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ABSTRACT

This study, part of the Colorado Science Meta-Analysis Project, was designed to assess the effectiveness of teacher education programs on preservice and inservice teachers having as measured outcomes one or more variables associated with inquiry teaching. Inquiry teaching within the context of the study addresses teacher behaviors facilitating student acquisition of concepts, processes, and skills through active involvement with general inquiry strategies. Specific outcome criteria which appeared in the research reviewed for the analysis and judged as falling within the confines of this definition include: knowledge of science processes, inquiry instructional strategy, indirect verbal behavior, accepting interpersonal behaviors, increased wait-time questioning behavior, higher cognitive questioning behavior, and discovery instructional strategy. Sixty-eight studies, involving at least one of these outcomes associated with inquiry strategy, were selected for analysis. Relevant variables (114) were identified and coded according to: study form/design characteristics, teacher/teacher trainee characteristics, student characteristics, treatment characteristics, outcome characteristics, and effect size calculation characteristics. Because descriptive reporting of teacher and/or student characteristics which might affect outcome measures was sporadic and occurred with frequencies too low to support analysis, the analysis was divided into categories focusing on variables associated with: methodological aspects of studies, study treatments, and the variety of teacher education outcomes sought. (JN)

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by

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A META-ANALYSIS OF RESEARCH ON SCIENCE TEACHER EDUCATION PRACTICES ASSOCIATED WITH INQUIRY STRATEGY

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INTRODUCTION

This meta-analysis study was a part of the Colorado Science Meta-Analysis Project (Anderson, 1982) designed to provide a synthesis of research related to science education on a number of important questions related to the teaching and learning of science and the preparation of teachers of science.

One of the important science education concerns has been the effects of different preservice and inservice science teacher education approaches on teachers and, ultimately, the effects of teachers on their students. During the 1960's and 1970's several of the curriculum projects developed materials designed to be taught in an inquiry style that was investigative and student centered; inquiry skills were also desired outcomes of instruction. This study was designed to assess the effectiveness of teacher education programs on preservice and inservice teachers having as measured outcomes one or more variables associated with inquiry teaching.

Inquiry teaching within the context of this paper addresses those teacher behaviors that facilitate student acquisition of concepts, processes, and skills through active involvement with general inquiry strategies. It incorporates aspects of the investigative and discovery phases of science and affords opportunities for the students to test and refine concept meanings. Through this tyne of learning, and the acquisition and synthesis of scientific knowledge and processes, the ability to perform scientific inquiry becomes possible. A teacher equipped to engage in inquiry teaching would possess questioning skills that are divergent, have a knowledge of science processes and have the capacity to conduct student-centered inductive learning activities. Specific outcome criteria which appeared in the research reviewed for this analysis and judged as falling within the confines of this definition include the following: knowledge of science processes, inquiry instructional strategy, indirect verbal behavior, accepting interpersonal behaviors, increased wait-time questioning behavior, higher cognitive level questioning behavior, and discovery instructional strategy. This meta-analysis was limited to studies involving at least one of these outcomes associated with inquiry strategy.

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LITERATURE SEARCH AND SELECTION OF STUDIES

Because this meta-analysis was focused upon inquiry teaching, research dated between 1965 and 1980 was considered. This period parallels the implementation period for the modern science curriculum projects.

A second limitation was suggested by the work of Munby (1980). He concluded that "on the basis of this analysis there are grounds for viewing research on the affective outcomes of science education with misgiving, simply because there seems little to be said of the instruments as to enlist our confidence in their use." Furthermore, if we are attempting to change attitudes with an eye toward teacher practice, a review of research on changing the attitude of student teachers by Morrisey (1981) is relevant. He claimed that the lack of change in the teaching of elementary school science indicates something more than just immediate attitude change must be considered. Therefore, studies involving <u>only</u> affective outcomes were not included in this meta-analysis.

The literature search process began with disserations. Dissertations listed in the <u>Science Education Dissertation Bibliography</u> (1978) were identified.

Journal articles were identified applying the same criteria as for dissertations by scanning the table of contents of the <u>Journal of Research in Science Teaching</u> and <u>Science Education</u> for the years 1965 to 1980. Research from sources other than dissertations and journals was identified through a search of the three ERIC compilations of abstracts from <u>Resources in Education</u> (1966-1972, 1973-1975, 1976-1977) and <u>Resources in Education</u> for later years. In addition, <u>NARST Annual Reviews of Research</u> and <u>NARST Abstracts</u> for many years were reviewed to identify potential studies.

A number of studies identified were rejected for the following reasons: (1) data needed for the calculation of effect size were incomplete, (2) measured outcomes were only in the affective domain, (3) the native language of the subjects was other than English, (4) the study was produced prior to 1965, or (5) the outcome variables were not associated with inquiry teaching strategy.

SELECTION OF STUDIES, CODING OF VARIABLES, AND EFFECT SIZE CALCULATIONS

Sixty-eight studies were selected for analysis. Relevant variables were identified and coded according to the following six major categories: study form and design characteristics, teacher/teacher trainee characteristics, student characteristics, treatment characteristics, outcome characteristics, and effect size calculation characteristics. These categories and six variables for the management of the data deck resulted in the delineation of 114 variables.

Effect size calculations were performed using the most straight forward method possible with the data presented in each study. The most straight-forward method available and the one used in 64% of the effect size calculations involved standardization of the mean differences between treatment and control groups.

ANALYSIS OF DATA

The 68 studies were coded; these resulted in 177 effect size calculations. Outcomes were measured on teachers, on students, and on students about teachers. While many researchers advocate measuring teacher behavior by evaluating student performance, this practice occurred in a very small number of cases. One hundred and fifty-four effect sizes were outcomes measured on teachers, while only nineteen were outcomes measured on students and four were student measures about teachers. Because of the small sample size, no analysis of the effect sizes related to outcomes measured on teachers by students was performed.

While many science educators advocate measuring teacher performance by measuring student outcomes, this practice occurred infrequently in this collection of studies on science teacher education. The nineteen effect sizes related to outcomes measured on students produced a mean effect size of .44 and a standard deviation of .67 when broken down across all variables. The mean reliability of the measurement instruments was .82 with a standard deviation of .06. The outcome most frequently measured (47% of the cases) was the knowledge of science processes.

