DOCUMENT RESUME

ED 161 680 SE 024 994

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TITLE The Effect of Teacher Participation in NSF Institutes Upon Student Achievement. Research Paper No. 10. Revised Edition.
INSTITUTION Minnesota Univ., Minneapolis. Coll. of Education.
SPONS AGENCY National Science Foundation, Washington, D.C.
PUB DATE [74]
GRANT NSF-GW-6800
NOTE 20p.; For related documents, see SE 024 989-999 and ED 148 632-640; Contains occasional light and broken type

EDRS PRICE MF-$0.83 HC-$1.67 Plus Postage.
DESCRIPTORS *Academic Achievement; *Educational Research; Inservice Education; *Institutes (Training Programs); Junior High Schools; Mathematics Education; *Mathematics Teachers; Science Education; *Science Teachers; Secondary Education; Secondary School Science; Student Teacher Relationship; *Teacher Education
IDENTIFIERS Minnesota Research & Evaluation Project; *National Science Foundation; Research Reports

ABSTRACT

This research study investigated the effect of the participation of science and mathematics teachers in the National Science Foundation (NSF) Institutes upon the achievement of junior and senior high school students. A randomly selected group of junior and senior high school science teachers and randomly selected classes of theirs were administered achievement tests in science. Chi square and analysis of covariance (ANCOVA) were used to analyze the data. Participation in NSF Science Institutes and geographic regions were factors in a two-way ANCOVA. Class mean for achievement was the dependent variable and teacher achievement was the covariate. NSF participation was found to be a significant factor in student achievement for high school teachers but not for junior high school teachers. The study was replicated for mathematics teachers and classes and the same results were found. It was concluded that significance at the senior high school and nonsignificance at the junior high level may be due to the difference in subject matter taught and the population of students between the two levels. (Author/HM)

RESEARCH PAPER #10 - REVISED

The Effect of Teacher Participation in NSF Institutes Upon Student Achievement

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September 30, 1974

This study was supported by grant GW-6800 from the National Science Foundation to the University of Minnesota. Wayne W. Welch, Project Director.

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Large foundations and institutes across the nation such as the National Science Foundation (NSF) have often assumed that the improvement of teacher knowledge and ability will result in improved student achievement. As a result of this assumption, much money and effort has been devoted to improving teacher knowledge, particularly in science. Since 1958, the NSF has spent nearly 750 million dollars for teacher training and upgrading. Most of the money has been used to support various training institutes, such as the Academic Year Institute (AYI), In-Service Institutes (ISI), Sequential Summer Institutes (SSI), and Unitary Summer Institutes (USI). Little evidence has been provided to show that the ultimate consumers, school children, have benefited. This report provides some additional evidence of benefit.

Previous Studies

A review of follow-up studies in Academic Year Institutes and In-Service teacher training in the areas of science and mathematics gives mixed results about improvement in the quality of education within these subject areas for teachers and students. In the utilization of the American Association for the Advancement of Science's (AAAS) "Science--A Process Approach" (SAPA) and the "Science Curriculum Improvement Study" (SCIS) Curricula, results are presented that teachers demonstrated marked improvement in the nine competency areas considered (Lashier and Kurtz, 1970) as well as in the desire to initiate science curriculum change through the use of the AAAS and SCIS philosophies and activities (Merkle, 1970). Moreover, Lashier and Kurtz (1970), in an experiment conducted after a summer institute, reported that students using the AAAS method scored significantly higher on three of four competency tasks than did a control group using other materials. Studies involving Academic Year Institutes participants also indicate that teachers experienced wider opportunities to use their abilities and improved their professional and economic stature (Bradberry, 1967; Irby, 1967; Martinen, 1967; Westmeyer, et.al., 1967).

In research reported involving Mathematics Academic Year Institutes, the Montgomery County (Md.) Public Schools held a three-week summer laboratory workshop in 1969 for teachers and low achievers in mathematics at the secondary level. The students were given a pre- and post-test sequence of instruments measuring mathematics achievement and self-concepts. The results of all tests indicated that (1) students showed an average gain of about one-half year in Mathematics Achievement, (2) that their self-concepts with regard to mathematics increased significantly, and that (3) none of the students' comments suggested unfavorable dispositions to the workshop as a whole. Regression effects may account for most of these changes, however. This study is one of only a few examining mathematics learning related to institute participation (See Irby, 1967; Martinen, 1967; Krieghbaum, 1968; and Slawson, 1970).

