgment; that is, a rejection of group pressures towards conformity and thinking. Walberg[16,17] concluded that the apparent trait discontinuities between feminine and scientific roles may help to explain the relatively low percentage of girls in physics and the relatively poor showing of women in scientific careers.

Student learning. A guiding principle behind the research and evaluation activity of Project Physics was that evaluation is the gathering of data to assist in decision making. The staff charged with the evaluation responsibility identified decisions facing teachers, school administrators, and students and gathered information to aid in these decisions. The research component of Project Physics was designed to gather information of general value to the overall improvement of education. In this section, studies concerned with the factors that affect student learning are reviewed. Studies were conducted to determine the impact of teacher characteristics, classroom climate, teaching duration, students recruited into the course, and course satisfaction on student learning. The final section of this part of the review concentrates upon the curricular effects on student learning, the curriculum in this case being the Harvard Project Physics course.

It is generally held that knowledge of the subject matter possessed by a teacher will have an influence upon his teaching effectiveness. To determine the validity of this assumption, a set of studies was conducted that correlated several teacher characteristics with students' gains on both cognitive and affective measures. Contrary to what might be expected, it was found that teacher personality characteristics exert a more powerful influence than does content preparation on what students learn, how their interest changes, and their overall attitude towards physics[20-22].

In the first study in this sequence[20], it was found that teachers' personalities and value systems were more strongly related to students' changes in physics achievement, attitude towards physics, and interest in science than were the extent of teachers' preparation in physics, mathematics, knowledge of physics, and years of physics teaching experience. Furthermore, among a sample of 36 male physics teachers, it was found that these teachers exerted a greater influence on boys in physics than on girls who were enrolled in physics. In a replication of this study using a random sampling of physics teachers, Walberg and Rothman[24] again found that teacher personality traits as measured by the Study of Values and the Edwards Personal Preference Schedule were better predictors of what students learned and how their attitudes changed than was previous training in physics. However, in the replication study using the random sampling of teachers, there was a slight correlation (r = .26) between knowledge of physics possessed by teachers and knowledge of physics gained by students. The strong relationship between personality and value measures was replicated in the second year.

To examine the relationship between teacher personality and student learning in more detail, an identification hypothesis was proposed[22] that predicted that male students in a classroom learn physics better because of the modeling behavior exhibited by the male physics teacher. The hypothesis also explained the decrease in interest, in that the male model in the classroom may in fact be a rival for the attention of female students in the same class. While this hypothesis had some interesting ramifications, the data supporting it from physics classes alone are not adequate to state with any degree of certainty that the hypothesis was supported.

The results of this set of three studies emphasize the need for scientists and science educators to examine more critically a training program of science teachers that fixes upon subject matter preparation and almost completely neglects teacher personality development.

Another set of HPP studies focused upon a measure of classroom climate as a predictor of student learning. These studies will be examined in more detail in the next section. In brief, using the Learning Environment Inventory (LEI) to assess students' perceptions of the activities taking place in their classrooms, there was a positive correlation with scores on this instrument and measures of student achievement and student attitude. The conclusion drawn from this set of studies (and again this will be elaborated in the next section) is that the students' perception of what occurs in a classroom is a good predictor of the outcome measures of physics student achievement.

A formative evaluation study, conducted by Welch and Bridgham[23], was concerned with determining the effect of varying amounts of instruction on a selected physics unit. Using the adjusted class mean gains on a physics achievement test, no relationship was found between the number of days that a Project Physics unit was taught and the resulting achievement gains when the range of instruction was from 25 days to 62 days. Because the unit was designed for students and teachers to finish within 30 days, this information was useful in determining an appropriate length of the course.

The correlation between the teaching duration (ranging from 25 to 62 days) and the mean achievement gain for a class was -.08, not significantly different from zero at the .05 level. The study was conducted on a total of 41 different classes. In a supplementary study on teaching duration, the length of time required to present the physics unit was found not to be correlated with mean class ability. Initially, it was hypothesized that teachers would tend to go slower with a class of less able students. The findings did not support the hypothesis.

Welch[24] examined the impact of course satisfaction upon student learning. He found that satisfaction is related to achievement gains, greater participation in science activities, and course grades. He also found a negative relationship with perceived course difficulty. The measure of course satisfaction was responses by students to items such as, "I would recommend this course to my friends," and "This course is one of the most interesting I have had in high school." It was also found that course satisfaction was not correlated significantly with student ability or initial interest in science but the changes that occurred to students during the year seemed to have an effect upon their overall course satisfaction.