The one hundred and fifty-four effect sizes related to outcomes on teachers produced a mean effect size of .85 with a standard deviation of 1.30 when broken down across all variables. One effect size determination was considered a far outlier, having a value three time greater than the next closest effect size and being approximately ten standard deviations above the mean. If this value is discarded, the mean effect size across all variables becomes .77 with a standard deviation of .86.

The size of the teacher samples ranged from 9 to 299, with a mean of 60.4 and a standard deviation of 45.2. The number of teachers assigned to each treatment ranged from 5 to 129, with a mean of 26.8 and a standard deviation of 17.6. Test reliability was reported for 50 percent of the outcome measurement instruments, yielding a mean of .81 and a standard deviation of .09. Duration of treatment (with seven missing cases) ranged from less than a day to one year. The mean was 70.0 days with a standard deviation of 71.4.

Descriptive reporting of teacher and/or student characteristics which might affect outcome measures was sporadic and occurred with frequencies too low to support analysis. Therefore the analysis was divided into the following three major categories: (a) variables associated with methodological aspects of the studies, (b) variables associated with study treatments, and (c) variables associated with the variety of teacher education outcomes sought.

Teacher Outcomes - Methodological Variables

Table I presents the means, standard deviations, and sample sizes of selected methodological variables broken down across outcomes measured on teachers. Table II presents the Pearson correlation coefficients and significance level between selected methodological variables and between selected methodological variables and effect size. In situations where the variable categories did not reflect an ordinal relationship the categories were coded dichotomously for correlational purposes.

Table I presents nine methodological variables with the categories that had sufficient sample size to warrant discussion. The form of publication variable indicates that the source of the information used for coding purposes. An attempt was made to locate the primary source whenever possible and if a study was presented as both a journal article and a dissertation, the dissertation was used as the source. The mean effect size calculated from journal articles was 1.01 while those calculated from dissertations was .59. There was significant positive correlation ($p=0.0004$) between journals as a source and effect size and a significant negative correlation ($p=0.05$) between dissertations as a source and effect size. These results indicate that a meta-analysis based solely on journals as a source has the potential of establishing effect size data higher than what might be expected if the extensive dissertation literature were used also.

The type of study variable was coded using the guidelines established by Campbell and Stanley (1963). Pre-experimental designs consisted of one-group pretest-posttest designs and static-groups comparison designs. Experimental designs involved pretest-posttest control groups designs and posttest-only control group designs with random assignment of subjects to treatment and control groups. Quasi-experimental designs involved the same designs as the experimental groups, but without random assignment of subjects. The mean effect size ranged from .90 for pre-experimental to .67 for experimental studies. The correlation coefficient was not significant at the .05 level.

The assignment of teachers to treatments was coded as random, matched, self-selected, intact groups, representative sample, and other. Random assignment and intact group assignment together accounted for 76% of the effect sizes produced. Random assignment studies had an average effect size of .67 and intact groups produced an effect size mean of .88.

The teacher unit of analysis variable indicated the unit (individual or group) that was used in establishing the degrees of freedom for the determination of significance level. The teacher unit of analysis used the number of individuals involved to determine degrees of freedom in 95% of the cases.

Table I
Teacher Outcome Effect Sizes
Across Study Methodological Variables

Variable	Mean Effect Size	Standard Deviation	N
Form of publication			
Journal	1.01	.98	61
Dissertation	.59	.77	85
Other	.75	.24	7
Type of study			
Pre-experimental	.90	.73	22
Quasi-experimental	.78	.83	69
Experimental	.67	.92	60
Assignment of teachers to treatments			
Random	.67	.91	61
Self-selected	.57	.78	17
Intact groups	.88	.86	56
Teacher unit of analysis			
Individual	.77	.88	145
Classroom or group	.75	1.00	4
Rated internal validity			
Low	.55	.55	25
Medium	.75	.82	55
High	.82	.98	68
Design Rating			
Low	.57	.80	41
Medium	.68	.61	38
High	.92	.99	72
Outcome instrument type			
Published, national stand.	.35	.58	16
Ad hoc, for that study	1.12	.94	59
Other	.60	.76	77
Measurement method			
Multiple choice	.48	.61	31
Likert	.50	.44	24
Observation	.84	.93	49
Other	1.14	1.07	35
Time of measurement			
After treatment	.62	.76	60
Pre-post	.90	.96	80
Other	.74	.59	9

Table II

Correlations Among Selected Methodological Variables and Between Methodological Variables and Effect Size

Variable A	Variable B	r	p	N
Form of pub. journal	effect size	0.23	0.004	61
Form of pub. journal	extent of treat	0.21	0.008	61
Form of pub. journal	# of teachers assigned	-0.04	0.634	61
Form of pub. journal	# of teachers analyzed	-0.00	0.959	61
Form of pub. journal	reported sig.	-0.22	0.010	61
Type of study	effect size	-0.09	0.248	151
Rated internal validity	effect size	0.10	0.214	148
Design rating	effect size	0.17	0.035	151
Outcome instrument, pub. national standardized	effect size	-0.17	0.039	16
Outcome instrument. ad hoc	effect size	0.32	0.000	59
Outcome instru. other	effect size	-0.20	0.012	77
Measurement method multiple choice	effect size	-0.17	0.039	31
Measurement method other	effect size	0.24	0.003	35
# of teachers assigned	effect size	-0.21	0.011	152
# of teachers analyzed	effect size	-0.17	0.031	153
# of teachers on outcome measure	effect size	-0.17	0.035	149

An internal validity variable addressed the assignment of individuals to treatments, and the percent mortality among treatment and control groups. Studies were rated high in internal validity if group equivalence was established through random assignment or other procedures and subject mortality was less than 15 percent. Studies were coded as medium if (a) randomization was not used but low mortality was maintained, (b) randomization existed but mortality was high or nonequivalent, and (c) if random procedures were used in the selection of intact groups and mortality was low. Studies were coded as low where intact convenience samples were used and/or where the existence of factors confounding the equivalence of the subject groups was apparent. Studies rated low in validity produced effect sizes with a mean of .55, medium validity studies produced effect sizes with a mean of .75, and high validity studies produced effect sizes with a mean of .82. The internal validity was positively correlated with effect size, but was not significant at the .05 level.

