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ABSTRACT

The effects of a 3-week summer workshop sponsored by the National Science Foundation (NSF) and seven seminars held in the following academic year on the learning environments of 40 participating teachers' high school biology and chemistry classes were assessed. In this 1988-89 program, the 40 teachers visited 10 industries and agencies to observe applications of basic science. From these observations, they developed, in the university laboratories, teaching modules for their classroom curricula. Development activities were augmented by lectures, demonstrations, and presentations by visiting scientists. Videotapes were prepared to demonstrate basic science applications and processes as part of the teaching modules. This evaluation focused on the ability of the inservice program to stimulate effective teaching approaches to theories and concepts in biology and chemistry for secondary school science teachers, to build curriculum units from industrial and societal applications of conceptual and syntactical science using teaching strategies geared toward a range of student abilities, and to provide lesser-prepared teachers an opportunity to build enriched curriculum units and develop effective teaching strategies. Evaluation data were gathered via a learning environment measure called "Our Class and Its Work." Results indicate that the program did improve the science education of participants, stimulating positive student attitudes and greater student achievement. Five data tables are included. (TJH)

CHANGING LEARNING ENVIRONMENTS IN HIGH SCHOOL SCIENCE: AN EVALUATION OF THE RESULTS OF AN NSF WORKSHOP

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The purpose of this investigation was to evaluate the effect of a specially designed three week summer workshop and seven seminars held in the following academic year on the learning environments of the forty participating teachers' high school Chemistry and Biology classes. * In this project the forty participating teachers visited ten industries and agencies to observe applications of basic science. From these observations they developed in the University laboratories teaching modules for their classroom curricula. The development activities were augmented by lectures, demonstrations and visiting scientists. As submitted for funding the project listed six objectives:

(1) to stimulate effective teaching approaches to theories and concepts in Biology and Chemistry for secondary science teachers who are teaching in several science disciplinary fields

(2) to build curriculum units from industrial and societal applications of conceptual and syntactical science using teaching strategies geared to a range of students' abilities

(3) while the major purpose of the project is teacher enhancement, a secondary focus is to provide training for teacher-leaders who will be identified and encouraged to give leadership in their schools and to science education in the Commonwealth

(4) to provide lesser prepared Biology and Chemistry teachers (especially those teaching in other than their major) an opportunity to build enriched curriculum units and develop more effective teaching strategies

(5) to develop long-range networking opportunities for secondary science teachers in the Boston metropolitan area to work together and profit from a continuous exchange of new materials and teaching strategies

(6) to provide impetus and incentive for development of long term collaborative relationships between secondary science teachers, college and university scientists, and industry and government-affiliated scientists

A comprehensive evaluation design was constructed to ascertain the accomplishment of these six objectives. In this paper the emphasis will be primarily on objectives 1, 2 and 4 which focus on directly improving the effectiveness of the teacher in the classroom. Activities of the workshop

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were directed to getting teachers to explore new developments in science and to build teaching modules with less reliance on textbooks and more student participation in the construction of the learning activities. These teaching modules were then tested in their classrooms during the regular academic year and reported back in the monthly seminars for discussion and critique. At the end of the academic year they were then edited, bound and distributed to all class participants. A number of video tapes were prepared demonstrating basic science applications and processes as part of the teaching modules. These were commercially edited, duplicated and distributed to the participants at the end of the year.

METHOD

Twenty Chemistry and twenty Biology teachers were selected from two pools of 76 applicants who responded to advertisements for the workshop and seminars. They were chosen to represent a mix of experienced and inexperienced teachers, the latter were defined as having 5 or less years of teaching experience. (See Table I) Attention was given to including teachers who were in schools that had a larger than average minority enrollment. Participants schools had 15% minorities enrolled where state-wide, representation of minorities in the Massachusetts population is slightly less than 8%. The teachers were from both suburban and urban schools, and averaged 15 years of teaching experience. Previous surveys of Commonwealth high school science teachers reported two findings that guided the development of the workshop and the selection of participants: (1) less than well-prepared teachers were filling high school science positions, especially in chemistry, and (2) the aging science teacher population had not been prepared in the newly emerging, most significant developments that were shaping the applications of science in government agencies and industries. A major working assumption in the design of the workshops and seminars was that the learning environment in the participant teachers' classroom would be improved if teachers experienced direct application of basic science in industries and government agencies and developed as teams instructional modules which they taught and critiqued with peers in a supportive setting. Science teaching in general has suffered from didacticism, teacher-centric and textbook dominated teaching (Stake and Easley, 1978). These teaching methods have been especially resistant to change and take on an ideological rationale among some science teachers (Tobin, 1988). Broadening teacher experience in constructionist approaches, i.e., shaping learning activities according to student purpose and disciplinary objectives rather then covering material (Tobin and Fraser, 1989), and sharpening participants' critical judgments of teaching in a supportive setting are fundamental to breaking the customary teacher-centric dominated classroom. An external and internal evaluator were used to assess the project. An external evaluator was used to develop an instrument and administer it for the purpose of gathering data on the extent of implementation of the design of the workshops and seminars and to obtain participants' reactions to the workshops and seminars. The external evaluator also processed and analyzed the third category of data, a measure of the learning environments in participants' classrooms and in three comparison groups.