For a course that was designed to attract a new group of students to enroll in physics, a study[25] of the success of this group seemed in order as part of the research program of the project. Accordingly, a group of 180 students that was recruited (recruits), i.e., selected and encouraged by teachers to enroll in physics during the 1966-1967 school year, was compared on twelve different criterion measures with students who enrolled in physics of their own (volunteers). The criteria were achievement, general understanding of science, interest in science, and participation in science-like activities. In summary, it was found that the gains of the recruited students on these measures were equal to gains made by students who volunteered to take physics. The implication of this evaluation study is that if teachers and school administrators can lure students into the Harvard Project Physics course, apparently such students will be just as successful on these select criteria as students who would enroll of their own volition.

In the final study related to this section[11], the impact of Project Physics upon student learning was assessed. Comparisons were made between the Project Physics course and other physics courses to determine the differing influence upon physics students using 70 different criterion measures including the cognitive, affective, and behavioral domains. A summary of the findings of this study is presented in the last section of this review.

Enrollment. Because Project Physics was designed in part to help stem the declining trend of enrollment in physics, the evaluation and research staff was concerned with assessing the impact of Project Physics upon physics enrollment. In order to obtain an estimate of enrollment in physics, Welch[26, 27] examined methods by which enrollment in existing physics courses was determined. Of most particular interest was the enrollment in the course developed by the Physical Science Study Committee (PSSC). This course had been in operation approximately eight years before Project Physics, with quoted enrollment figures indicating the percentage of the total market using the PSSC materials. However, the enrollment figures varied considerably among the various agencies doing the counting: USOE, NSF, and several private agencies. A similar contradiction appeared in the new curriculum projects in chemistry and biology. Welch cautioned, on the basis of his study, that the use of textbook sales as an estimate for enrollment in science courses was very suspect and urged that an independent group not connected with any of the curriculum projects be assigned the task of accurately measuring enrollment in science courses.

In a related study using a national sample of 124 physics teachers randomly selected from a total population of 16,911, Welch[28] reported that 50% of the teachers were using a conventional textbook, *Modern Physics*, by Dull, Metcalf and Williams; 26.5% of the teachers were using the PSSC textbook, and 23.5% of the physics teachers were using other textbooks. At the time of the study, enrollment in Project Physics could not be obtained because the course was not available on a nationwide basis. However, Welch urged that a true test of the Project Physics impact could be obtained five years in the future (1974) by making an accurate determination of its usage.

Because it was thought that the source of low interest in physics, and therefore low enrollment in physics, might be due to teachers' attitudes, a questionnaire was administered to 162 physics teachers attending summer institutes in preparation for teaching physics in subsequent years[28]. Questions were designed to determine if the attitudes of teachers could be the reason for low student interest. However, responses such as the following, "Ninety-five percent stated that physics should be taken by girls," "Eighty-two percent agreed that all high school graduates should have some understanding of physics," and other related items led to the conclusion that physics teachers as a group believed that more, rather than fewer, students should be taking physics.

In the final study in this series, Bridgham and Welch[29] found a relationship between the grading practices of physics teachers and physics enrollment. They determined that teachers who assign grades lower than students normally receive tended to have smaller physics classes. Although the relationship was determined in only one of three criteria used to analyze the data, the results do suggest an association between severity of grading and current and future enrollment in physics courses. Accordingly, Project Physics staff members urged physics teachers to be fair and understanding in assigning grades in physics.

Research on Learning Environments*

A large block of research studies associated with Harvard Project Physics focused upon learning environments as a factor in student learning. Original interest in measuring classroom environments arose when it became necessary to evaluate the effectiveness of the Project Physics under different classroom conditions. Available behavioral scales and observations were examined, but these were rejected for several reasons: the problem of training staff sufficiently to produce objective, reliable results; travel costs to scattered locations throughout the country; and the unnatural, sometimes threatening, nature of a strange observer in the classroom. But the most important reservation was the validity of these measures; few studies have reported significant predictions of learning from them, and these few have failed to account for substantial variance, say 20%, in learning criteria.

Aside from the necessity of a potentially obtrusive observer, the available measures may be handicapped by one-dimensional scores which do not reflect the complexity of the classroom. Further, they largely assess teacher behavior, and even in these cases, they focus on the frequency rather than relative intensity of acts such as rewards. For example, it seems obvious that one wink from a grouchy teacher during a semester may be more important to the student than lots of verbal praise from a teacher conditioned to gush. Since a stimulus from the teacher, fellow students, the text, or other sources affects learning only insofar as it registers with the learner, a logical starting point seemed to be the student's perception of the learning environment.

