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ABSTRACT

This research tested the validity of the prevalent assumption that a teacher's conception of the nature of science influences his/her classroom behavior. The subjects consisted of 18 senior high school biology teachers and one randomly selected tenth-grade biology class of each teacher. Each class (mean size of 22.72 students) was heterogeneous with respect to sex, race, and socioeconomic status. Teachers were compared with respect to their conceptions of six aspects of the nature of science (amoral, creative, tentative, testable, parsimonious, and unified) as measured by the Nature of Scientific Knowledge Scale (NSKS). Quantitative comparisons were made between "high" teachers (those exhibiting the highest NSKS scores) and "low" teachers (those exhibiting the lowest NSKS scores) with respect to 44 classroom variables. Only one variable differentiated between the "high" and "low" groups of teachers. Thus the data did not support the prevalent assumption that a teacher's conception of the nature of science influences his/her classroom behavior. Interestingly, most of the classroom variables used for teacher comparisons have previously been shown to be related to improved student conceptions of the nature of science. (Author/JN)

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Science Teachers' Conceptions of the Nature of Science: Do They Really Influence Teaching Behavior?

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PURPOSE

Improving the scientific literacy of the public is the most compelling challenge facing science educators (National Science Teachers Association, 1982). Furthermore, an adequate conception of the nature of science is considei .o be a distinguishing attribute of the scientifically literate individual (Collette & Chiappetta, 1984; Klopfer & Cooley, 1963; NSTA, 1982; Showalter, 1974). The "nature of science" has been defined in numerous ways, but it most commonly refers to the values and assumptions inherent to scientific knowledge (e.g., tentativeness, parsimony, empirically based, amoral, etc.).

Researchers have long been dismayed by the apparent misconceptions held by secondary school students (Bady, 1979; Rubba, Horner, & Smith, 1981) as well as those misconceptions possessed by science teachers (Carey & Stauss, 1968, 1970; Miller, 1963; Schmidt, 1967). Consequently, much time and effort have been invested in programs specifically designed to improve science teachers' conceptions of science with the anticipation that improved student c nceptions would necessarily follow. Such programs (Billeh & Hassan, 1975; Welch & Walberg, 1968; among others) clearly assumed that a teacher's classroom behavior is influenced by his/her conception of t e nature of science and that a significant positive relationship exists between teachers' conceptions and changes in the conceptions of their students. The presumed relationship between teachers' conceptions and their classroom behavior is a rather intuitive notion and has been reiterated throughout the three decades of research concerned with the "nature of science" (Cotham & Smith, 1981; Hurd, 1969; Robinson, 1972).

Since this belief has provided the framework for much empirical research and curriculum development, one is readily disconcerted by the realization that it has remained virtually untested.

The purpose of this research was to test the validity of the prevalent assumption that a teacher's conception of the nature of science influences his/her classroom behavior. It is believed that the results of this investigation will help to redirect the focus of future efforts to promote more adequate conceptions of the nature of science in our secondary school students.

SUBJECTS

The subjects consisted of 18 senior high school biology teachers and one randomly selected tenth grade biology class of each teacher. Each class was heterogenous with respect to sex, race, and socioeconomic status. The mean class size was 22.72 students. All instruction followed the New York State Biology Regents Syllabus (State Education Department, 1982).

METHOD

A blend of quantitative and qualitative techniques best served the purpose of this study. The design used was largely derived from the approach developed for the Beginning Teacher Evaluation Study (Tikunoff, Berliner, & Rist, 1975). Space does not permit a complete description of the entire methodology, but the most salient points are presented here.

The "Nature of Scientific Knowledge Scale" (NSKS; Rubba, 1976) was administered to each of the 18 teachers at the beginning and end of the fall semester. The NSKS is purported to be an objective measure of a respondent's understanding of the nature of scientific knowledge. The instrument contains 48 statements with a Likert scale format containing five choices. In addition to a total score, the NSKS yields scores on each of six additive subscales. The subscales are as follows: 1) amoral (scientific knowledge itself cannot be judged as good or bad), 2) creative (scientific knowledge is partially a product of human creative imagination), 3) developmental (scientific knowledge is tentative), 4) parsimonious (scientific knowledge attempts to achieve simplicity of explanation as opposed to complexity), 5) testable (scientific knowledge is capable of empirical test), and 6) unified (the specialized sciences contribute to an interrelated network of laws, theories, and concepts).

One of the two researchers conducted intensive qualitative classroom observations in each of the 18 classes between the NSKS pretest and posttest. The researcher was unaware of the teachers' NSKS pretest performance while making observations. During each observation, an attempt was made to record all teacher and student verbalizations, chalkboard notes, handouts, assignments, teacher mannerisms, nonverbal cues, and classroom physical plan. Classroom observations were conducted throughout the fall semester and resulted in over 1600 pages of field notes (approximately 90 pages per teacher).