Because learning environments in the classroom are so crucial to the development of student attitudes toward science and shapes not only their present but future achievement (Talton and Simpson, 1986), a learning environment measure, Our Class and Its Work (OCIW) (Eash and Waxman, 1983) was used as the principal comparative measure.

The modified OCIW, contains 9 scales composed of 50 items. As a validated instrument, eight of the scales gather data on student perceptions of teacher behaviors that have been found to raise or lower student achievement. (Waxman and Eash, 1983) A 9th scale was added to OCIW which gathers data on students' perception of science as a subject, as a potential career, and as a contributor to social policy. (for the scales and a sample item of each, see Table IV) The OCIW was administered:

(1) as a pre-post measure in participant teachers' classroom
(2) to another science teachers' class in the same school with similar students
(3) to students in the classrooms of a second group of teachers who had been accepted for the AY89-90 workshop and seminars but had not taken the AY88-89 workshop and seminars.

RESULTS

The results of the three different categories of data are carried in tables II, III,IV and V. Tables II and III present the reactions of teachers to the workshop and seminars and the perceived utility and usefulness of the activities in their classrooms. Sixty one % of the teachers said they utilized the activities which were targeted by the workshop and designed to promote constructionists approaches to teaching. The six activities used by three quarters of the teachers were: used a different method to teach a concept or major learning (75%), introduced new materials into regular curriculum (93%), shared my project experience and materials with other teachers (93%), included in classroom work direct applications of science concepts in industry (82%), focused specific lessons on importance of science in society and specific community (75%) and expanded the science content taught into new areas this year (82%). Teacher participants rated workshop experiences on a four point scale (1: extremely valuable, 4: not valuable) gave the different summer workshop experiences a mean rating of 1.48. They rated as highest the relationships with University scientists ($\bar{x}$ 1.13) and other teacher participants ($\bar{x}$ 1.18) and as lowest the relationships with scientists in agencies ($\bar{x}$ 2.00) and industries ($\bar{x}$ 1.70). In two of the three comparisons on the <u>OCIW</u> the workshop participants had significantly higher results.

The OCIW which was the chief objective measure of the classroom learning environments collected three sets of data. It was assumed in the evaluative model that the workshops and seminars impact on teachers' knowledge of and teaching of science would be reflected in participants' classroom performances when compared with teacher control groups. On the OCIW improved scores of teacher classroom behaviors as perceived by students have been found to reflect greater student achievement in the subject, i.e., science. The OCIW result of the comparisons pre vs post-test scores of participants, workshop participants vs non-workshop participants, 1988 participants vs 1989 participants (pre-test), and experienced teachers vs inexperienced teachers, and boys vs girls in workshop participants classes are shown in tables IV and V.

The combined workshops of Biology and Chemistry were significantly higher on 7 of the 9 scales in the post-test than the pre-test (See Table V). The Biology workshop alone did not show a significant difference on the overall pre vs post-test. On the comparison between participants vs non-participants' classes there was a significant difference in favor of the workshop participants' classes. A somewhat surprising finding was the 1989 NSF participants overall pre-test scores were significantly higher than the 1988 post-test scores. We believe after nearly a year's experience with the 1989-90 workshop participants that they are, as these data reflect, a superior group of teachers and reflect selective recruitment by the 1988 workshop participants. Experienced teachers, as expected, performed significantly better than inexperienced teachers. There was no significant difference overall on the OCIW for boys vs girls, though in the comparisons of the individual scales there were two significant differences, one favoring boys,and one favoring girls.

