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ABSTRACT

An attribute-treatment interaction study was conducted with two groups of teachers exhibiting contrasting natural teaching styles, teaching a Biological Sciences Curriculum Study (BSCS) based biology course in a natural school setting. Annotated transcripts of lessons were analyzed to provide data for the validation and description of the contrasting styles. Multiple regression techniques provided a parsimonious statement of relationships between 15 individual predictors (general ability, four personality factors, two cognitive preferences, treatment, and seven attribute-treatment interactions) and each criterion variable (four attitude scales and two achievement tests). For three outcomes, treatment interactions were found with personality characteristics and/or cognitive preferences. (Author/CP)

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Effects of Interactions of Teaching Styles and Student Characteristics on Attitudes and Achievement in Biology

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ABSTRACT

An attribute-treatment interaction study was conducted with two groups of teachers exhibiting contrasting natural teaching styles, teaching a BSCS-based biology course in a natural school setting. Annotated transcripts of lessons were analyzed to provide data for the validation and description of the contrasting styles. Multiple regression techniques enabled a parsimonious statement of relationships between fifteen individual predictors (general ability, four personality factors, two cognitive preferences, treatment, and seven attribute-treatment interactions) and each criterion variable (four attitude scales and two achievement tests). For three outcomes, treatment interactions were found with personality characteristics and/or cognitive preferences.

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In this investigation we measured the effect on a number of affective and cognitive outcomes of interactions between selected student attributes and contrasting styles of teaching in a BSCS-based school biology program.

Critics of comparisons of teaching methods have observed that the methods may not live up to their descriptions nor differ from one another in the manner claimed. Often, too, one method carries a strong ideological commitment by the researcher and has carefully prepared materials or conditions while the other, often named the control or traditional method, is given little support. A further weakness is that alternative methods would be expected to have different rationales and purposes, but are often evaluated by criterion tests which measure the objectives of neither method or favour the objectives of one.

Even when researchers avoid these pitfalls and one treatment leads to a better mean criterion score than the other, it should not be assumed that the more successful method should obliterate the other, since it is possible that for many students the generally less successful method will be better. It is commonly held by teachers that students, who differ in so many ways, also differ in their response to different teaching methods. Although most earlier reviewers of research on attribute-treatment interaction (Bracht, 1970; Bracht & Glass, 1968; Cronbach & Snow, 1969) found little experimental support for this common knowledge, Mitchell (1969) and later reviewers (Berliner & Cahen, 1973; Hunt, 1975; Tobias, 1976) are more positive about the prospect of discovering significant interactions which would be useful in improving instruction. Cronbach and Snow (1969) and Glaser (1972) suggest that information-processing abilities may prove to be more interactive with instruction than are the more traditionally researched abilities.

Since Campbell and Stanley's (1963) description of threats to the internal and external validity of experiments, the notion of representativeness or ecological validity has been discussed by Bracht and Glass (1968), Snow (1968, 1974), Pereboom (1971), and Bronfenbrenner (1976). Brunswik (1956), Millman (1966), and Snow (1974) argue that an experiment should be fully representative of the variety of conditions to which it is intended to generalize the result. Cattell (1966), Pereboom (1971), and Bronfenbrenner (1974) support the value of naturalistic observation and argue, as ethologists would argue, against manipulative experimentation on the grounds that it risks disturbing the very processes which are to be observed. McKeachie (1974) suggests that part of the reason the laws of learning are often found not to hold in educational situations is that there are many important variables that are controlled in laboratory experiments which interact with independent variables in the natural classroom setting.

Such arguments suggested that, in answering the question "For which students is the course succeeding and in the hands of which teachers?", we should use natural assemblages of teachers and students engaged in their normal school programs, and should avoid experimental intrusion as much as possible. The preservation of the ecological integrity of the classroom setting, the use of teachers' natural styles, a full year's instruction, and criterion tests appropriate to the course objectives should guarantee considerable ecological validity.

METHOD.