In an international study of science curricula in nineteen countries, Comber and Keeves (1973) examined the relationships between teacher-related variables and student achievement. They reported

> There is some evidence that teachers who show a professional attitude toward their work, for example, in the preparation they do and in their membership in professional associations, achieve, in general, better results than those who do not.

Specific variables reported significant in regression analyses on achievement were teacher training in six of fifteen countries at the senior high level and attendance at conferences in two countries at the senior high level.

Thelen and Litskey (1972) reported a study in which students of teachers who participated in a six-week summer institute on water pollution control were compared with students of teachers who did not attend. The non-attending group included teachers who had applied but were not selected to attend the institute. Analysis of covariance was used, a test of student achievement on knowledge of water pollution control as dependent variable, and DAT scores as covariate. Reported means for the classes of teachers who attended were significantly higher than means for classes whose teachers did not attend.

Method

As part of an independent evaluation of five NSF Comprehensive Teacher Training Projects funded by the NSF, Gullickson and Welch (1972) carried out a large scale experimental design in which schools were systematically sampled within strata of urban-rural, geographic region, junior and senior high school, and subject matter (science and mathematics were nested within the comprehensive regions).[1] Within each school selected, the principal was asked to select randomly one teacher from the science (or mathematics) faculty, who in turn was asked to select one class at random from the teacher's class load. Teachers and their selected students were given a series of questionnaires, including background questions for teachers and the National Teacher Examinations in Physics-Chemistry-Science or Mathematics (Educational Testing Service, 1970). Science students took the Test of Achievement in Science, or TAS (Lawrenz, 1972) which consists of items selected from the National Assessment of Educational Progress items in science; and mathematics students took the Mathematics Achievement Test, abbreviated MAT, which was composed of items from The National Longitudinal Study of Mathematical Abilities (NLSMA) pool in mathematics (Sandman, 1972). Two forms were developed in science and in mathematics, one for junior high level students (8th grade) and one for senior high level students (11th grade). A total of 346 teachers and classes[2] participated in science, and 211 teachers and classes in mathematics. Reliabilities reported for the tests are given in Table 1.

Table 1

Reliabilities of Test Instruments

Instrument	N	Reliability
NTE (Mathematics)	Not Available	.94
NTE (Science)	Not Available	.90
TAS		
Senior High	1921	.87(KR-20)
Junior High	981	.87(")
TAM		
Senior High	1261	.86(")
Junior High	1424	.92(")

[1]Regions were centered in Wyoming, South Dakota, and Mississippi for science; California and Indiana for mathematics.

[2]Not all students took the achievement test. The teacher was given instructions for random division of students; others took attitude and process instruments. Thus, class means are estimates for the class.

Analysis

As a way to estimate the contributory effect of NSF participation by teachers upon the achievement of their pupils, analysis of variance was chosen to partition possible factors in student achievement. A regional effect was included as a fixed factor, since the generalizability to other regions is uncertain. An urban-rural factor was considered but rejected, since for the science study no major urban centers were represented in all three regions. Only Denver, sampled in the Wyoming region, was a major urban center for science teachers. Similarly, the urban representation in the mathematics regions was small (only Indianapolis). The majority of the schools sampled were in small towns and cities under 50,000 population (81% in science, 91% in mathematics).

A second factor considered was NSF participation by teachers. Participation was defined as cumulative attendance at the following NSF-sponsored programs and institutes: AYI, ISI, SSI, and USI. Cooperative College and School Science Programs (CCSS) were not considered since no information was gathered from the teachers about this type of NSF participation. No attempt was made to look at each type of institute separately since the sample sizes for participation vs. non-participation was so disparate. A frequency distribution of number of institutes attended by science teachers yielded approximately equal percentages for no participation (36%), one or two institutes attended (36%), and three to fourteen institutes attended (28%). These levels were then assigned as "No", "Low", and "High" levels of participation in NSF-sponsored institutes. The percentages of mathematics teachers were 43% for the "No" group, 29% for the "Low" group, and 28% for the "High" group, quite similar to the figures for the science teachers.

A possible contaminant to examination of the effects of institute participation by teachers upon student achievement would be differential assignment of teachers to ability-grouped classes. Teachers having attended institutes might be assigned to higher ability classes through seniority or for other reasons. This hypothesis was examined by testing the independence of NSF participation from the teachers' assessment of the ability group of the class from which the achievement data were drawn (high ability, average ability, low ability, and mixed ability grouping). Also tested within the senior high school science data was the independence of type of class (biology, chemistry, and physics) from NSF participation. The chi-square statistic was used for each test, and results are presented in Table 2. All chi-square statistics were non-significant at p = .05, indicating independence of the distribution of teacher assignments by ability grouping, or subject matter in science, from NSF institute participation.