DISCUSSION

Curriculum evaluation has never been a favorite field for investigation by researchers as Wayne Welch observed. The difficulty of developing random assignment to treatment(s) or even of producing matched studies is legendary. Nevertheless the consistency of outcome measures and the repeated replication of findings does provide some confidence in the belief that the changes as observed, measured and contained in the self reports are not simply due to chance.

While the results of these comparisons are not the products of a true experimental design (random assignment to treatment), the outcomes based on two different comparisons (pre and post, and other science classes) do consistently reflect significant differences that favor the classes of the participants who have received the treatment of the summer workshop and follow-up seminars in 1988. (See Tables IV and V)

Overall, workshop participants from the 1988 workshop and seminars showed personal growth in all nine of the OC? .V scales. When 1988 participants were compared with other science teachers in their schools they showed gains in those behaviors which stimulate student subject achievement in six of the nine scales. When 1988 participants post tests, i.e., measures taken after they had completed the summer workshops, taught their modules, and been through the academic year seminars, were compared to their pre-tests, they were significantly higher in seven of the nine scales. In the other two scales while not achieving significance, the trends were in favor of the 1988 workshop participants.

The 1988 workshop participants when compared on their post-test scores with the 1989 participants pre-test scores (both having been administered in May 1989) were significantly higher on the three scales of Enthusiasm, Structuring Comments and Task Orientation. The 1989 participants were higher on the three scales on Instructional Time, Opportunity to Learn, and Pacing. There was no significant difference on the three scales of Didactic Instruction, Feedback, and (Student) Attitude toward Science. These findings confirmed the PIs' belief that the two workshops were composed of different teachers. The 1989 participants appear as a group to be more motivated and have a greater professional orientation than 1988 participants. This greater professionalism has been manifest in their better attendance at the academic year seminars and in the greater progress they have made in preparing teaching modules.

Student observations of teaching behaviors have been found to be highly accurate indicators of teachers' classroom functioning and strong predictors of students' level of learning of subject matter. After completing the workshop, the 1988 participants were viewed by students as being more enthusiastic and using more and different materials in their classrooms, behaviors that stimulated student interest in science. Students of teachers who finished the workshop were much more likely to strongly agree with the statement, "Students are more interested in science", than their counterpart control students in classes whose teachers had not been in the workshop.

Workshop teachers upon completion of the 1988-89 experience were viewed far more often by their students to use more effective techniques of instruction that promote students' learning through: immediate feedback, providing appropriate challenging assignments, and keeping students' task oriented. Teacher performance was improved in using community resources for science, and providing greater variety in classroom instruction. Most importantly for the future of science the students of workshop participants strongly agreed with the statements, "I understand the relationship of science to industry" and "I am interested in a career in science." at a statistically significantly higher rate. Boys and girls did not differ in their response to these statements. In both the teachers' self-report data in Tables II and III and the students' observation data in Tables IV and V there is consistency in these two data sets in describing changed teacher behavior and improved teacher performance in the classroom.

The comparative results on experienced vs inexperienced teachers and boys vs girls (Comparisons Table IV) (4 and 5) reflect two other significant outcomes. The designation of experienced and inexperienced teachers based on preparation and teaching is supported in the empirical data as experienced teachers significantly ranked higher on the OCIW than inexperienced teachers on both pre and post measures in two comparisons. However the inexperienced teachers made greater gains on the two scales of Pacing and Attitude Toward Science (See Table V). Comparison five which examined the treatment effect on boys and girls produced one of the most interesting and important findings. Boys and girls did not differ significantly but on two scales. Enthusiasm was higher for boys and Opportunity to Learn was statistically significantly higher for girls. From these results we conclude their growth in achievement in science does not differ greatly. Given that the preponderance of data in previous research on gender differences in science finds boys performing better in both attitude and achievement, this is an unusual, unanticipated outcome (Becker, 1989). Moreover, we believe the finding of little difference in boys and girls' results in the 1988 workshop participants' classes, if substantiated by future studies, potentially underscores an important contribution of this type of workshop to both Biology classes (which are mostly required science), and to Chemistry classes (which are generally elective) to attracting more women into science careers.