Treatments

The Web of Life biology course materials (Australian Academy of Science, 1969-1976) consist of a text-book, teachers' guides, and students' manuals. As with the parent BSCS course, there is a strong commitment to the development of inquiry skills through laboratory-centered inquiry-oriented teaching strategies. The course objectives are spelled out in behavioral terms, and the rationale and suggested teaching strategies feature prominently in the teachers' guides. Although there are many optional units available, there was a large number of teachers available who were teaching the same course content, towards the same agreed objectives and giving assent to the same inquiry-centered teaching strategies suggested in the curriculum materials. Despite the general commitment to inquiry-oriented teaching strategies it was expected that there would be considerable variation in natural teaching styles (Gallagher, 1967; Tamir, 1975; Thomas & Snider, 1969; Yager, 1968). It was believed that consonance or dissonance between an intellectual commitment to the importance of the process of inquiry and more deep-seated and habitual responses, which may be related to personality and background, may be an important difference in the treatment variable. Consequently, by reference to a panel of judges two groups of four teachers were chosen. The characteristics the judges believed to belong to the groups are shown in Table 1.

TABLE 1

CHARACTERISTICS BELIEVED TO BELONG TO TWO GROUPS OF TEACHERS

Group A	Group B
Good teachers	Good teachers
Use flexible lesson structures	Structure the learning situation closely
Use materials and sources additional to text and laboratory manual	Follow text and laboratory manual faithfully
Emphasize acquisition of skills of inquiry	Emphasize acquisition of knowledge
Tolerate uncertainty in results of laboratory investigations	Organize laboratory sessions so that most students reach satisfactory conclusions
Do most teaching with individuals or small groups	Do most teaching with class as a whole
Students active in discussion and problem solving	Students disciplined and quiet

In many studies these two groups would have been accepted at face value and described perhaps as authority-centered teachers and inquiry-centered teachers. However, in this investigation, it was considered important to observe systematically the classroom behavior of these eight teachers throughout the year to check that the treatment within each group was similar and between the groups was different, and to be able to describe what the similarities and differences were. Audiotapes were made of a sample of five one-hour lessons for each teacher over the school year. The teacher wore a radio-microphone sewn into a specially modified laboratory coat and the observer made a concurrent written record of the teacher's non-verbal behavior especially any non-verbal behavior that modified the intent of the spoken word. From the audiotapes and written records annotated transcripts were produced which were analyzed by a specially developed system of Categories for Analysis of Teaching Styles (CATS) (Theobald, 1977).

Although high levels of coder consistency and inter-coder agreement are necessary, it is clear that these can be obtained, even for the most idiosyncratic system, by sufficiently extensive periods of training. In this investigation coders used the CATS without prior training, and substantial agreement between different workers coding the same transcript, and substantial consistency by the same worker coding the same transcript on different occasions, should also reflect on the face validity of the system. Values of Cohen's (1960) κ for the consistency of two coders were .80 and .76 and the mean value of inter-coder agreement was .74.

In attempting to determine the relation between the observed classroom behavior of a teacher and some outcome it is important to know whether or not the behavior is stable. However, it is important to recognize that teachers consciously adapt their behavior to different teaching situations, e.g., individual laboratory work and class discussion, as suggested by the teachers' guides. In view of these suspected "lawful adaptations of behavior to different situations" (McGaw, Wardrop, & Bunda, 1972, p.16) a similar range of lesson types was chosen for each teacher. The frequencies of behavior in each category for each recorded lesson were ranked and correlations were calculated between ranks for each lesson and ranks from a composite of the remaining lessons for that teacher, providing an unbiased estimate of the stability of teacher behavior. The median coefficients for the eight teachers were .71, .66, .55, .72, .76, .63, .67, and .80. Within the context of this investigation these estimates are regarded as conservative, and these values give grounds for believing that a sufficiently representative sample of lessons was recorded to provide measures of teaching style that are stable enough for group comparisons.

The data on teacher behavior were then clustered by both a Q-mode factor analysis and a hierarchical grouping method (H group, Veldman 1976). These two methods of clustering are based on different measures of similarity and on different assumptions about orthogonality and as both methods produced the same clustering considerable confidence can be placed in the results. As expected, the teachers clustered into two groups, but contrary to expectation three were in one group and five in the other. One, originally believed to be in group 1, was found to be a typical member of group 2. Figure 1 shows the teachers plotted according to their rotated factor loadings and illustrates the remarkable degree to which the teachers did cluster and the clarity of the separation. The mean frequencies of behavior for the two groups of teachers on 45 separate categories provided a basis for description of the teaching styles. In brief, the contrasts between the styles may be characterized as follows: one group carried out most of its teaching with individuals or small groups, and asked more questions, both memory and open questions, whereas the other group did most of its teaching by talking to the class as a whole. The contrasting teaching styles are better characterized as individual-centered and class-centered styles than as inquiry-centered and authority-centered.