Hemphill and Westis developed the Group Dimensions Description Questionnaire to measure general characteristics of adult groups, and their work is the most extensive factor analytic research on group properties. The items are inappropriate for the classroom group, but they did suggest a number of dimensions possibly related to learning. On the basis of these dimensions and others hypothesized to be relevant, 90 items were written for the Classroom Climate Questionnaire (CCQ). The instrument was administered to a national sample of 500 high school physics students. The items were factor analyzed and the resulting factor scores were used in a series of studies described below. Despite the validity of this instrument, psychometric studies showed that the scales were unreliable and redundant, and work began on a new instrument, the Learning Environment Inventory (LEI).

The Getzels-Thelen theory of the class as a social system had proven useful in prior research, and was used as a guide for constructing the new instrument. Item and intuitive criterion analyses were employed to increase the reliability and validity of scales from the first instrument and an effort was made to reduce the inter-correlations among scales. Assuming a maximum testing of 40 minutes to tap the fourteen dimensions thought important for learning, seven items per scale were selected. Spearman-Brown forecasts indicated moderate internal consistency reliabilities, from 0.5 to 0.8. These are tolerable since the goal was to measure many dimensions validly rather than a few very reliably.

One of the first studies of learning environments examined the correlations between the CCQ scales and several posttests regression-adjusted for initial differences on corresponding pretests[30]. This study employed individual students as the units of analysis. More specifically, the study tested the hypothesis that eighteen structural and affective aspects of classroom climate predict nine cognitive, affective, and behavioral adjusted posttests. Simple and multiple

*The content of this section is adapted in part from "A Case Study in Curriculum Evaluation: Harvard Project Physics" by Welch, Walberg, and Watson[39].

correlations revealed significant and complex relations between climate measures and learning criteria. For example, stratification and friction predicted science understanding, but other climate variables predicted physics achievement and attitudes toward laboratory work. In addition, groups of climate variables correlated with learning better than others. These groups of climate variables had been identified in an earlier study[31]. Among the structural variables, "isomorphism" (the tendency for class members to be treated equally) and "organization" (efficient direction of activity) predicted learning much better than "coaction" (compulsive restraint or coercion). Among the affective climate measures, "synergism" (personal relations among class members) predicted learning better than "syntality" (identification with group goals). This exploratory study indicated that further studies of the instrument were worthwhile on the select group and that it would be feasible to construct a better instrument for future work.

All the other studies of the select group of teachers used class means as the units of analysis. One of these[32] was similar to the first study except for the analytic units. The latter study employed the eighteen climate scales to predict raw gains (posttest minus the pretest) of classes on a physics achievement test, a science understanding test, and a semantic differential measure of physics interest. Multiple correlations revealed significant predictions could be made, and canonical correlations revealed two of the variates joined the predictors and criteria. The first variate predicted gains on all three criteria, but the second variate implied a trade-off between cognitive and noncognitive learning.

The separation of cognitive and noncognitive tendencies was also implicit in a study by Walberg and Anderson[33]. This study tested the predictiveness of the climate scales themselves from a battery of pretests. The Getzels-Thelen socio-psychological framework was useful in conceptualizing the research and interpreting the results. The central distinction of the framework is between *individual* "need-dispositions" and shared *group* "role-expectations" of students. The distinction seemed to fit the statistical description of two types of classes. The "achieving class" appears to have a friendly, democratic, goal-directed character which would fit in nicely with the organization of the school, while the "creative class" seems to threaten the established adult order with diverse interests, friction among its members, and high group status. The "achieving class" seems to represent the collective role-expectations of the "ideal student" from the point of view of the educational establishment. On the other hand, the "creative class" is not a group conforming to a prescribed role but an assortment of individuals apparently expressing individual needs: physical manipulation, inquiry, and answers to the impertinent, ultimate questions. The result–high status, recognition of diverse individual interests, friction among members, and perhaps because of these, the tendency to formality. Thus, classroom climate may be viewed as hypothesized by Getzels and Thelen as a function of interaction within the classroom group.

A second series of studies used the improved instrument, the Learning Environment Inventory (LEI) on the random sample of physics teachers. One of these studies[34] was a true experiment and contrasted the physics classes on teacher selectness, teacher experience, and course dimensions. Highly significant differences were found among the three groups of this study; Project Physics classes taught by experienced teachers, Project Physics classes taught by inexperienced teachers, and control classes taught by experienced teachers. Of most importance was the finding that the course effects seem to account for considerably more variance than teacher selection and experience with the course[34].

Another study in the second series concerned class size and perceived environments[35]. Although many teachers and students have strong preferences for small classes, the literature suggests that there is little consistent evidence that class size is related to achievement and interest in the subject. It was hoped, however, that the LEI might detect differences in class sizes and reveal something about their nature. Multivariate and univariate regression revealed significant correlations between several environment scales and class size. It was found that the larger classes tended to be more formal and diverse and less intimate and difficult.