Systematic pairwise qualitative comparisons were made among the 18 sets of field notes. These comparisons were made without knowledge of the teachers' NSKS scores and resulted in the derivation of 44 classroom variables which appeared to discriminate among the behaviors of the 18 teachers under investigation. A complete lising of these variables and their operational definitions is provided in Appendix A. An indepth discussion of the procedure used to qualitatively derive classroom variables may be found elsewhere (Lederman & Druger, 1985). However, the primary focus of this investigation was to ascertain whether any of the derived classroom variables were related to the teachers' conceptions of the nature of science. In order to pursue this question, NSKS scores (i.e., the mean of the pre and posttest) were used to rank order teachers with respect to their Overall and subscale scores. Those teachers who exhibited the highest scores (i.e., a ranking in the top six) on at least four of the seven NSKS scales were categorized as "high" and those exhibiting the lowest scores (i.e., a ranking in the bottom six) were categorized as "low." This procedure resulted in four teachers designated as "high" and four designated as "low." Only these teachers were used in subsequent analysis. The teachers' specific NSKS scores and their categorization may be found in Tables 1 and 2.

The second researcher, who was unaware of the aforementioned classification scheme, systematically compared the field notes of each "high" teacher with each "low" teacher for each of the qualitatively derived classroom variables. For each variable, the researcher was asked to describe which teacher exhibited "more" or "less" of that particular variable. The researcher who originally derived the classroom variables also performed these same comparisons. An agreement level exceeding 96% was exhibited for the 16 teacher comparisons. The data generated by the comparison of field notes were perceived as a series of binomial variables and their statistical

TABLE 1

Classification of Teachers With Respect to Average (Mean of Pre and Postest) NSKS Score

Overall Scale	Amoral Subscale	Creative Subscale	Developmental Subscale	Parsimonious Subscale	Testable Subscale	Unified Subscale
			High			
224(G)	40(H)	38(N)	38(F)	36(G)	40(H)	40(O)
220(L)	40(O)	38(G)	38(R)	36(L)	39(F)	40(L)
215(H)	39(L)	36(H)	36(N)	32(H)	39(O)	39(N)
205(K)	38(G)	35(E)	36(H)	32(R)	39(L)	39(G)
204(O)	38(E)	34(L)	36(G)	31(I)	39(B)	38(F)
202(C)	38(B)	33(K)	36(B)	30(Q)	38(G)	38(K)
			Medium			
200(E)	35(I)	32(B)	34(I)	29(C)	36(K)	36(M)
200(B)	35(K)	32(D)	34(K)	28(O)	36(M)	35(E)
200(R)	35(F)	32(P)	33(E)	26(N)	35(N)	35(J)
198(F)	34(Q)	32(O)	33(J)	26(K)	35(E)	34(R)
194(I)	33(P)	31(Q)	33(L)	25(J)	35(C)	33(B)
190(J)	33(C)	31(J)	32(Q)	25(A)	35(R)	33(C)
			Low			
186(N)	31(M)	30(I)	30(D)	24(D)	34(J)	32(Q)
183(M)	31(R)	30(A)	30(P)	24(B)	33(I)	32(A)
177(P)	30(N)	29(C)	30(A)	23(M)	32(D)	31(H)
173(D)	30(A)	29(M)	28(C)	23(F)	32(Q)	30(I)
172(A)	26(D)	27(R)	27(M)	21(E)	32(P)	30(P)
165(Q)	24(J)	22(F)	25(O)	20(P)	31(A)	29(D)

NOTE: The letters within the parentheses are the identification codes used to maintain anonymity of each teacher.

TABLE 2

Summary of Teacher Classification With Respect to NSKS Scores

Teacher	Overall Scale	Amoral Subscale	Creative Subscale	Developmental Subscale	Parsimonious Subscale	Testable Subscale	Unified Subscale
A	L	L	L	L		L	L
B		H		H	L	H	
C	H		L	L			
D	L	L		L	L	L	L
E		H	H		L		
F			L	H	L	H	H
G	H	H	H	H	H	H	H
H	H	H	H	H	H	H	H
I			L		H	L	L
J	L					L	
K	H		H				H
L	H	H	H		H	H	H
M	L	L	L	L	L		
N	L	L	H	H			H
O	H	H		L		H	H
P	L			L	L	L	L
Q		L			H	L	L
R		L	L	H	H		

significance was tested accordingly. In summary, those variables which were found to statistically differentiate between "high" and "low" teachers were considered to be related to a teacher's conception of the nature of science.

RESULTS AND CONCLUSIONS

The ability of each classroom variable to statistically discriminate between "high" and "low" teachers was assessed using a non-directional binomial test (α=.05). The results of this statistical analysis are presented in Table 3.

Research concerned with an understanding of the "nature of science" as an outcome variable has consistently assumed that a teacher's classroom behavior is directly influenced by his/her own conception of the nature of science (Billeh & Hassan, 1975; Cotham & Smith, 1981; among others). Consequently, much research has focused on the improvement of teachers' conceptions as a mechanism for bringing about improvement of students' conceptions. Interestingly, the presumed relationship between teachers' conceptions of science and their classroom behavior has remained virtually untested.