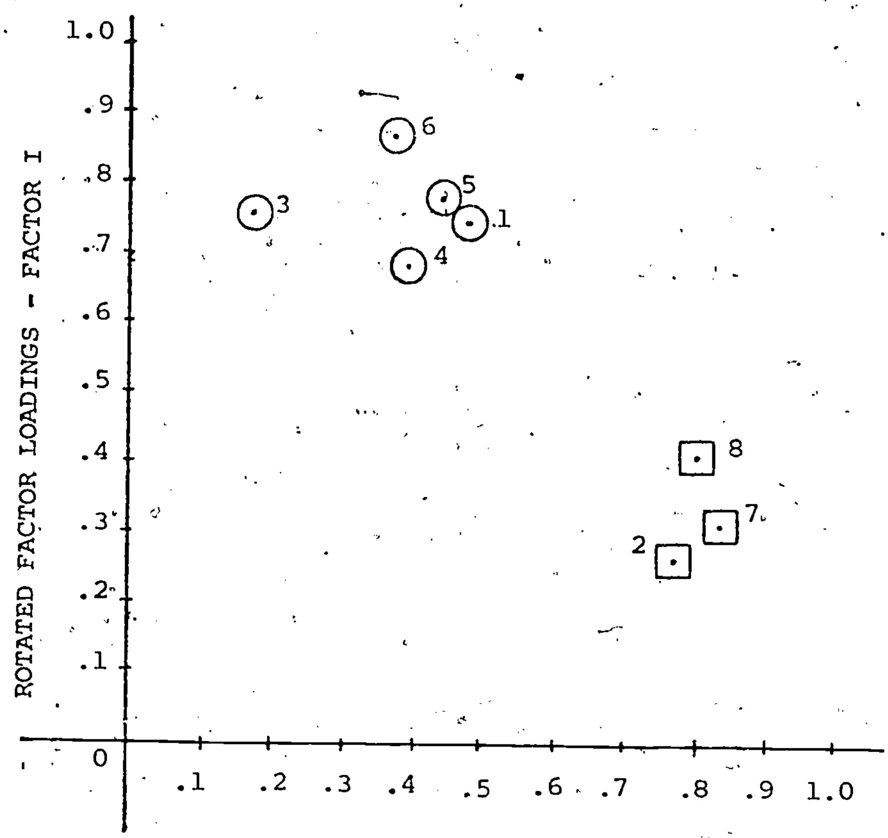

Figure 1 Clustering of teachers by inverted factor analysis

Subjects

The experimental population comprised the eight selected teachers and the 146 students in their grade 11 biology classes who were taking the subject for the first time. In Victoria (Australia), biology is studied as a subject for the first time in the eleventh grade so that prior achievement in or attitudes towards biology are unlikely to affect the outcomes. In order to investigate the relations between personological variables, instructional treatment, and outcomes, the individual student must be the unit of analysis, but the use of the individual as the unit of analysis in intact class groupings poses particular problems. There is the possibility that because of the moderating influences of classroom interaction, students in a class may become more similar in performance than students undergoing individual instructional treatment. Also any untoward interference to the routine of one class affects all students in that class, but no students in other intact class groupings. These threats to the independence of observations have to be recognized but, quite apart from any threats to ecological validity, the teachers in this investigation came from different schools and there was no practical possibility of randomly assigning students to them. In this situation the minimum requirement must be to establish that the two groups had similar characteristics as they would if they had been generated through random assignment: the researcher may then have more justification for using inferential statistics based on the assumption of random assignment. The two treatment groups were found to contain 67 and 79 students respectively and the difference between group means reached the .05 level of significance on only one of the thirteen attribute variables on which data were gathered: general ability (Advanced Test B 40, Australian Council for Educational Research, n.d.), ten personality scales from the Omnibus Personality Inventory (Heist & Yonge, 1962), and two cognitive preference variables developed by Mackay (1972) based on the work of Heath (1964). There were substantial intercorrelations between the ten personality scales, and in order to resolve this non-orthogonality and to reduce the number of variables a principal components factor analysis was carried out followed by varimax rotation and an eigenvalue cut off of 1.0. The first four roots extracted 72.6% of the trace. The factor matrix was relatively simple with six of the ten scales having only one significant non-zero loading. By referring to the characteristics of high and low scorers on the original scales the four factors can be briefly described as reflecting characteristics of impulsivity (PF1), neuroticism (PF2), non-intellectualism (PF3), and dogmatism (PF4). These short titles are not, however, to be taken to imply an exact congruence with constructs of the same names measured by other instruments. Cronbach and Snow's (1969) suggestion that information-processing variables may be more interactive than the traditionally researched abilities, Glaser's (1972) pleas for the investigation of the 'new aptitudes', and the growing research in cognitive style suggested the inclusion of measures of cognitive preferences developed originally by Heath (1964) in research on student response to the objectives of the new inquiry-oriented science curricula of the 1960s. Mackay (1972) produced two approximately orthogonal cognitive preference variables from Heath's four scales by an unfolding analysis (Coombs, 1958, 1964) which are described as representing a student's relative cognitive preference for theoretical rather than applied presentations of scientific material (CP1), and a student's relative cognitive preference of scientific phenomena in terms of the fundamental scientific principle involved, as compared to rote memory tasks (CP2).