The design rating variable addressed the apparent degree of control of the confounding variables by the experimental procedure. Studies were rated as high if the design established control to the extent that post-treatment differences could be attributed to treatment effects. The study was rated as medium if the design indicated lack of control of a variable that probably contributed to some outcome differences. The study was rated as low if the failure to control a given variable obviously contributed to outcome differences. Studies with a low design rating had an average effect size of .80, medium studies had an average effect size of .61, and high studies had an average effect size of .99. A positive correlation coefficient with a significance level of .035 indicated that larger effect sizes were associated with higher design ratings.

A variable, outcome instrument type, included instruments categorized as (a) published, (b) ad hoc developed for that particular study, or (c) other. Most of the tests in the "other" category were developed ad hoc for another study and then used in existing form or with modifications for the study being coded. The effect sizes that resulted from ad hoc instruments produced a mean effect size of 1.12. Other instruments produced an effect size of .60 and published instruments a mean of .35. The ad hoc instruments had a significant positive correlation with effect size ($p > 0.001$) and the published and other categories had a significant negative correlation with effect size ($p > .05$). While these notable higher effect sizes for the specially designed instruments could be due to investigator bias, it seems more likely the result of the instruments being better designed to detect outcome differences to which the given study is directed.

Measurement method categories produced the following results for mean effect size: multiple choice .48, Likert .50, observation .84, and other 1.14. Multiple choice methods correlated negatively with effect size with a significance of .039. The "other" category correlated positively with effect size with a significance of .003. The remaining categories did not correlate significantly at the .05 level.

The time of measurement variable included the following categories: (a) after treatment, (b) pre-post, and (c) other. The latter category was used when different instruments on the same outcome were averaged to determine one effect size. The pre-post measurement produced the largest mean effect size, .90. The "other" category had a mean effect size of .74 and the after treatment category .62.

The number of teachers assigned to the study, the total number analyzed, and the number measured on each outcome instrument correlate negatively with effect size (significant at level of $p > .05$). The journal category of the form of publication variable did not correlate significantly at the .05 level with any of the variables related to sample size, but the journal category did correlate significantly with the reported significance variable and the extent of treatment variable. The extent of treatment variable addressed the scope of the treatment with a multi-grade treatment, a program, or an on-going institute being at the broad end of the scale and a specific training technique being at the narrow end of the scale. These correlations indicated that studies taken from journals had low values for p and that these studies addressed treatment types of narrow scope.

Table III presents the average effect size, standard deviations and correlation coefficients for two of the variables related to effect size calculations: (a) source of means i.e., unadjusted posttest, pre-post difference or other and (b) method for calculation. Means for the calculation of effect size were unadjusted post-test means in 83 cases and provided a mean effect size of .62 with a standard deviation of .74. Means were a result of pre-post differences in 47 cases with a mean effect size of 1.00 and a standard deviation of 1.09. The "other" category involved pre-experimental studies wherein pre-test data were used to generate a control group mean. This category provided a mean effect size of .88 and a standard deviation of .75. The unadjusted post-test source of means had a negative correlation with effect size significant at the .05 level. The source of means in the pre-post category had a positive correlation with effect size significant at the .05 level also.

The methods used for calculating the effect size included the following: (a) calculating directly from reported means and variances or from raw data, (b) calculating with direct estimates of the variance from ANOVA, t, and F values, (c) calculating using reported probability levels, and (d) calculating using pre-test data as a control group. Using pre-test data as a control group produced the highest mean effect size, 1.01 with a standard deviation of .78. The means and standard deviations for using directly reported means and variances and direct estimates were close, having mean effect values of .72 and .84 respectively. None of the calculation method variables showed a significant correlation with effect size at the .05 level.

Table III

Teacher Outcome Effect Sizes Across Effect Size Calculation Variables

Variable	Mean Effect Size	Standard Deviation	N
Source of means unadjusted post-test	.62	.74	83
Source of means pre-post differences	1.00	1.09	47
Source of means other	.88	.75	19
Calculated directly from reported values or raw data	.72	.90	96
Calculated with direct estimates (ANOVA, t, F)	.84	.87	34
Calcuated from reported probability levels	.71	.15	5
Calculated using pre-test data as a control group	1.02	.78	15

Correlation with Effect Size

Variable	r	p	N
Source of means unadjusted post-test	-0.1865	0.021	83
Source of means pre-post dif.	0.1745	0.031	19
Calculated directly from reported values or raw data	-0.0694	0.394	96
Calculated with direct estimates (ANOVA, t, F)	0.0420	0.606	34
Calculated from reported probability levels	-0.0131	0.872	5
Calculated using pre-test data as a control group	0.0948	0.244	15

Summary

Many methodological variables were correlated with effect sizes. Nearly all the results of the correlations agree with the general findings of the other meta analysis studies when these variables were analyzed (Anderson, 1982). Methodological variables correlating positively with effect size at the .05 level (or higher) of significance were (1) studies published in journals, (2) better research designs, (3) the use of specially designed instruments (rather than standardized, nationally used instruments), and (4) studies involving smaller numbers of teachers. High internal validity correlated positively but was not significant at the .05 level.

These results indicate that the design of the study, the sample size (or the intensity of the instruction), and the appropriateness of the instrument for the outcomes being measured all relate to the level of the effect sizes in a significant way. The relationships found in this meta-analysis and in other meta-analysis studies provide guidance for designing effective instruction. Some cautions are suggested in interpreting non-significant results in research that have not considered these relationships; the non-significant finding may not be due to the instruction, but rather to the problem of sample size (or intensity of instruction) and inappropriate instruments. Careful analysis of non-significant studies may provide clues for studies that might give significant results with better instrumentation and more attention to sample size and intensity of instruction.

The correlations of sample size to effect size help to explain why some effective research results are hard to implement effectively with larger samples of teachers. Providing adequate instruction, getting teachers to follow guidelines, and providing feedback for a large sample is much more difficult than working with a small sample.

The significant correlation of journal articles with effect size presents a caution to people doing secondary analysis of research. The primary literature usually contains more non-significant studies and studies with smaller effect sizes. While these additional studies from the primary literature may not change the conclusions in all meta-analysis studies, the differences encountered in some studies such as this one indicate that there is a good possibility that different conclusions might result without the use of primary literature data.