De Rose and others (De Rose, 1979) have commented on the critical role of the teacher in establishing the quality of the learning environment. The teacher is the key player in ensuring an environment which promotes continuing interest in science, but there are some structural impediments which preclude teachers following a more constructionist approach to curriculum — the short 40-45 period that most high schools schedule and the lack of good serviceable equipment to use in teaching and demonstrating. Schools seem to be both short of budget for new equipment and even to be unable to keep equipment repaired and in operating condition. Teachers' failure to bring students into the planning of instruction (see Table II) and the persistence of didactic instruction (see Table V) we believe is related to the 40 minute period.

Of particular note is the increase in interest in science in the students of workshop participants. This seems contrary to the national trend of diminished interest in science for upper adolescents and young adults (Hofstein et al, 1986, and Yager, Penich, 1986). The need for building enthusiasm and interest in science heightens when one looks at the problem of the diminishing numbers of students choosing science majors as under-graduates and pursuing advanced degrees in science. Recently the President of AAAS produced an analysis which demonstrated that students who had taken ten or more semesters of science and mathematics in high school but did not enroll in any type of science program constitute a large pool of potential science manpower that in itself would erase the projected shortfall in the next two decades, if they were induced to enroll in science and engineering programs -- even allowing for subsequent attrition (Atkinson 1990).

Do these NSF workshops and seminars effect longer range changes in students' attitudes and achievement in science? The current measures are not adequate to give a definitive answer to this crucial question. However, the consistency of these data favoring the NSF workshop participants' classes, do point strongly toward the belief that the workshop treatments are directly contributing to improving teacher performance that leads to higher student achievement in science (Biology and Chemistry). Moreover, these teaching behaviors strongly stimulate interest in science.

What are the variables in the workshop and seminars' design that contribute to the effectiveness of the treatment? The evaluative data indicate that the prior assumptions guiding the original design of the workshop are supported. Teacher performance affecting student achievement is improved by:

(1) expanding teachers' horizons on new developments and applications of science in industry and government

(2) having teachers generate instructional modules stimulates classroom interest and builds teaching competency

(3) providing a supportive setting for critical examination of try outs of teacher generated materials

(4) fostering a supportive network of relationships between university scientists and high school science teachers

(5) continuing a program that maintains the network of relationships established by the cooperative atmosphere of the NSF workshop

Thus we conclude from the evaluative data that the 1988-89 workshop and seminars linked with a continuing program of activities did improve the science education efforts of those teachers who participated. These efforts in turn stimulate more positive student attitudes towards science and greater student achievement. Progress along these two lines advances national goals for science as well as promotes the scientific accomplishments of individual boys and girls.

TABLE I

EXPECTED AND ACTUAL ENROLLMENTS OF COHORT GROUPS IN BIOLOGY AND CHEMISTRY SUMMER 1988 WORKSHOPS

	Expected (Percentage)	Actual (Percentage)
Minorities	10	7.5
Women	50	45.0
Physically-disabled	2	0.0
Well-prepared Teacher	60	62.5
Under-prepared Teachers	40	37.5

Note: The project participants have a heavier representation in students taught who are classified disadvantaged and minorities than originally targeted. In the original proposal, minorities and disadvantaged students taught by participants were targeted at an expected rate of 20 percent and 10 percent respectively. In the teacher participants selected they were found to be 25 percent and 15 percent of the school populations. The state-wide representation of minorities in Massachusetts population is slightly less than 8 percent.

TABLE II

UTILITY OF WORKSHOP EXPERIENCES ACTIVITIES IN CLASSROOM ENHANCEMENT (Participants Self-Report)

Activity or Experience	Percentage
Have taken a field trip(s) that replicated those in NSF Workshop	42
Have used new equipment in my teaching this year	64
Have used a different method to teach a concept or major learning *	75
Have introduced new materials into regular curriculum *	93
Have had students plan and organize cooperative group projects*	43
Have changed my approach to incorporate more student planning in new curriculum	21
Have brought more resource people from industry into my classroom	29
Have Shared my project experience and material with other teachers	93
Have included in classroom work direct applications of science concepts in industry *	82
Have observed increased student interest in science as a career this year *	54
Have increased use of questioning in my class this year *	57
Have found students with a wider range of academic abilities more interested in science this year *	50
Have focused specific lessons on the importance of science in society and specific community *	75
Have expanded the science content taught into new areas this year *	82

* Item verified by student observation data from a standardized instrument.