Using the improved environment measure (the LEI) on the 1967-1968 random sample, Walberg[36] attempted to replicate an earlier study[32] predicting posttest criteria from environment scores. Canonical analysis of the fourteen environment scores and six posttest learning criteria revealed two significant canonical variates joining the sets. The environment scales by themselves accounted for up to 40% of the variance in a single criteria. Plots of the canonical variates revealed that the cognitive posttests were predicted (positively) mainly by perceived difficulty. Noncognitive achievement was mainly predicted by satisfaction (positively) and by apathy, cliqueness, and friction (negatively).

A correlational study[37] of several teacher personality variables and the LEI was conducted to determine the effect of teachers on the learning environment. The measures of personality included the Edwards Personal Preference Schedule, the Study of Values, and the Minnesota Teacher Attitude Inventory. This study indicated that the teacher does indeed influence the social climate of learning. For example, among the findings was the fact that teachers with high need for affiliation tend to have classes with low internal cohesiveness. The hypothesized explanation of this finding is found in the reinforcement literature. When the teacher is actively involved with the students, he becomes the source for student approval. On the other hand, when a teacher is distant from the class (low need for affiliation) the students turn to each other for reinforcement. This latter type of social environment would yield high cohesive scores.

In the final study of this section, Walberg and Ahlgren[38] identified predictors of the social environment of learning to determine if student characteristics were related to LEI scores. They found it was possible to accurately predict December measures of classroom climate using a battery of student measures obtained in September. As yet, the relative influence of teacher personality variables versus student characteristics on the social environment of learning has not been determined.

Final Evaluation Year Results

During the last year of the organized evaluation of the Project Physics course, a concerted effort was made to identify those variables that discriminated between Project Physics and other kinds of physics courses. These results to date have appeared as a final USOE report and are obtainable through the ERIC system. It seems appropriate at this time to summarize these findings as the final section of this review.

A total of 70 different criteria were used to assess the effects of the Project Physics course. A detailed analysis of these variables is presented by Welch, Walberg, and Watson[11]. A summary of the results was recently published[39] and the following table summarizes the main findings.

A total of seventeen significant course differences was found in this analysis, all of them reflecting positively on the HPP course. However, no significant differences were found on the three cognitive measures of the study; physics achievement, Test on Understanding Science, and the Welch Science Process Inventory. To some, the lack of significant differences on these measures is disappointing. Perhaps the more important implication is that the attitudinal goals of the course were achieved without a resulting loss in physics achievement.

Among the significant results, "Other Physics" courses rated higher on the variables: difficulty, favoritism, physics is difficult, mathematical, and applied. However, the goals of the Project Physics authors were to reduce the difficulty stigma attached to physics, reduce the

TABLE II

Summary of Significant Findings
Project Physics Versus Other Physics
Final Evaluation Year

Dependent Variable	Univariate F^*	Higher Mean
Course satisfaction	9.38	HPP
Difficulty	4.21	Other
Favoritism	3.31	Other
Diversity	6.52	HPP
Questionnaire items		
Math not essential (#3)	57.67	HPP
Historical approach good (#9)	72.36	HPP
Book enjoyable to read (#12)	15.95	HPP
Class finished text (#14)	3.80	HPP
Most difficult high school course (#16)	8.22	Other
Physics has to be difficult (#17)	7.90	Other
Hope course doesn't change (#19)	6.45	HPP
Historical	27.16	HPP
Philosophical	19.60	HPP
Mathematical	14.76	Other
Humanitarian	4.18	HPP
Social	11.85	HPP
Applied	7.90	Other

*F's significant at the $\rho < .10$ level.

mathematical orientation, and to show physics as an intellectual endeavor rather than as applied technology. The results of the study suggest the course was successful in achieving these goals.

The findings on the eleven variables where the Project Physics group was higher can be characterized as follows: students in HPP find the course more satisfying, diverse, historical, philosophical, humanitarian, and social; their questionnaire responses suggest a belief that mathematics is not essential to understanding physics; the historical approach is interesting; the book was enjoyable to read; their class finished the text; and they hoped the book would not be changed. Findings of this nature permit teachers to characterize the HPP course when faced with adoption decisions.

In summary, the results of the final year evaluation suggest that Project Physics was partially successful in achieving the objectives outlined by the course developers (HPP Newsletter No. 8). In addition to these general summative findings, considerable research on the teaching-learning process was carried out as part of the HPP evaluation program. This review has sought to characterize this national research and evaluation effort.

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