Teacher Outcomes - Treatment Variables

Tables IV and V present the effect sizes of teacher outcomes broken down across various treatment variables. Table VI presents correlations between treatment variables and effect size. The first of these variables, time of treatment, was categorized as pre-service and in-service. These two groups produced mean effect sizes of .78 and .72 respectively.

Table IV

Teacher Outcome Effect Sizes
Across Treatment Variables (Part I)

Variable	Mean Effect Size	Standard Deviation	N
Time of treatment			
Pre-service	.78	.90	122
In-service	.72	.74	31
Site of treatment			
Field-based, site of employment	.74	.86	5
Field-based, not the site of employment	.77	.60	20
University-based	.77	.88	112
Extent of treatment			
Multi-grade or level, e.g., program or ongoing institute	.45	.45	12
One grade level, e.g., course or workshop	.75	.78	69
Training technique	.84	.98	72
Treatment geared to grade level			
Elementary school	.76	.86	123
Secondary	.39	.32	8
General	1.24	.97	15
Number of variables used to describe each treatment			
1	.67	.57	42
2	.65	.89	64
3	.73	.62	31
4	1.25	1.03	14

The site of treatment variable categorized field-based treatments versus university based treatments. The field-based treatments category was further divided into treatments that ocurred in the schools in which the teachers were employed versus treatments in schools where the individuals were not employed. Treatments were predominately university-based, accounting for 77% of the reported effect sizes. The mean effect sizes for the three groups were very close in value ranging from .74 to .77.

The extent of treatment variable ranged from a broad scope addressing multi-grade or program treatments to treatments that focused on a particular training technique. The multi-grade or program level produced a mean effect size of .45, the one grade or level variable produced a mean effect size of .75, and the training technique level produced a mean effect size of .84.

The "treatment geared to grade level" variable categorized the target population where the treatment outcomes were to be applied. The elementary level group accounted for 81% of the effect sizes coded and produced a mean effect size of .76 with a standard deviation of .86. Those treatments categorized as secondary had a mean effect size of .39 and those categorized as general had a value of 1.24.

In many instances more than one treatment variable was used to classify a treatment. Those treatments that were described using one variable produced a mean effect size of .67; two variables, .89; three variables, .73; and four variables, 1.25. A positive correlation between this variable and effect size occurred at a probability level $p > .001$.

Of the many treatment variables, those designated here as "treatment type" are of particular interest. The data on these variables is found in Table V; this Table, in contrast to the previous Tables, includes all variables regardless of the number of effect sizes recorded.

Treatment type variables were divided into the following sections: organizational pattern, type of instruction, mode of instruction, source of structure, locus of control, training techniques and technology employed. The first of these categories refers to the form of organizational pattern within which the instruction was offered. The next five all refer to the type of instruction offered.

Some treatments were categorized in terms of the treatment organizational pattern and included the following: field-based programs, workshops, methods courses, science courses designed for teachers, and units of study. Those variables with an N of more than three included the field-based program category with a mean effect size of .35, the workshop level at .73, methods courses at .79, science courses designed for teachers at .97, and specific units of study at 1.38. The type of instruction category pertains to the instructional approach used in the teacher education activities. If the treatment involved instruction versus no instruction with no further delineation of approach, it was categorized as general. Other approaches

Table V

Teacher Outcome Effect Sizes Across Treatment Variable (Part II)

Treatment Type			s	n
Organizational Pattern	Field-based Program	.35	.40	8
	Ongoing Institute	.64	.48	2
	Summer Institute	.14	.09	3
	Workshop	.73	.75	16
	Methods Course	.79	.94	22
	Science Course	1.28	.48	2
	Science Course Designed for Teachers	.97	.70	9
	Units of Study	1.38	1.29	22
Type of Instruction	General	.79	1.21	35
	Traditional	.30	.32	5
	Inquiry	.63	.63	9
	Discovery	.40	.29	7
Mode of Instruction	Verbal	-.03	.18	2
	Mixed	.45	.86	12
	Concrete	.75	.75	20
Source of Structure	Student Self-Directed	.04	.46	8
	Student Interacting with Teacher and/or Materials	.70	1.01	8
	Teacher	--	--	0
	Criterion referenced	.69	.02	2
Locus of Control	Student self-directed	.82	.88	44
	Teacher directed	1.44	0	1
	Mix, part student, part teacher	---	---	0
Training Technique	Interaction Analysis Feedback	1.33	0	1
	Instructional Strategy Feedback	.67	.91	10
	Wait-Time Analysis	3.95	.07	2
	Questioning Analysis	1.38	1.65	8
	Micro-teaching Peers	.72	.35	4
	Micro-teaching Students	.81	.52	6
	Modeling Strategy	1.56	1.19	14
	Behavior Coding Training (e.g. IA) or Strategy Analysis	1.37	.87	8
Technology Employed	Audio Technology	1.04	.25	4
	Video Technology	1.82	1.44	9
	Programmed Material (Audio-Tutorial)	.99	.76	17
	Print Material	1.40	0	1

Table VI

Correlations between Selected Treatment Variables and Effect Size

Variable	r	p	N
# of variables describing treatment	0.3123	0.000	153
treatment units of study	0.2884	0.000	22
source of structure student self-directed	-0.2003	0.013	8
questioning analysis	0.1664	0.040	8
modeling strategy	0.2928	0.000	14
behavior coding training or strategy analysis	0.1637	0.043	8
video technology	0.3039	0.000	9
outcome science processes	0.1871	0.021	33
outcome questions process directed	0.1962	0.015	9