Criterion variables

In this investigation all teachers are teaching the same course towards the same agreed ends using the same instructional materials and the same recommended broad teaching strategies: the differences in instructional treatment between the groups lie in the teachers' natural teaching styles. In this situation criterion tests designed to measure the agreed outcomes of the program should favour neither group.

The authors of the Web of Life course developed a hierarchy of process goals and divided the course content into a number of 'major ideas' or major generalizations of biological science, which in turn were subdivided into the constituent individual concepts or 'single propositions'. Using these content and process objectives as a test grid the Australian Council for Educational Research developed batteries of multiple-choice achievement tests for the Web of Life course. Two of these were used as measures of cognitive outcomes: test AD1--Diversity, and test AI1--Inter-relationships. Test AD1 is almost entirely a memory task whereas test AI1 requires skills of Comprehension, Application, and Analysis (Bloom, 1956). The virtual identity of the expressed objectives of the PSSC physics course and the Web of Life biology course persuaded Lucas and Broadhurst (1972) to adapt four attitude scales developed by Gardner (1972) in his research into attitudes to physics for use in biology classes. The four scales were views about biology learning (VABL), views about biology as a process (VABP), views about scientists (VAS), and enjoyment of biology (EOB). VABL purports to measure the extent to which students view biology learning as a non-authoritarian situation in which students are stimulated to think about biological phenomena, encouraged to 'discover' biological phenomena for themselves and to participate in the development of methods for solving problems; VABP the extent to which students view biology as an open rather than a closed process which by its very nature is dynamic, creative, tentative, and unfinished; VAS the extent to which students view scientists as normal, active, occasionally fallible human beings who are different from other people only in the area of their special training; and EOB the extent to which students come to view biology as an important and enjoyable activity for themselves.

Method of analysis

Multiple regression techniques were used to analyze the data. The full regression model for each criterion variable consisted of the main effects for treatment, four personality factors, two cognitive preferences, and general ability as well as the first-order interactions of treatment with each of the seven attribute variables. The intent of the analysis was to reduce this model to the simplest possible model which describes the relations between the independent variables and each criterion variable without significant loss of explanatory power. As 'general ability' is widely accepted as 'the ability to learn', the total contribution of general ability was included in the regression equation along with the unique contributions of the other predictor variables. The unique contribution of each term, controlling for all others, was tested, first the interactions then the main effects, and those terms that did not significantly contribute to the explained variance were progressively eliminated. The last variable to be tested was the total contribution of general ability which acted as the covariate control for all other variables.

The result of this progressive simplification of the regression model for each criterion variable can be seen in Table 2. The R^2 values indicate the percentage variance in each criterion variable explained by the terms in the regression equation acting jointly, and the R^2 change values reflect the loss of explanatory power accompanying the removal of the unique effect of that particular variable from

TABLE 2

PERCENTAGE OF VARIANCE IN EACH CRITERION VARIABLE EXPLAINED BY VARIOUS REGRESSION MODELS AND INDIVIDUAL PREDICTORS.

