DOCUMENT RESUME

ED 092 360 SE 017 725

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TITLE A Comparison of Structured and Unstructured Modes of Teaching Science Process Activities.
PUB DATE Apr 74
NOTE 15p.; Paper presented at the Annual Meeting of the National Association for Research in Science Teaching (47th, Chicago, Illinois, April 1974)

EDRS PRICE MF-$0.75 HC-$1.50 PLUS POSTAGE
DESCRIPTORS *Achievement Gains; *Educational Research; *Elementary School Science; *Instruction; Learning Processes; Science Activities; Science Education; *Teaching Styles
IDENTIFIERS Research Reports

ABSTRACT

In this study, the two modes were operationally distinguished by the degree of teacher control over the conduct of pupil investigations. In the unstructured mode the teacher identified the area of investigation and supplied appropriate apparatus. The structured mode was identifiable with the teaching strategy typical of a curriculum such as Science--A Process Approach. The teacher controlled specific arrangements of apparatus, the method of investigation, the amount of data to be collected, and directed pupil discussion toward a specific objective. Four classes of grade 6 pupils were required to complete two sets of activities modified from a process based elementary science curriculum. In both treatments, introductory and summary class discussions were conducted, and pupils worked in pairs. Two achievement tests were used as a pretest and posttest for each set of activities as well as a preference scale, in modified semantic differential format. The independent variables were treatment, sex, IQ, creativity, personality (extraversion, neuroticism, and dependency), and socioeconomic status. In general, subjects achieved better when taught in the structured mode. It was also found that subjects exhibited a significant preference for the structured mode and that preference was significantly related to class and IQ. (Author/EB)

A COMPARISON OF STRUCTURED AND UNSTRUCTURED MODES OF TEACHING SCIENCE PROCESS ACTIVITIES

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There has been a tendency in science education research for curriculum development studies and studies of teaching strategies to be carried out independently of each other. This has resulted in, or is perhaps a result of, confusion between such ideas as the teaching of science as a process on inquiry and the use of inquiry as a teaching strategy or, to use Rutherford's (1964) terms, "inquiry as content" and "inquiry as technique". Thus, while most of the major elementary science curriculum projects emphasize, either explicitly or implicitly, the process component of science, it is possible to identify with different projects teaching strategies which range from highly structured (S-APA, SCIS) to quite unstructured (ESS, Nuffield). The degree to which pupils can carry out the independent, open-ended type of investigation that would characterize inquiry as a teaching strategy, therefore, varies quite widely even among curriculums with the same scientific basis.

If one argues that "process" and "inquiry" mean essentially the same thing from a scientific point of view, then it should follow that processes can be best learned in a classroom situation which would permit pupils to inquire in the same sense as the scientist inquires. On the other hand, if one regards

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Paper presented at the 47th Annual Conference of the National Association for Research in Science Teaching, Chicago, Illinois: April, 1974

process, in the AAAS sense, as simply a set of skills prerequisite to the conduct of inquiry, then this does not suggest any particular teaching strategy as being preferred. The research on discovery learning suggests, if anything, that some form of guided discovery may be the most appropriate teaching strategy (Wittrock, 1966). Furthermore, there is a substantial body of research (Flanders, 1960; Tuckman, 1969; Rushton, 1966; Gibbony, 1959; Anderson, 1960; Getzels and Jackson, 1962) which suggests that a number of pupil characteristics may interact with teaching strategy such that different degrees of guidance may be desirable for different types of learners.

Objectives of the Investigation

The above considerations would suggest that it might be fruitful to explore the problem of structured versus unstructured teaching strategies in the context of process oriented elementary science curriculum. In this study, the two modes were operationally distinguished by the degree of teacher control over the conduct of pupil investigations. In the unstructured mode, the teacher identified the area of investigation and supplied appropriate apparatus. This mode can thus be identified closely with a curriculum such as ESS. In the structured mode, the teacher also controlled specific arrangements of apparatus, the method of investigation, the amount of data to be collected, and directed pupil discussion towards a specific objective. The structured mode was thus identifiable with the teaching strategy typical of a curriculum such as S-APA.