Table VII

Teacher Outcome Effect Sizes by Type of Outcome

Type of Outcome			s	n
Knowledge and Intellectual Processes	Science Content	.52	.79	7
	Science Processes	1.08	1.03	33
	Methods of Science and the Scientific Enterprise	.14	.74	3
	Critical Thinking	.09	0	1
	Creativity	.19	0	1
	Problem Solving	.04	.23	5
	Behavioral Objectives	.75	.14	3
	Planning (organizational skill)	.90	.12	2
	Composite Knowledge and Intellect	.80		55
Teacher Classroom Behavior	Verbal Behavior, General	.15	0	1
	Inquiry Strategy	.89	.47	4
	Concrete Manipulative Strategy	1.26	0	1
	Indirect Verbal Behavior	.72	.82	18
	Interpersonal Behaviors	.54	.26	5
	Questioning-level	.72	1.18	13
	Discovery Strategy (Student Centered, Open)	.70	.53	7
	Group Process Skills	.26	0	1
	Question - Process Directed	1.45	.60	9
	Reactions to Classroom Situations	.84	0	1
	Composite Teacher Classroom Behaviors	.82		60
Affective	Attitude (general)	.79	.56	6
	Attitude toward Science	.39	.29	10
	Attitude toward Science Teaching	.09	.21	4
	Attitude toward Treatment	.46	0	1
	Dogmatism (toward open)	.34	.34	5
	Philosophy of Teaching (toward student centered)	.72	.65	4
	Attitude toward Treatment Emphasis	.60	0	1
	Composite Affective	.47		31

were termed traditional, inquiry, and discovery. The classification as inquiry or discovery was made from the language used in the study coded even though the terms were considered as synonymous in this report. The general instructional category produced a mean effect size of .79, traditional instruction had an effect size of .30, the inquiry category had a mean effect size of .63, and the discovery approach had an N of .40.

The mode of instruction categorized the approaches as predominately verbal, predominately concrete, indicating a high level of student involvement with manipulative exercises; or mixed, involving both the verbal and the concrete. Little data were found in the verbal category but the concrete mode produced a mean effect size of .75 and the mixed mode produced a mean effect size of .44.

The source of structure concept addressed the source of instructional objectives, content, and/or method used in the treatment. The categories included student self-directed, student interacting with materials/and or the teacher, the teacher as the source of structure, and criterion referenced sources. The source of structure involving student self-direction produced a very low average effect size, .04. The structure that involved interaction of the student with materials and/or the teacher produced a mean effect size of .70. A similar effect size (.69) was found for "criterion referenced," although this result is based on only two studies.

The locus of control concept addressed the approach used in meeting the objectives, etc., set forth in the structure component. The categories included student self-directed, student and teacher working together, teacher directed, and a mix of part student and part teacher directed. The student self-directed category produced a mean effect size of .81, based on 44 effect sizes. Though a higher value is reported for "teacher directed," it is based on only one study.

The training technique concept addressed educational practices usually employed within the confines of a course or workshop. This concept included the following categories: interaction analysis feedback, instructional strategy feedback, wait-time analysis, questioning analysis, micro-teaching peers, micro-teaching students, modeling strategy, and behavior coding training or strategy analysis. Instructional strategy feedback produced a mean effect size of .67; modeling strategy, 1.56; micro-teaching peers, .72; micro-teaching students, .81; behavior coding training analysis, 1.37; and questioning analysis, 1.38.

The technology concept addressed the use of audio technology, video technology, programmed material or auto-tutorial methods as treatment variables. Treatments using audio technology had a mean effect size of .99.

Summary

The data analyzed in this study tend to agree with other meta-analysis studies (Anderson, 1982) and other reviews of research (Helgeson, Blosser, and Howe, 1977). Higher effect sizes were generally obtained with (1) more specific instruction, (2) instruction that involved a substantial amount of concrete experience, and (3) instruction involving elementary school teachers.

Positive gains were made by groups in both preservice and inservice instruction, and using a variety of techniques.

These results suggest that some alternatives to more traditional instruction should be explored. They may produce equal or better gains and save resources. Studies that involved analysis of instruction (modeling, behavior analysis, and questioning analysis) tended to have the highest effect sizes. Work with elementary teachers showed substantial gains, suggesting that they probably had few inquiry skills and gained from the instruction provided.

Teacher Outcomes - by Outcome Category

Outcome criteria were classified into the following three categories: criteria related to knowledge and intellectual processes, criteria related to classroom teacher behaviors, and criteria related to affective outcomes. Information on teacher outcome effect sizes by type of outcome is found in Table VII.

In the knowledge and intellectual processes category, knowledge of science processes was by far the most commonly measured. It was measured in 33 cases and produced a mean effect size of 1.08. Other outcome variables were measured much less frequently, as shown in Table VII. The knowledge and intellectual processes category, overall, produced an average effect size of .80 based on 55 effect sizes.

The measurement of outcome variables in the teacher classroom behavior category was more varied with six different variables being measured in four or more studies. The variable inquiry strategy had a mean effect size of .89; indirect verbal behavior, .72; interpersonal behaviors, .54; questioning-level, .72; discovery strategy, .70; and questions (process directed), 1.45. The teacher classroom behavior category overall produced a mean effect size of .82 based on 60 effect sizes.

A variety of affective measures was used in these teacher education studies including measures of attitudes toward science, science teaching, and several others. The average effect size in these categories varied from .09 to .79, with a mean overall effect size for the affective category of .47 based on 31 effect sizes.

Summary

Teaching science processes appeared to be a realistic goal, effectively taught in many studies. The mean of effect size, 1.08, was the highest mean in the knowledge and intellectual processes category. While some other variables had mean effect sizes from .5 to .90, a few studies (particularly problem solving) had low effect sizes.

Teacher classroom behavior appeared to be effective in many studies. Nearly all the skills and processes that were taught had mean effect sizes of .5 to over 1.0. Questioning skills and other verbal skills had mean effect sizes from .7 to 1.45.

Affective variables appeared to be more difficult to teach or to gain large effect sizes. Most means ranged from about .34 to .7.

These results are very similar to the conclusions of the review of research by Balzer, Evans, and Blosser (1973). Cognitive (low level) and skill outcomes are usually easiest to teach. Complex behaviors and affective outcomes are usually harder to teach. The data indicate that many treatments were able to achieve respectable effect sizes emphasizing a variety of learning outcomes. Instruction with groups involving fewer students were usually more effective than for groups with larger numbers of students.

Bibliography I

CODED STUDIES
ALPHABETICAL BY AUTHOR

Almase, A. G. "Modification of Teacher Behavior Through an Inservice Biology Methods Course." Unpublished doctoral dissertation, Michigan State University, 1973.

Anderson, Ronald D., and Jerry G. Horn. "Evaluation of the Colorado Elementary Science Project." Colorado University, Boulder, March 7, 1970.