Criterion	R^2[a] Full Model	R^2 change T x PF1	T x PF2	T x PF3	T x PF4	T x CP1	T x CP2	T x I	R^2[b] Revised Model	R^2 change PF1	PF2	PF3	PF4	CP1	CP2	T	R^2 change[c] I	R^2[d] Final Model	$\hat{R}^2$[e]
VABL	19.9	1.3	0.0	0.4	1.1	0.9	1.0	0.8	15.4	0.0	0.8	3.8	5.1	0.0	0.4	0.1	4.9	14.3	12.0
VABP	23.8	0.3	0.0	0.3	2.8	3.0	0.1	0.1	23.1	0.0	0.0	12.6	0.0	0.9	0.0	3.1	4.9	22.1	19.3
VAS	12.3	0.5	2.3	0.0	0.0	0.2	1.0	0.2	8.2	0.2	0.0	2.1	0.6	0.2	1.6	3.0	0.5	3.3	2.3
EOB	18.9	0.0	0.1	0.1	0.8	2.4	0.0	0.0	15.5	3.4	1.5	7.7	0.4	0.9	0.3	0.3	0.5	11.8	10.5
AD1	37.2	0.0	0.1	0.1	2.6	1.1	4.0	0.0	35.9	0.7	0.1	2.1	4.4	0.0	0.1	2.7	12.0	34.9	32.1
AI1	32.8	0.0	0.9	2.1	0.4	0.1	1.3	1.7	28.4	2.2	0.4	0.3	2.8	0.0	0.1	5.5	11.5	27.6	25.0

[a]Full model contains 15 terms: treatment, 4 personality factor scores, 2 cognitive preference scores, general ability, and 7 attribute-treatment interaction terms.

[b]Revised model for each criterion variable contains all main effects terms and all significant interaction terms.

[c]Compared against a model containing significant interactions, treatment and I only.

[d]Final model for each criterion variable contains only terms which make a significant contribution to explanation of variance: main effects and interactions.

[e]Estimated squared multiple correlation in the population corrected for shrinkage.

Note: R^2 change values which reach levels of significance of $p < .05$ or better are underlined.

the regression model. Because of the manner in which the unique contributions of the variables were defined, the R^2 change associated with general ability represents the total contribution of general ability to explanation of variance. The full regression model for each criterion variable contained fifteen terms: the four personality factors, two cognitive preferences, general ability, seven attribute-treatment interaction terms, and the main effect of treatments. This full model was used to compute the error term for the test of interaction effects. However, at the completion of this analysis the full model was revised for each criterion variable so that it included only those interaction terms that were significant and the revised models were used to compute the error term for the main effects analysis (Theobald, 1977).

The final models for each criterion variable are:

$Y_{VABL} = f\ (PF3,\ PF4,\ I)$

$Y_{VABP} = f\ (T,\ PF3,\ I,\ \overline{PF4 \times T},\ \overline{CP1 \times T})$

$Y_{VAS} = f\ (T)$

$Y_{EOB} = f\ (PF1,\ PF3)$

$Y_{AD1} = f\ (T,\ PF3,\ PF4,\ I,\ \overline{PF4 \times T},\ \overline{CP2 \times T}$

$Y_{AI1} = f\ (T,\ PF1,\ PF4,\ I,\ \overline{PF3 \times T}$

To achieve orthogonality for the multiple regression analysis the attribute variables were redefined as the total contribution of general ability and the unique contributions of the other variables, but in determining the final trend equations the factor scores for the four personality factors and the raw scores for the cognitive preference scales and for general ability were used. For descriptive and predictive purposes these original variables have more meaning than the redefined variables and, in fact, differ very little from them. There were only two significant non-zero correlations, those of PF3 with CP2 (.183) and with I (-0.306): all other intercorrelations were non-significant at the .05 level. Therefore in interpreting the results it should be borne in mind that the unique contributions of PF3 and CP2 are slightly less than their total contributions.

RESULTS

1. Increased levels of general ability, a disposition to intellectual pursuits, and open-mindedness all contribute to a student viewing biology learning as a non-authoritarian and participatory activity.

2. Increased levels of general ability and an intellectual disposition contribute to a student viewing biology as an open, dynamic, and creative process. Two attribute-treatment interactions are illustrated in Figures 2 and 3. In Figure 2 PF4 scores are plotted against VABP scores for treatments 1 (the individual-centered treatment) and 2 (the class-centered treatment), as the mean values of PF4, I, and CP1. Similarly in Figure 3, CP1 scores are plotted against VABP scores for treatment 1 and 2 at the mean values of PF3, PF4, and I. In plotting the values of the attribute variables for the contrasting treatments against criterion scores, scores at, or nearly at, one standard deviation above and below the mean have been used to give a consistent meaning to the terms 'high' and 'low' on attribute variables. The interpretation of each disordinal interaction on its own is relatively straightforward but both interactions can be considered together. For dogmatic students with a cognitive preference for application, the individual-centered teaching style appears to stimulate a view of biology as an open process, but it appears to be counter-productive for open minded students with a cognitive preference