A possible confounding of the analysis is due to the non-random selection of teachers for NSF institutes. If "better" teachers (more academically capable) go to institutes, then a significant difference in student achievement among participation levels might be due to teacher subject matter competence. Accordingly, teacher achievement, as measured by the NTE, was included in the analysis as a covariate, so that analysis of covariance with two fixed, crossed factors was performed on four sets of data: Test of Achievement in Science (TAS) scores for senior high students, TAS for junior high, Test of Achievement in Mathematics (TAM) scores for senior high, and TAM for junior high. Similar results for both science and mathematics would be interpreted as validating the conclusions, since the groups and tests are independent.

Disproportionate cell sizes were encountered in the science data, so that the design was made proportional to aid interpretation. This was done by

Table 2

Chi Square Values for Contingency Tables of NSF Institute Participation by Ability Grouping or Subject Matter

NSF Institute Participation (3 levels) by	Science		Mathematics	
	Junior High	Senior High	Junior High	Senior High
1. Teacher Rating of Class Ability (4 levels)	$\chi^2 = 1.12$ (df = 6)	7.85 (df = 6)	9.87 (df = 6)	4.31 (df = 6)
2. Subject Matter	- (all 8th grade) science	7.63 (df = 4) (biology, chemistry, physics)	- (all 8th grade) mathematics	- (all 11th grade) mathematics

$_{.95}\chi^2_4 = 9.488$

$_{.95}\chi^2_6 = 12.592$

randomly selecting out subjects in oversize cells, and increasing sample size in one case by including cell means as three dummy subjects' scores (in the science Mississippi junior high "High" participation group). Disproportionality was not as great in the mathematics study so that no sampling was performed. Cell sizes, unadjusted means, and standard diviations are given in Table 3.

Analysis of covariance was performed using the MULTIVARIANCE Program of Finn (1968). The results of the four analyses are presented in Table 4.

Table 3

Within-Cell Sample Size, Unadjusted Means, and Standard Deviations for Four ANCOVA Problems

Senior High Science Achievement

Region	NSF Participation: NO	LOW	HIGH	Total
Mississippi	n=21 $\overline{X}$=19.06 s= 4.10	21 18.83 4.13	14 18.41 2.94	56 18.81 --
South Dakota	21 21.21 2.89	21 23.51 3.98	21 24.71 3.94	63 23.15 --
Wyoming	21 26.85 4.79	21 26.42 3.60	21 28.37 3.08	63 27.21 --
Total	63 22.37	63 22.92	56 24.51	

Junior High Science Achievement

Region	NSF Participation: NO	LOW	HIGH	Total
Mississippi	14 20.35 5.81	7 19.61 3.24	7[1] 18.00 1.11	28 19.58 --
South Dakota	14 23.80 3.17	14 21.92 4.13	14 25.28 2.07	42 23.67 --
Wyoming	14 22.46 3.56	14 24.11 2.73	14 23.59 2.34	42 23.39 --
Total	42 22.20	35 22.33	35 23.15	

[1] Only four valid observations were made for this cell; remaining observations were cell means. The standard deviation is based on four observations.

Table 3 (Continued)

Senior High Mathematics Achievement

Region	NSF Participation NO	LOW	HIGH	Total
California	18 23.46 5.99	17 25.68 3.62	20 25.64 3.53	55 24.94 --
Indiana	16 22.26 5.61	22 25.73 2.96	19 24.15 4.82	57 24.23 --
Total	34 22.90	39 25.71	39 24.91	

Junior High Mathematics Achievement

Region	NSF Participation NO	LOW	HIGH	Total
California	22 19.11 7.41	15 21.99 6.97	11 22.87 6.07	48 20.87 --
Indiana	33 21.00 5.69	7 17.52 7.14	11 21.15 5.03	51 20.55 --
Total	55 20.24	22 20.57	22 22.01	

Table 4

ANCOVA Summary Table for Four Analyses

Science: Senior High

Source	SS	df	MS	F	p[1]
A (Region)	2,064.6	2	1,032.3	71.29	<.01
B (NSF Participation)	79.8	2	39.9	2.76	<.06[3]
A X B	99.2	4	24.8	1.72	<.15
Error (within cell)	2,490.6	172	14.48		
Covariate	R^2=.006	1	--	.1	<.75

Science: Junior High

Source	SS	df	MS	F	p[2]
A (Region)	331.8	2	165.9	13.65	<.01
B (NSF Participation)	13.1	2	6.5	.54	<.59
A X B	114.06	4	28.5	2.35	<.06
Error (within cell)	1,239.95	102	12.16		
Covariate	R^2=.002	1	--	.22	<.64

[1] p is referenced for 168 df error, reduced by one for covariate and three for dummy subjects.