Bedwell, Lance Eugene. "The Effect of Training Teachers in Question-Asking Skills on the Achievement and Attitudes of Elementary Pupils." Unpublished doctoral dissertation, Indiana University, 1974.

Berkland, Terrill Raymond. "An Investigation of the Understanding of Science Processes and Attitudes Toward Science of Prospective Elementary Teachers From an Unstructured Science Foundations Course and Non-Science Students from a Structured Earth Science Course." Unpublished doctoral dissertation, University of Iowa, 1973.

Bluhm, William J. "The Effects of Science Process Skill Instruction on Preservice Elementary Teachers' Knowledge of, Ability to Use, and Ability to Sequence Science Process Skills," Journal of Research in Science Teaching, 16(5): 427-432, 1979.

Bowman, Harold Eugene. "The Effect of Alternative Technique for Modifying Student Teacher Behavior During the Field Experience." Unpublished doctoral dissertation, University of Pittsburgh, 1972.

Bozardt, Delphine Anita. "Development of Systematic Questioning Skills in an Elementary Science Methods Course." Unpublished doctoral dissertation, University of Georgia, 1974.

Breit, Frank and David P. Butts. "A Comparison of the Effectiveness of an Inservice Program and a Preservice Program in Developing Certain Teaching Competencies." Science Education Center, University of Texas, Austin; University of South Florida, Tampa, February, 1969. ED 028 069.

Bridges, C., et al. "Evaluation of the Cooperative College-School Science Improvement Program to Prepare Teachers to Teach the DISCUS Program," Science Education, 57(2): 193-199, 1973.

Brown, William R. "Checklist for Assessment of Science Teachers and Its Use in a Science Preservice Teacher Education Project," Journal of Research in Science Teaching, 10(3): 243-249, 1973.

Brown, William R. "The Effect of Process-Skill Instruction on Performance of Preservice Elementary Teachers," Journal of Research in Science Teaching, 14(1): 83-87, 1977.

Caldwell, Harrie Eugene. "Evaluation of an Inservice Science Methods Course by Systematic Observation of Classroom Activities." Unpublished doctoral dissertation, Syracuse University, 1968.

Campbell, Richard Louis. "The Effects of Instruction in the Basic Science Process Skills on Attitudes, Knowledge and Lesson Planning Practice of Prospective Elementary School Teachers." Unpublished doctoral dissertation, Indiana University, 1973.

Campbell, Richard L. and James R. Okey. "Influencing the Planning of Teachers with Instruction in Science Process Skills," Journal of Research in Science Teaching, 14(3): 231-234, 1977.

Coffey, Warren Chester. "Change in Teachers' Verbal Classroom Behavior Resulting from an Inservice Program in Science Education." Unpublished doctoral dissertation, University of California Berkeley, 1967.

Damewood, Judith Carter. "Evaluation of a Physical Science Course for Prospective Elementary Teachers in Terms of Competence Attained in the Processes of Science." Unpublished doctoral dissertation, Auburn University, 1971.

Eaton, David. "An Investigation of the Effects of an Inservice Workshop Designed to Implement the Science Curriculum Improvement Study Upon Selected Teacher-Pupil Behaviors and Perception." Unpublished doctoral dissertation, West Virginia University, 1974.

Fitzgerald, Russell Guy., Jr. "The Effect of Video Taped Modeling Procedures on the Verbal Behaviors of Student Teachers." Unpublished doctoral dissertation, West Virginia University, 1970.

Gabel, Dorothy L., Peter A. Rubba, and Judy R. Franz. "The Effect of Early Teaching and Training Experience on Physics Achievement, Attitude Toward Science and Science Teaching, and Process Skill Proficiency," Science Education, 61(4): 503-511, 1977.

Glenzer, John Alfred. "A Study to Determine the Effects of Exposure to the American Association for the Advancement of Science, Commission on Science Education, Developed Process Sessions on the Teaching Behaviors of Preservice Elementary Teachers." Unpublished doctoral dissertation, State University of New York at Buffalo, 1972.

Grabes, Mary. "A Comparison of Two Methods of Teaching an Elementary School Science Methods Course at Hunter College." Unpublished doctoral dissertation, New York University, 1971.

Gruber, Ellen Joan. "The Effects of a Course in Basic Science Processes on Attitudes and Creative Behavior of Teachers." Unpublished doctoral dissertation, Georgia State University, 1974.

Harris, William N., et al. "Effectiveness of Micro-Teaching Experiences in Elementary Science Methods Classes," Journal of Research in Science Teaching, 7(1): 31-33, 1970.

Horak, Willis J., and Kuita Slobodzian. "Influence of Instructional Structure and Locus of Control on Achievement of Preservice Elementary Science Teachers," Journal of Research in Science Teaching, 17(3): 213-222, 1980.

Jacobs, Joseph H. "An Investigation of Structured Observation Experiences as a Self-Improvement Technique for Modifying Teacher's Verbal Behaviors." Unpublished doctoral dissertation, New York University, 1971.

Jaus, Harold H. "The Effects of Integrated Science Process Skill Instruction on Changing Teacher Achievement and Planning Practices," Journal of Research in Science Teaching, 12(4): 439-447, 1975.

Jaus, Harold H. "Using Microteaching to Change Elementary Teachers' Attitudes Toward Science Instruction," School Science and Mathematics, 77(5): 402-406, 1977.

Kelsey, Kenneth W. "Performance Criteria and Operant Methods: An Analysis of Effects on Cognitive and Reinforcing Behaviors of Student Teachers," Science Education, 61(2): 201-208, 1977.

Konetski, Louis G. "Instructional Effect on Questions Asked by Preservice Science Teachers." Unpublished doctoral dissertation, Indiana University, 1969.

Koran, John J., Jr. "The Relative Effects of Classroom Instruction and Sebsequent Observational Learning on the Acquisition of Questioning Behavior by Pre-Service Elementary Science Teachers," Journal of Research in Science Teaching, 6(3): 217-223, 1969.

Koran, John J., Jr. "A Study of the Effects of Written and Film-Mediated Models on the Acquisition of a Science Teaching Skill by Preservice Elementary Teachers," Journal of Research in Science Teaching, 8(1): 45-50, 1971.