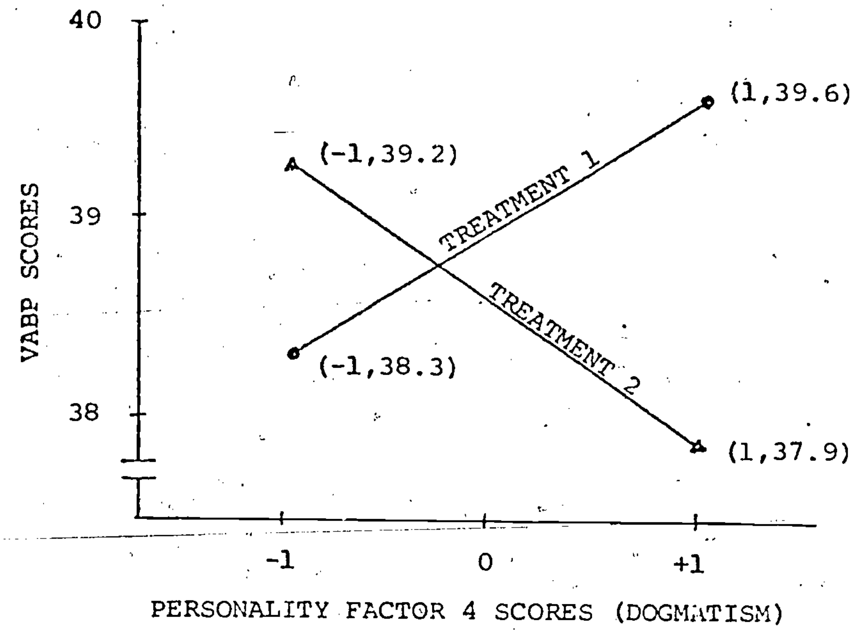

Figure 2 Plot of personality factor 4 (Dogmatism) scores against VABP scores showing the PF4 x treatment interaction

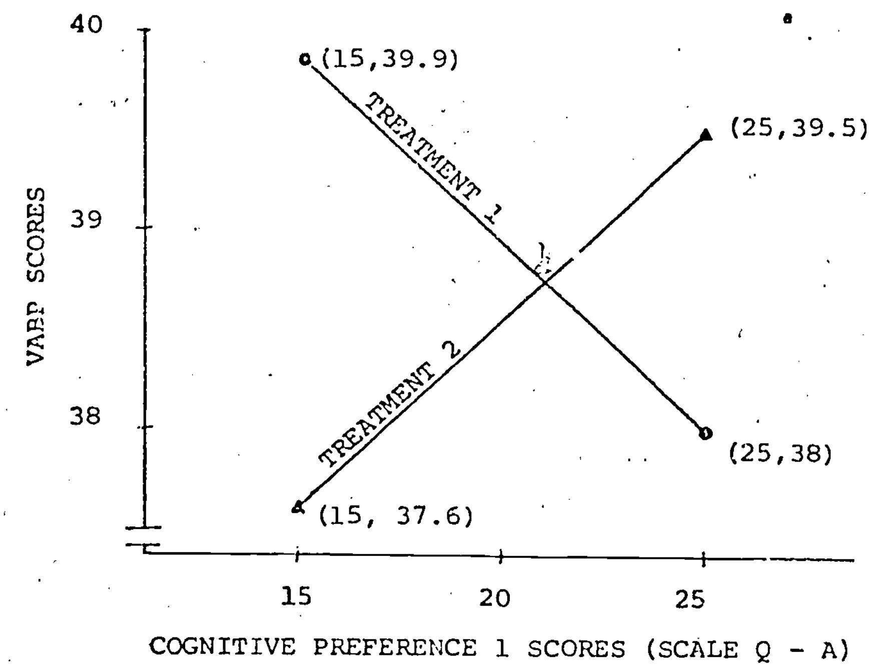

Figure 3 Plot of cognitive preference scale Q - A scores against VABP scores showing the CP1 x treatment interaction

for theory. For these latter students the class-centered teaching style appears to be better, although it is relatively ineffective for the dogmatic students with an 'applied' cognitive preference.

3. When corrected for chance over-fit, only 2.3% of the total variance in scores on Views about scientists is explained by the final regression equation: a finding of little practical significance. The only variable considered in this investigation which significantly contributes to a student viewing scientists as normal human beings, different from others only in the area of their special training, is their experience of individual-centered teaching rather than class-centered teaching.

4. Enjoyment of biology appears to be basically a function of two personality characteristics: a cautious, convergent outlook, and an intellectual disposition.