The following null hypotheses were tested:

1. There is no significant difference between teaching modes in (i) achievement of science process objectives and (ii) preference for teaching mode.

2. There is no significant interaction between teaching mode and each of the following variables, with achievement and preference as criterion variables:

   (i) sex

   (ii) intelligence

   (iii) creativity (verbal and figural)

   (iv) personality (extraversion, neuroticism, dependency)

   (v) socioeconomic status

Method

The classroom activities consisted of two sets of lessons modified from a process based elementary science curriculum developed by one of the authors (Crocker, 1973). Each set was designed to be taught in both the structured and unstructured modes. The activities were selected so that each set formed a unified sequence of five activities on the same topic. One activity set dealt with balancing and the other with density-volume.

Four classes of grade six pupils, a total of 120 subjects, were required to complete the two sets of activities. The activities were conducted by two teachers, both of whom were new to the pupils. Order of presentation of treatment and type of activity were counterbalanced. Teachers were counterbalanced with respect to treatment, time, and type of activity, but only partially with respect to class.

In both treatments, introductory and summary class discussions were conducted and the activities were carried out by the pupils working in pairs. Beyond this, the treatments differed in the manner already described. More precisely, for example, in the structured mode subjects were told which values of an independent variable to use when measuring the effect of this variable on a dependent variable, whereas in the unstructured mode, while the idea of collecting data would be discussed, the number of data points, the intervals

to be used, and the method of measurement were decided by the subjects. Thus, the unstructured mode permitted different groups within a class to have different sets of data, with the differences being explored in the class discussion at the end. The structured mode yielded essentially the same data for all groups, the differences to be discussed being confined to measurement errors.

Data Sources

Two fifteen item achievement tests were constructed, based on the objectives of the two activity sets, and modelled partially after the AAAS Science Process Instrument (AAAS, 1970). There tests were validated using a procedure suggested by Tannenbaum (1971). Test-retest reliabilities, determined during a pilot study using subjects not otherwise involved in the study, were .70 for the density-volume test and .76 for the balancing test.

In measuring preference, it was planned to administer a semantic differential at the end of each treatment and use the difference scores as a measure of preference. However, it was found in the pilot study that responses to the semantic differential were highly positive for both treatments so that a meaningful set of difference scores could not be computed. Consequently, the preference scale was modified to a forced choice scale in which, following both treatments, subjects were asked, on a number of scales paralleling the original semantic differential scales, to indicate which type of activity they preferred. Although type of activity was confounded with teaching strategy for a given subject, the counterbalanced design permitted separation of the activity effect from the treatment effect in the analysis.

The Blishen Socioeconomic Index (Blishen, 1967), the Eysenck Junior Personality Inventory, the Torrance Test of Creative Thinking, and a Dependence Proneness Scale (based on Flanders, Anderson, and Amidon, 1961) were

administered to all subjects prior to the experiment. Because the Dependency Proneness Scale has not been widely used, a local reliability test was carried out. A reliability coefficient of .91, based on a ten day test-retest on 35 subjects, was found. This is substantially higher than the reliability of .68 reported by the authors of the test.

The appropriate achievement test was used as a pretest and posttest for each set of activities. Because the analysis was to be by treatment rather than by type of activity, the posttest scores were standardized over both tests and the resulting standard scores used as the criterion variable. This, however, resulted in loss of information about the possible interaction of treatment and type of activity.

Results

Hypothesis 1, for the achievement criterion, was tested using multiple linear regression in a mode essentially equivalent to two-way analysis of covariance, with posttest as criterion, pretest and IQ as covariates, and treatment and either class or time as predictors. The latter two variables were added, post facto, to the analysis because of the possibility, suggested by the means in Table I, that they might exhibit significant main effects or interactions with treatment. Table I also suggests a possible interaction of type of activity and treatment. However, as already pointed out, information on the significance of this interaction was lost because of the standardization of the scores. More specifically, the means for balancing and density represent separate tests, while all other means in Table I represent a composite of the two tests.