Lindberg, Normalee Harrington. "A Study of an Inservice Course in Science Education Methods for Elementary Teachers." Unpublished doctoral dissertation, University of Missouri, Columbia, 1969.

Larson, James Holmes. "A Study of the Effectiveness of a Science Methods Course in Increasing Science Knowledge and the Development of Selected Skills and Abilities of Prospective Elementary Teachers." Unpublished doctoral dissertation, University of Wisconsin, 1969.

Lavach, John F. "Organization and Evaluation of an Inservice Program in the History of Science," Journal of Research in Science Teaching, 6(2): 166-170, 1969.

Lucy, Edward Christopher. "An Evaluation of a Laboratory Science Program in a Professional Education Course for Prospective Secondary Science Teachers at The Ohio State University." Unpublished doctoral dissertation, The Ohio State University, 1972.

McCormick, Florence Rieger. "The Outdoor Laboratory: Inservice Education in the Processes of Science." Unpublished doctoral dissertation, University of Arkansas, 1967.

McElhattan, Glenn Richard. "Development and Evaluation of an Auto-Instructional Individualized College Physical Science Course for Prospective Elementary School Teachers." Unpublished doctoral dissertation, University of Pittsburgh, 1973.

McLeod, Richard J. "Changes in the Verbal Interaction Patterns of Secondary Science Student Teachers Who Have Had Training in Interaction Analysis and the Relationship of these Changes to the Verbal Interaction of Their Cooperating Teachers." Unpublished doctoral dissertation, Cornell University, 1966.

Macklem, Roger E. "The Effects of a Specific Teacher Inservice Program in BSCS Biology Upon Teacher and Student Verbal Behaviors and Selected Student Learning Outcomes." Unpublished doctoral dissertation, University of Nebraska, 1973.

Markle, Glenn, and William Capie. "Assessing a Competency-Based Physics Course: A Model for Evaluating Science Courses Servicing Elementary Teachers," Journal of Research in Science Teaching, 14(2): 151-156, 1977.

Menzel, Ervin Wesley. "A Study of Preservice Elementary Teacher Education in Two Processes of Science." Unpublished doctoral dissertation, Temple University, 1968.

Merkle, Dale Gordon, Sr. "A Leadership Workshop in Elementary School Science: An In-Depth Evaluation." Unpublished doctoral dissertation, Michigan State University, 1969.

Miller, Robert Joseph. "An Investigation of the Cognitive and Affective Verbal Behavior of Selected Groups of Physical Science Teachers." Unpublished doctoral dissertation, University of Texas Austin, 1970.

Mitchell, Charles William. "An Investigation of the Effects of Three Different Instructional Strategies of Teaching Science Methods on Selected Attitudes and Perceptions of Prospective Elementary School Teachers and Science Skills and Knowledge of Their Respective Children." Unpublished doctoral dissertation, West Virginia University, 1972.

Oberlin, Lynn and Lowell B. Sanders. "A Comparison of the Science Content Knowledge of Graduates from Florida's New Elementary Program and Graduates who had Their Science Education in a Traditional Course," Science Education, 57(3): 331-334, 1973.

Ochs, Vincent Daniel. "Evaluation of BSCS Inservice Training of Secondary Teachers of Biology Through Analysis of Classroom Verbal Behavior and the Relationship of Selected Teacher Factors to Observed Verbal Behaviors." Unpublished doctoral dissertation, University of Virginia, 1971.

Perkes, V. A. "Preparing Prospective Teachers of Elementary Science: An Appraisal Between Prescriptive Involvement of Teaching Behavior," Science Education, 55(3): 295-299, 1971.

Pinkall, Joseph E. "A Study of the Effects of a Teacher Inservice Education Program on Fifth and Sixth Grade Teachers and the Students Whom They Teach in Their Knowledge of Scientific Processes, Scientific Content and Attitude Toward Science and Scientists." Unpublished doctoral dissertation, University of Nebraska, 1973.

Pisano, Dorothy Palermo. "The Effects of Supervisory Feedback on Behavior and Attitudes in the Micro-teaching of Elementary School Science." Unpublished doctoral dissertation, Temple University, 1974.

Ponzio, Richard Carl. "Evaluation of an Auto-Tutorial Criterion-Referenced Science Eduation Program for Preservice Elementary Teachers." Unpublished doctoral dissertation, University of California Berkeley, 1974.

Rice, Dale R. "The Effect of Question-Asking Instruction in Preservice Elementary Science Teachers," Journal of Research in Science Teaching, 14(4): 353-359, 1977.

Riley, Joseph P., II. "A Comparison of Three Methods Improving Preservice Science Teachers Questioning Knowledge and Attitudes Toward Questioning," Journal of Research in Science Teaching, 17(5): 419-424, 1980.

Riley, Joseph P., II. "The Effects of Studying a Question Classification System on the Cognitive Level of Preservice Teachers' Questions," Science Education, 62(3): 333-338, 1978.

Romero, Frank S. "The Effects of Auto-Tutorial Science Process Instruction on Teacher Achievement and Its Relation to Specific Undergraduate Majors," Journal of Research in Science Teaching, 14(4): 305-309, 1977.

Santiesteban, A. Joseph and John J. Koran, Jr. "Acquisition of Science Teaching Skills Through Psychological Modeling and Concomitant Student Learning," Journal of Research in Science Teaching, 14(3): 199-207, 1977.

Santiesteban, A. Joseph. "The Relative Effects of Video and Audio Models on the Acquisition of a Teaching Skill by Preservice Elementary Teachers and Concomitant Student Learning." Unpublished doctoral dissertation, University of Florida, 1974.

Siemankowsi, Francis T. "An Auto-Paced Teaching Process in Physical Science for Elementary Teacher Preparation: A Pilot Report," Journal of Research in Science Teaching, 6(2): 150-156, 1969.

Siemro, Donnal Louise. "An Investigation of Two Approaches for Education in Science of Preservice Elementary School Teachers." Unpublished doctoral dissertation, University of Iowa, 1974.

Simmons, Herbert Nelson. "An Evaluation of Attitudinal Changes in Teaching Behavior of Elementary Teachers Enrolled in Eleven SCIS Workshops Directed by Leadership Teams Trained in a SCIS Leader's Workshop." Unpublished doctoral dissertation, University of Kansas, 1973.