5. Increased levels of general ability, and an intellectual disposition contribute to higher scores on an achievement test which is basically a memory task. Two attribute-treatment interactions are illustrated in Figures 4 and 5. In Figure 4 PF4 scores are plotted against AD1 for treatments 1 and 2 at the mean values for the other variables in the final regression equation. In Figure 5 CP2 scores are treated similarly. The interpretation of each set of relationships by itself is straightforward, but the combination of the ordinal PF4 x T interaction and the disordinal CP2 x T interaction is more complex. In brief, for students who have both a cognitive preference for rote learning and who are open-minded, class-centered teaching appears to lead to higher scores, but for dogmatic students and those with a cognitive preference for principles and generalizations, individual-centered teaching appears to be the more effective.

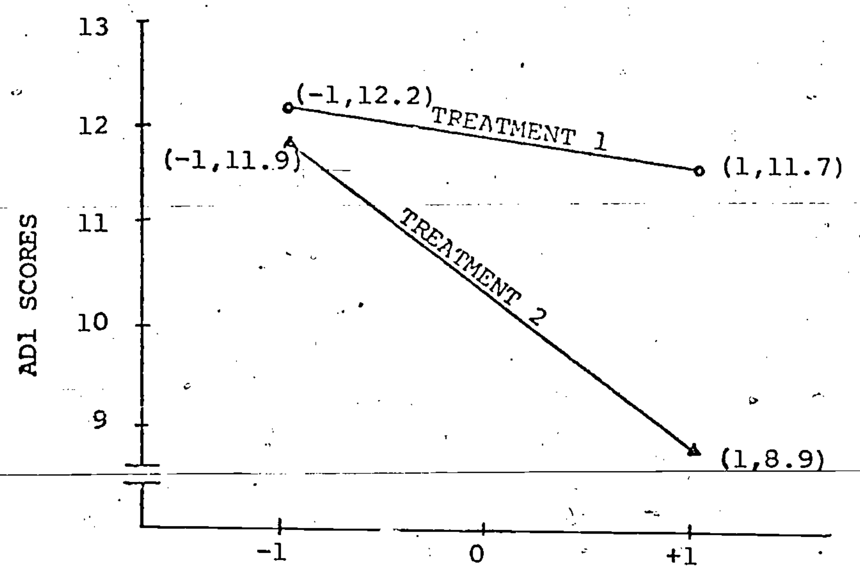

Figure 4 Plot of personality factor 4 (Dogmatism) scores against AD1 scores showing the PF4 x treatment interaction

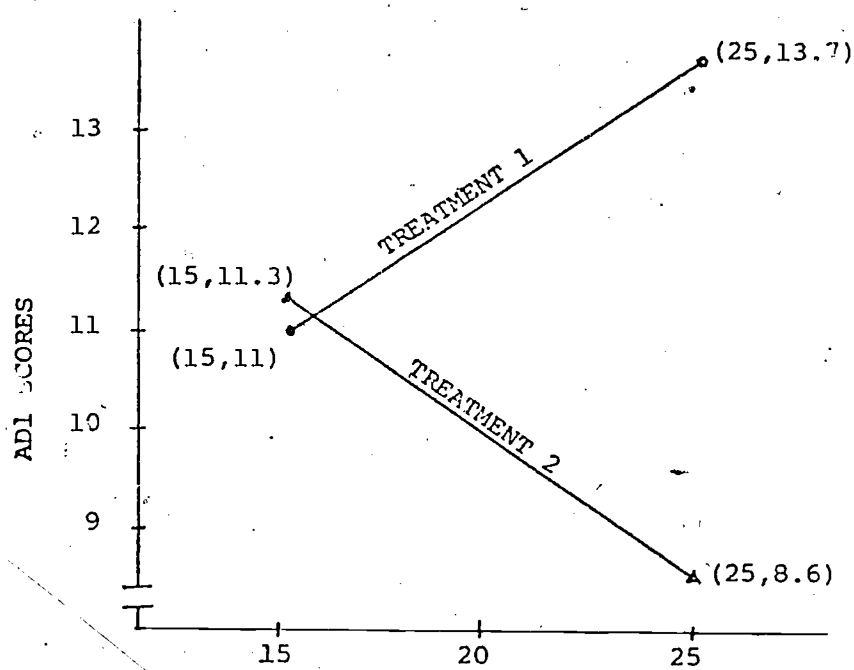

Figure 5 Plot of cognitive preference scale P - M scores against AD1 scores showing the CP2 x treatment interaction.