TABLE III

RATING OF THE OVERALL WORKSHOP AND EXPERIENCES BY PARTICIPANTS (YEAR I)

Overall Workshop	Percentage (Responding positively)
Overall I found project experience valuable	95
Project will enhance my teaching	100
As result of the site visits my development of classroom teaching units will be enhanced or greatly enhanced	100

Activities Ratings (1 extremely valuable, 4 not valuable)	x Rating
Lectures	1.40
Site Visits	1.40
Experiments	1.50
Seminars	1.54
Relationships with Scientists in Industry	1.70
Relationships with Scientists in Universities	1.13
Relationships with Scientists in Agencies	2.00
Relationships with Other Participants	1.18

TABLE IV

COMPARISONS OF IMPACT OF WORKSHOPS AND SEMINARS ON 1988 PARTICIPANTS' CLASSROOM TEACHING BEHAVIORS AND STUDENT ACHIEVEMENT (OCIW)

GROUP COMPARISONS	N	F	t	Level of Significance
1. PRE and POST TESTS:				
NSF Participants' Classes				
Biology	469	0.3125	- 0.5681	NS
Chemistry	1047	0.9352	2.9692	0.003
Combined Biology & Chemistry	1516	0.3717	- 0.7906	NS
2. 1988 NSF PARTICIPANTS' CLASSES COMPARED TO NON NSF CLASSES:				
Combined Biology & Chemistry 1988	572	0.4395	2.6912	0.007
Combined Non NSF Classes	310			
3. 1988 NSF PARTICIPANTS (Post-Test May 1989) COMPARED TO 1989 NSF PARTICIPANTS (Pre-Test May 1989):				
Combined Biology & Chemistry 1988	634	0.9513	- 6.4418	0.001*
Combined Biology & Chemistry 1989	672			
4. EXPERIENCE TEACHERS 1988 COMPARED TO INEXPERIENCE TEACHERS	442	0.4782	14.85	0.01
5. BOYS COMPARED TO GIRLS	625	0.1148	2.12	NS

* The 1989 participants significantly outperformed the 1988 participants -- see text.

TABLE V

IMPACT OF WORKSHOPS AND SEMINARS ON 1988 PARTICIPANTS' CLASSROOM TEACHING BEHAVIORS AND STUDENT ACHIEVEMENT (OCIW, SCALES COMBINED BIOLOGY AND CHEMISTRY)

SCALES AND DESCRIPTION [Reliabilities in ( ) reported in Chronbach Alphas]	Level of Significance (.05 and above reported)				
	Pre Post	Other Science Classes	1988 vs 1989	Experienced vs Inexperienced Teachers '88	Boys vs Girls 1988
Didactic Instruction(.87) Implies that the teacher controls and directs the instruction for all students in the class. Sample item:"Our teacher lets us do things our own way."	.05	NS	NS	NS	NS
Enthusiasm (.92) Considers the extent to which a student sees the teacher exhibit excitement and interest in teaching. Sample item: "We try new and different things in our classroom."	.01	.01	.01	NS	.01
Feedback (.91) Describes the extent to which the teacher respond to students answers and provide students with feedback about their schoolwork. Sample item:"Our teacher carefully checks all our work."	NS	.001	NS	NS	NS
Instructional Time (.86) Refers to the time students spend in learning. Sample item:"We are always working in our class."	NS	.05	.01*	NS	NS
Opportunity to Learn (.92) Indicates how well the teacher provides opportunities for all students to learn or cover criterion material. Sample item:"Many students do not finish their work."	.05	.01	.01*	NS	.01***
Pacing (.92) Deals with whether or not the classroom work is at the appropriate level of difficulty for students in the class. Sample item: "Our teacher spends too much time going over work."	.01	NS	.01*	.05**	NS
Structuring Comments (.91) Refers to whether the teacher provides overviews at the beginning and end of instructional sequences and whether students understand. Sample item:"Our teacher often reviews yesterdays work."	.01	.01	.05	NS	NS
Task Orientation (.84) Indicates the extent to which the classroom is businesslike. Sample item:"We always have an assignment to work on."	.05	NS	.01	NS	NS
Attitude Toward Science (.77) Indicates students attitudes toward importance of science in society, the scientific method in their lives, and science as a chosen career. Sample item:"Scientists improve our lives."	.01	.05	NS	.05**	NS

* The mean differences favored the control group (see text)

** The inexperienced teachers made greater gains on these two scales than experienced teachers but the difference in means favored the experienced teachers.

*** Boys had higher means than girls on "Enthusiasm scale" and girls had higher means on "Opportunity to Learn scale".

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