Table II summarizes the results of the regression analysis for the treatment effect and the class by treatment and time by treatment interactions.

TABLE I

MEANS AND STANDARD DEVIATIONS OF ACHIEVEMENT POSTTESTS

BY TREATMENT FOR CLASS, TYPE OF ACTIVITY, AND TIME

Variable	Category	Structured Mean	Structured S.D.	Unstructured Mean	Unstructured S.D.	Overall Mean
Treatment		8.38	2.29	7.76	2.62	
Class	I	8.65	1.93	7.54	2.39	8.11
	II	8.63	2.31	9.88	2.22	9.30
	III	7.40	2.17	6.84	2.21	7.11
	IV	8.91	2.41	6.76	2.32	7.79
Type of Activity	Balancing	8.68	2.13	6.80	2.26	7.74
	Density	8.13	2.41	8.79	2.57	8.46
Time	Week I	8.78	2.18	8.33	2.68	8.56
	Week II	8.00	2.34	7.13	2.39	7.57

TABLE II

MAIN EFFECTS AND INTERACTIONS WITH TREATMENT

OF CLASS, TYPE OF ACTIVITY, AND TIME, FOR ACHIEVEMENT POSTTESTS

Predictor*	R^2 Full Model	R^2 Restricted Model	F	df	P
Treatment	.32	.31	4.48	1/184	.04
Class X Treatment Interaction	.34	.32	3.54	3/181	.02
Class	.32	.30	2.25	3/184	.09
Time X Treatment Interaction	.34	.33	1.44	1/184	.23
Time	.33	.30	8.46	1/185	.004

*IQ and Pretest Covariates

The analysis by treatment alone would appear to indicate that hypothesis 1 can be rejected. However, the existence of a significant class by treatment interaction suggests that the situation was more complex than proposed in hypothesis 1. An examination of Table I reveals that Class II is anomalous, not only in attaining a higher overall mean, but also, more significantly, in exhibiting better performance in the unstructured mode, hence the interaction.

To test hypothesis 1 for the preference criterion, preference scores were divided into three categories, prefer structured, neutral, and prefer unstructured. The frequencies of expressed preference were then tabulated. Table III shows the observed and expected frequencies and the χ^2 test, based on the assumption of equal expected probability for all scale values. An alternative procedure, disregarding the neutrals and assuming equal expected frequencies for prefer structured and prefer unstructured, yielded comparable results. The null hypothesis was thus rejected. The tendency was clearly towards preference for the structured mode.

In a supplementary procedure, paralleling that for the achievement data, the preference distribution was crosstabulated by class, type of activity, and time, as shown in Tables IV and V. Because of the counterbalancing procedure, the neutrals could not be classified by type of activity or time. The results show that preference was related to class but not to the remaining two variables. The nonindependence of treatment and class in the χ^2 analysis parallels the existence of the class by treatment interaction in the regression analysis. Again, as Table IV indicates, Class II is different from the remaining three classes in exhibiting preference for the unstructured mode.

A summary of the regression analysis for the interaction referred to in hypothesis 2 is given in Table VI. The null hypothesis was rejected only for

TABLE III

FREQUENCY DISTRIBUTION OF PREFERENCE FOR TREATMENT

	Prefer Structured	Neutral	Prefer Unstructured	χ^2	P
Observed	52	23	24		
Expected	36	27	36	12.43	<.05

TABLE IV

FREQUENCY COMPARISONS OF PREFERENCE FOR TREATMENT BY CLASS

Class	Prefer Structured		Neutral		Prefer Unstructured		Total
	0	(E)	0	(E)	0	(E)	
I	18	(15)	6	(6)	4	(7)	28
II	6	(12)	4	(6)	14	(6)	24
III	18	(11)	3	(5)	0	(5)	21
IV	10	(14)	10	(6)	4	(6)	26
Total	52		23		24		99