6. Increased levels of general ability, open-mindedness, and a cautious, convergent personality all contribute to increased scores on an achievement test which requires a student to process his knowledge by reordering it, applying it to new situations, or analyzing its elements. The interaction of teaching style and PF3 can be seen in Figure 6. Over the range of scores on Non-intellectualism -1σ to +1σ, the individual-centered teaching style leads to higher achievement, and is distinctly superior to class-centered teaching for the extreme non-intellectual student. For students with a highly intellectual outlook (< -1.4σ), class-centered teaching becomes more effective and individual-centered teaching becomes counter-productive.

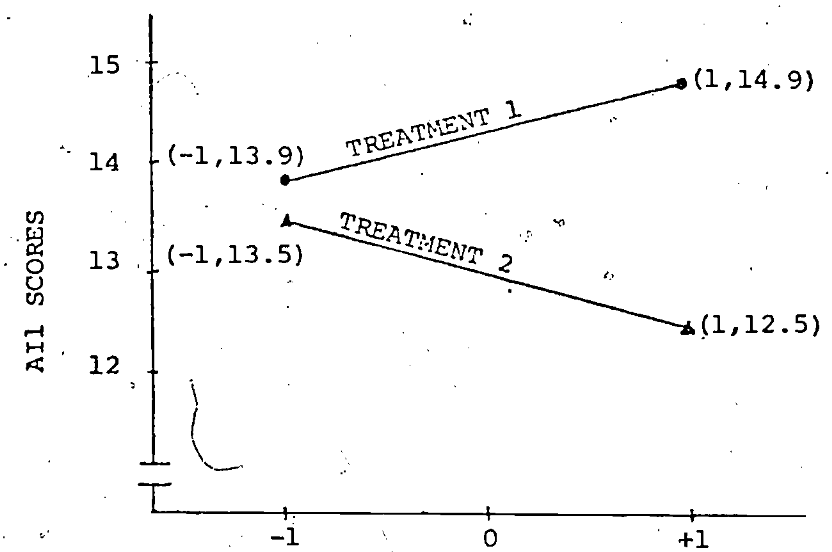

Figure 6 Plot of personality factor 3 (Non-intellectualism) scores against AI1 scores showing the PF3 x treatment interaction

At the conclusion of the year's teaching the eight teachers were asked to rank the four attitude scales and the two achievement tests in terms of importance in their own teaching priorities. The mean rankings for the six outcome variables were AI1 (1.5), VABF (1.5), AD1 (3.5), VABL (4.1), EOB (4.4), and VAS (6.0).

CONCLUDING OBSERVATIONS

If AIl, VABP, and ADl are seen by the teachers to be the most important of these outcomes, it may be reasonable to assume that they devoted most of their teaching effort in these directions, thus giving greater possibility to the interaction of teaching style and student attributes. These criterion variables are, in fact, the only ones on which significant attribute-treatment interactions were observed.

The attribute-interactions found tend to support the earlier contention that studies of main effects tend to provide an over-simplified picture of classroom performance, and provide still further evidence for the need for individualized instruction. Stripped of the detail, the findings could be interpreted as suggesting that individual assistance and stimulation are beneficial for students who are closed-minded, non-intellectually inclined, or who have a cognitive preference for application; but may, in fact, be counter-productive for open-minded and intellectually disposed students.

This research suggests a number of possibilities. Using the student attributes and the characteristics of teaching styles shown to be important in this study more economical methods of data gathering may be used as a basis for grouping students with teachers, where there are teachers available who exhibit these natural styles. Then again those natural patterns of teacher behavior such as giving individual assistance and stimulation within class groupings may be deliberatly encouraged. Hunt (1974) describes a number of skills required for meeting the needs of individual students: skills in distinguishing between students, learning environments, and outcomes; skills in 'radiating' particular learning environments; and skills in 'flexible modulation' from one environment to another. In teacher training courses these skills could be practised in micro-teaching sessions with peer-group role players, or with school students selected because of their differences.

The view of Berliner and Cahen (1973), Hunt (1975), and Mitchell (1973) that interaction should be seen in developmental perspective is of some relevance. Perhaps teaching to promote maximum learning is not enough. It has been argued (Cronbach & Snow, 1969; Mayer, 1975; Messick, 1970) that to circumvent a student's deficiency in information-processing or to capitalize on his present capabilities may not be in his long term interests. The student's present needs should be viewed as a stage in his development towards the long-term objective of independence and less need for assistance.

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