Sparks, Rebecca L., and Earl L. McCallon. "Fostering Indirect Teaching Behavior in an Elementary Science Methods Course," School Science and Mathematics, 71(5): 381-383, 1971.

Strawitz, Barbara Marie. "The Development and Evaluation of a Verbal Interaction System Designed to Modify the Verbal Behavior of Secondary Science Student Teachers." Unpublished doctoral dissertation, University of Texas Austin, 1970.

Sunal, Dennis W. "Effect of Field Experience During Elementary Methods Courses on Preservice Teacher Behavior," Journal of Research in Science Teaching, 17(1): 17-23, 1980.

Sweeney, Margaret Wilson. "The Effects of Two Organizational Patterns of Microsimulated Teaching Experiences on the Verbal Behavior of Student Teachers Trained and Not Trained in Interaction Analysis." Unpublished doctoral dissertation, West Virginia University, 1968.

Symington, David J. "Improving the Ability of Student Elementary Teachers to Propose Investigable Scientific Problems," Journal of Research in Science Teaching, 16(5): 453-457, 1979.

Wideen, Marvin F., and Richard L. Butt. "Student and Instructor Directed Approaches to Elementary Science Education: A Comparative Analysis," Journal of Research in Science Teaching, 12(2): 95-100, 1975.

Yeany, Russell Jr. "The Effects of Model Viewing with Systematic Strategy Analysis on the Science Teaching Styles of Preservice Teachers," Journal of Research in Science Teaching, 14(3): 209-222, 1977.

Yeany, Russell Jr. "Effects of Microteaching with Videotaping and Strategy Analysis on the Teaching Strategies of Preservice Science Teachers," Science Education, 62(2): 203-207, 1978.

Bibliography II

GENERAL REFERENCES*

Anderson, R. D. "A Consolidation and Appraisal of Science Education Meta-Analyses." Journal of Research in Science Teaching. In press.

Anderson, R. D. "Science Education: A Meta-Analysis of Major Questions." Journal of Research in Science Teaching. In press.

Anderson, R. D., S. Kohl, M. L. Smith, and G. V. Glass. Science Meta-Analysis: Final Report of NSF Project No. SED 80-12310, Volume I and II. Boulder, Colorado: Laboratory for Research in Science and Mathematics Education, University of Colorado, 1982.

Balzer, A. L., T. P. Evans, and P. E. Blosser. A Review of Research on Teacher Behavior Relating to Science Education. Association for the Education of Teachers in Science; ERIC Information Analysis Center for Science, Mathematics, and Environmental Education, The Ohio State University, Columbus, Ohio, December 1973.

Baumgart, Neil and Brian Low. "Reporting Practical and Statistical Significance in Science Teaching Research," Journal of Research in Science Teaching, 17(3): 269-274, 1980.

Campbell, D. T. and J. C. Stanley. Experimental and Quasi-Experimental Designs for Research. Chicago: Rand McNally and Company, 1963.

Craven, Gene F. "Preservice Science Teacher Education," Science Teacher Education: Vantage Point 1976, 1977 AETS Yearbook. Association for the Education of Teachers in Science; ERIC Clearinghouse for Science, Mathematics, and Environmental Education, The Ohio State University, Columbus, Ohio, 1977.

Glass, Gene V., Barry McGaw, and Mary Lee Smith. Meta-Analysis in Social Research. Beverly Hills, California: Sage Publications, Inc., 1981.

Helgeson, Stanley L. Science Education--A Dissertation Bibliography. Ann Arbor, Michigan: Dissertation Publishing, University Microfilms International, 1978.

Helgeson, Stanley L., Robert W. Howe, and Arthur L. White. Science Education, (Abstracts and Index from Research in Education 1966-1972): Education Associates, Inc., Worthington, Ohio, 1973.

*In addition, NARST Abstracts of Presented Papers and NARST Annual Reviews of Research were reviewed for the appropriate years 1965-78. A listing of these is available from ERIC/SMEAC, 1200 Chambers Road, Room 310, Columbus, OH 43212.

Helgeson, Stanley L., Robert W. Howe, and Arthur L. White. Science Education. A Bibliography of Abstracts from Resources in Education (RIE). 1973-1975. Science, Mathematics, and Environmental Education Information Reference Center, Columbus, Ohio, 1976.

Helgeson, Stanley L., Robert W. Howe, and Arthur L. White. Science Education. A Bibliography of Abstracts from Resources in Education (RIE), 1976-1977. Science, Mathematics, and Environmental Education Information Reference Center, Columbus, Ohio, 1978.

Hurd, Paul DeHart. New Directions in Teaching Secondary School Science. Rand McNally and Co., 1969.

Kagan, Martin, and Harold Lindman. "The Proper Experimental Unit Once Again," Journal of Research in Science Teaching, 17(4): 351-358, 1980.

Koran, John J., Jr. "Application of Science Education Research to the Classroom: Validating Science Teacher Training Through Student Performance," Journal of Research in Science Teaching, 14(1): 89-96, 1977.

Kyle, William C. "The Distinction Between Inquiry and Scientific Inquiry and Why High School Students Should be Cognizant of the Distinction," Journal of Research in Science Teaching, 7(4): 123-130, 1980.

Ladd, George T. and Hans O. Andersen. "Determining the Level of Inquiry in Teachers' Questions," Journal of Research in Science Teaching, 7(4): 395-400, 1970.

Morrisey, J. T. "An Analysis of Studies on Changing the Attitude of Elementary Student Teachers Toward Science and Science Teaching," Science Education, 65(2): 157-177, 1981.

Munby, H. "An Evaluation of Instruments Which Measure Attitudes to Science," World Trends in Science Education. Halifax, Nova Scotia: Atlantic Institute of Education, 1980.

Rowe, Mary Budd. "In Pursuit of Quality: Research on the Education of Teachers," in Science Teacher Education: Vantage Point 1976, 1977 AETS Yearbook. Association for the Education of Teachers in Science; ERIC Clearinghouse for Science, Mathematics and Environmental Education, The Ohio State University, Columbus, Ohio, 1977.

Welch, Wayne W., Leopold E. Klopfer, Glen S. Aikenhead, and James T. Robinson. "The Role of Inquiry in Science Education: Analysis and Recommendations," Science Education, 65(1): 33-50, 1981.