$\chi^2 = 25.2$, df = 6, $P < .05$

TABLE V

FREQUENCY COMPARISONS OF PREFERENCE FOR TREATMENT

BY TIME AND TYPE OF ACTIVITY

Variable	Category	Structured 0	(E)	Unstructured 0	(E)	χ^2	P
Type of Activity	Balancing	22	(18)	6	(9)	2.83	N.S.
	Density	27	(30)	18	(13)		
Time	Week I	28	(28)	14	(13)	.11	----
	Week II	23	(22)	10	(10)		

TABLE VI

MAIN EFFECTS AND INTERACTIONS WITH TREATMENT FOR ACHIEVEMENT POSTTEST OF IQ, SEX, PERSONALITY, CREATIVITY, AND SOCIOECONOMIC STATUS

Predictor	R^2 Full Model	R^2 Restricted Model	F	df	P
I.Q.*	.30	.22	10.4	2/185	<.001
I.Q. X Treatment Interaction	.30	.30	.73	2/184	--
Sex	.36	.32	11.18	1/182	<.001
Sex X Treatment Interaction	.36	.35	.37	1/179	--
Extraversion	.31	.30	1.00	2/138	--
Extraversion X Treatment Interaction	.33	.32	1.78	2/135	.17
Neuroticism	.31	.30	.74	2/138	--
Neuroticism X Treatment Interaction	.36	.31	4.78	2/135	.01
Dependency	.32	.30	1.86	2/138	.16
Dependency X Treatment Interaction	.33	.32	.64	2/135	--
Verbal Creativity	.31	.31	.36	2/178	--
Verbal Creativity X Treatment Interaction	.31	.31	.36	2/177	--
Figural Creativity	.32	.32	.76	2/181	--
Figural Creativity X Treatment Interaction	.32	.32	.22	2/180	--
Socioeconomic Status	.34	.30	5.42	2/179	.005
Socioeconomic Status X Treatment Interaction	.35	.34	1.40	2/176	.25

*Pretest only as covariate. All other cases IQ and pretest covariates.

the neuroticism variable. The direction of the interaction was such that neurotics tended to score higher than stable individuals in the structured treatment, while the opposite occurred for the unstructured treatment. It is also of interest to note that IQ, socioeconomic status, and sex exhibited significant main effects. Females scored significantly higher overall than did males. The IQ and socioeconomic status effects were in the usual direction.

The χ^2 analysis was again used in testing hypothesis 2 for the preference effect. Table VII gives the frequency distribution for preference crosstabulated by treatment and each of the other variables of interest. With the exception of IQ, no significant relationships appeared. The hypothesis of no interaction was thus rejected only for IQ by treatment. The direction of the relationship between treatment and IQ is not immediately apparent from Table VII. There is perhaps a slight tendency for high IQ subjects to prefer unstructured relatively more frequently than low IQ subjects. However, the opposite does not occur for structured. The O-E discrepancies for the neutrals are not readily interpretable in terms of the hypothesis.

Discussion

The marginally significant treatment effects for the achievement test must be interpreted in the light of the significant class by treatment interaction. Thus it is not possible to state unequivocally that the structured mode leads to greater achievement. It is here that the limitation of assignment to treatment by class rather than by individual becomes apparent. The direction of the interaction indicates that Class II was markedly different from the remaining classes. The only measured variable on which this difference was detected was IQ. Class II had a mean IQ some 17 points higher than the remaining classes. However, since IQ was controlled in the analysis, the observed interaction cannot be attributed to this variable. In any case, there was no significant IQ by treatment interaction when IQ was used as a blocking variable.