[2] p is referenced for 98 df error, reduced by one for covariate and three for dummy subjects.

[3] p is a liberal estimate; positively correlated sample size and error variance implies smaller p values.

Table 4 (Continued)

Mathematics: Senior High

Source	SS	df	MS	F	p[3]
A (Region)	16.60	1	16.60	.83	<.37
B (NSF Participation)	157.94	2	78.97	3.93	<.02
A X B	581.68	2	5.5	.28	<.76
Error (within cell)	2,107.94	105	20.08		
Covariate	R^2=.10	1		1.15	<.29

Mathematics: Junior High

Source	SS	df	MS	F	p[4]
A (Region)	2.69	1	2.69	.066	<.80
B (NSF Participation)	47.9	2	23.95	.59	<.56
A X B	168.8	2	84.40	2.06	<.13
Error (within cell)	3,767.9	92	40.96		
Covariate	R^2=.008	1		.70	<.41

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3 p is calculated for 104 df error, reduced by one for covariate.

4 p is calculated for 91 df error, reduced by one for covariate.

Results

The marginal means of student achievement for NSF participation show a consistent trend in the direction of better student performance with increased teacher NSF participation for all four analyses in Table 3 (note a minor reversal between low and high participation for senior high science; both means are higher than that for no participation). These means are essentially unaffected by adjustment for the covariate, since none of the regressions were significant at $p = .10$. Regional differences did occur, as noted by the marginal means in Table 3.

The analysis of variance on adjusted means also shows consistent results: at the senior high level, differences occur on the NSF participation factor for both science and mathematics, while at the junior high level, the means are not significantly different, although ordered in the appropriate direction. Also for the junior high analyses, marginally significant region by participation interactions occur. These may be plotted but do not seem to provide very enlightening results.

The disproportionality and unequal variances of the science data were examined in order to adjust the estimated probability of occurrence of the observed F-statistics (see Glass, Peckham, and Saunders, 1972). The small variances with small cell sizes and large variances with large samples requires either conducting a more liberal test ($p = .10$) or interpreting the observed probability as being liberal. In either case, the NSF participation factors are significant for senior high science and mathematics. Of interest within these factors is where the differences lie. Two planned orthogonal contrasts were performed, as diagrammed below: (See Winer, 1971; p. 172).

NSF Participation

Level	NO	LO	HI
Contrast 1	-2	1	1
Contrast 2	0	-1	1

Results are presented in Table 5. Among the contrasts, all had high significance except that of senior high mathematics for Low vs. High participation. The significant contrasts suggest that teacher attendance at institutes is associated with higher student achievement than no attendance, and that the students of teachers with high institute attendance perform better than students of teachers who have only attended one or two institutes.

Conclusions

The data presented here support the thesis that participation by senior high school science and mathematics teachers in NSF-sponsored institutes results in higher achievement scores by their pupils than for pupils of teachers who do not attend. The effects of differential teacher ability were removed by covariation. Similar trends were observed at the junior high level, but the results are not significant. That two independent data analyses should give such similar results is itself unusual, and the similarity is taken as support for the thesis. The results also are supported by the International Study on Science in which teacher training variables were significant only at the senior high level.

Significance at the senior high school and nonsignificance at the junior high level may be due to the difference in subject matter taught and the population of students (ability, motivation, attitude) between the two levels.

Table 5: Planned Orthogonal Contrasts for Significant NSF Participation Factors

Achievement Subject	Contrast	$MS_{\hat{\psi}}$	df	F[1]	P
Senior High Science	1	74.43	1,172	5.14	<.01[2]
	2	74.95	1,172	5.18	<.01
Senior High Mathematics	1	137.53	1,105	6.85	<.01
	2	12.48	1,105	.62	<.5

[1] MSe is referenced from Table 4.

[2] The actual value may be lower because of disproportionality and unequal cell variances; no research data are available on the robustness of Planned Orthogonal Contrasts for violations of assumptions.

Thus, the functions played by institutes may operate more effectively with the more select senior high school students who elect biology, chemistry, and physics. This group is not identical in composition with the junior high science students, all of whom must take science, generally.

An alternative explanation for the results may be a selection bias between those who attend and those who do not attend based upon motivation and attitude. These criteria were not used to select individuals for NSF institutes but may, in fact, operate through self-selection of teachers who apply. As with teacher achievement, however, little research data has shown conclusively that teacher attitude is a determinant for student achievement.

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