TABLE VII

FREQUENCY COMPARISONS OF PREFERENCE FOR TREATMENT

BY IQ, SEX, PERSONALITY, CREATIVITY, AND SOCIOECONOMIC STATUS

Variable	Category	Prefer Structured		Neutral		Prefer Unstructured		2	df	P
IQ	High	15	(14)	1	(6)	12	(6)	17.94	4	< .01
	Medium	17	(19)	11	(8)	9	(8)			
	Low	17	(14)	9	(6)	1	(6)			
Sex	Male	28	(28)	14	(13)	12	(14)	.52	2	--
	Female	23	(23)	10	(11)	13	(12)			
Extraversion	Extraverts	15	(17)	6	(8)	14	(9)	1.3	4	N.S.
	Neutrals	19	(19)	11	(9)	9	(10)			
	Introverts	17	(14)	9	(7)	4	(7)			
Neuroticism	Neurotics	16	(15)	9	(7)	5	(7)	4.87	4	N.S.
	Neutrals	19	(19)	11	(9)	8	(9)			
	Stables	16	(16)	5	(8)	12	(8)			
Dependency	High	17	(17)	6	(8)	12	(8)	6.04	4	N.S.
	Moderate	18	(18)	9	(8)	9	(8)			
	Low	15	(13)	9	(6)	3	(6)			
Verbal Creativity	High	15	(16)	9	(8)	9	(8)	3.06	4	N.S.
	Medium	19	(20)	10	(10)	13	(10)			
	Low	14	(11)	6	(5)	3	(5)			
Figural Creativity	High	26	(26)	13	(12)	13	(12)	2.45	4	N.S.
	Medium	16	(14)	8	(7)	5	(7)			
	Low	9	(9)	3	(4)	6	(4)			
Socio-economic Status	High	14	(12)	6	(7)	5	(6)	2.01	4	N.S.
	Medium	20	(23)	14	(12)	11	(10)			
	Low	16	(15)	6	(8)	7	(7)			

The consistency between the achievement and preference results in terms of treatment effects and the treatment-class interaction is worthy of note. In the case of preference, the IQ explanation of the treatment-class relationship is more plausible since IQ was uncontrolled in analyzing this relationship and since a significant IQ-treatment interaction was found to exist.

Any attempt to explain the class-treatment interaction in terms of the other variables under investigation would not be fruitful in view of the general lack of interactions between treatment and these variables. Even in the case of neuroticism, there was no indication that Class II contained more neurotics than the other classes.

The lack of interaction between treatment and dependency is inconsistent with the findings of Flanders (1960) and Tuckman (1969). However, it tends to support the findings of Brown (1967). No other studies report a result comparable to the neuroticism-treatment interaction. To the extent that one might tend to associate neuroticism with feelings of insecurity the observed effect is perhaps not surprising. On the surface this interpretation would seem to suggest that a dependency-treatment interaction should exist. However, the lack of correlation of neuroticism and dependency ($r = -.13$) indicates that neuroticism and dependency are essentially orthogonal variables.

The IQ and socioeconomic status main effects are not surprising and are consistent with previous studies. However, the finding that girls performed better than boys seems unusual. Direct comparability with other studies is not possible, however, because the nature of the activities was perhaps not typical.

The study is suggestive of further research in a number of respects. Further studies with larger samples and improved sampling procedures are obviously necessary. While the use of each class as its own control with respect to treatment obviated the most serious problems of the use of intact classes,

the difficulty in interpreting the class by treatment interaction suggests that random sampling of individuals or random sampling of large numbers of classes would be preferable. On the other hand, the detection of the class-treatment interaction suggests an important area for further study. It is possible, for example, that Class II had become accustomed to a teaching style which would have influenced the pupils' ability to operate in an unstructured mode. Thus, the recent school experience of the subjects might become an important variable to be explored in future studies. It is suggested that the use of interaction analysis to identify the predominant teaching style to which subjects have become accustomed would represent a significant refinement of the study.

One further area worthy of exploring is that of the operational definitions of the treatments. Although the study was conducted under relatively highly controlled conditions with respect to teaching mode, it would have been valuable to have conducted an analysis of the classroom episodes in order to determine whether the treatments were indeed consistent with the operational definitions. Furthermore, before any highly generalizable results could be obtained, it would be necessary to explore whether the defined treatments would be applied in the classroom without bias by the regular classroom teacher or whether a particular treatment can be applied best by particular types of teachers.

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