The data in Table 3 clearly indicates that, with the exception of "Down Time," none of the 44 classroom variables significantly differentiated between the "high" and "low" groups. The variable "Down Time" was more common ($p<.05$) to the "low" group of teachers and it refers to instances in which students must wait for the teacher to give direction or proceed with instruction. "Down Time," in and of itself, can only be considered as a "generic" teaching behavior which is more logically related to a variety of factors (e.g., poor planning,

TABLE 3

Results of Paired Comparisons

Classroom Variable	"High" Teacher Exhibiting More	"Low" Teacher Exhibiting More	Probability (p)
Teacher's General Instructional Approach			
1. Anecdotal	8	8	>.9999
2. Dynamic	10	6	.4580
3. Emphasis on rote memory/recall	7	9	.8036
4. Extended lecturing	5	11	.2100
5. Frequent questioning	9	7	.8036
6 Fragmented	8	8	>.9999
7. Higher cognitive level questions	10	6	.4580
8. Instructional digression	11	5	.2100
9. Pacing	9	7	.8036
10. Periodic review	9	7	.8036
11. Predictable	5	11	.2100
12. Problem solving	7	9	.8036
13. Receptive to unsolicited questions	9	7	.8036
14. Rushing	12	4	.0766
15. Seat work	7	9	.8036
16. Sequential probing	7	9	.8036
17. Supportive	9	7	.8036
18. Use of humor	11	5	.2100
19. Variety of instructional media	11	5	.2100
Teacher's Content-Specific Characteristics			
20. Amoral	5	11	.2100
21. Anthropomorphic language	10	6	.4580
22. Arbitrary constructs	8	8	>.9999
23. Creativity	6	10	.4580
24. Developmental	7	9	.8036
25. Fallibility	6	10	.4580
26. Language accuracy	12	4	.0766
27. Misinformation	7	9	.8036
28. Moral & ethical implications	8	8	>.9999
29. Parsimony	7	9	.8036
30. Quantity of material	12	4	.0766
31. Relevancy	10	6	.4580
32. Superficiality	7	9	.8036
33. Testable	7	9	.8036
34. Unified	8	8	>.9999
Teacher's Non-Instructional Characteristics/Attitude			
35. Demeanor	8	8	>.9999
36. Impersonal	8	8	>.9999
37. Non-instructional digression	11	5	.2100
Student Characteristics			
38. Active engagement	12	4	.0766
39. Attentive	9	7	.8036
40. Unsolicited questioning	11	5	.2100
Classroom Atmosphere			
41. Discipline	7	9	.8036
42. Down time	3	13	0210
43. Low anxiety	6	10	.4580
44. Rapport	7	9	.8036

classroom discipline, etc.) than to the teacher's conception of science. However, the most elucidating result of this investigation was the failure of those classroom variables specifically related to the nature of science (e.g., Amoral, Creative, Developmental, Parsimony, Testable, and Unified) to statistically differentiate between the "high" and "low" teachers. Therefore, with the exception of the "generic" teaching variable of "Down Time," the data did not support the prevalent assumption that a teacher's conception of the nature of science influences his/her teaching behavior. In addition, it is rather disconcerting that many of the classroom variables used for teacher comparisons have previously been shown to be significantly related to changes in students' conceptions of the nature of science (Lederman, 1985). The results of this investigation do not derogate the importance of a teacher's conception of the nature of science. Afterall, a teacher must have at least a working knowledge of what he/she is expected to teach. However, the results do indicate that simply possessing valid conceptions of the nature of science do not necessarily result in the performance of those teaching behaviors which are related to improved student conceptions.

IMPLICATIONS FOR SCIENCE EDUCATION

Teachers have been berated in the past for failure to promote adequate student conceptions of science (Miller, 1963) and are currently being strongly urged to reverse the situation (NSTA, 1982). Consequently, science educators continue to invest much time and effort in programs specifically designed to improve science teachers' conceptions (Duschl, 1985; Gallagher, 1984; among others). Such "remedies" are based on the assumption that a teacher's conceptions influence his/her teaching behavior and that improved student conceptions will, therefore, necessarily follow improved teacher conceptions. However, the findings of this investigation clearly do not support this perennial assumption and, thus, call into question the ultimate effectiveness of our present approach to improving students' conceptions of the nature of science. Indeed, it is quite reasonable to expect that many factors (e.g., curriculum constraints, administrative policies, supplies, etc.) other than a teacher's conceptions of science influence classroom behavior. Nevertheless, research on teaching has provided strong empirical support for the relationship of selected teaching behaviors and classroom climate to a wide variety of student outcomes (Medley, 1978). More specific to the problem at hand, recent research has helped to elucidate those specific teaching behaviors which influence students'conceptions of the nature of science (Haukoos & Penick, 1983; Lederman, 1985). Consequently, it appears that a more balanced treatment of history/philosophy of science and specifically targeted teaching behaviors/skills is needed in preservice and inservice science teacher education if we are to successfully promote more adequate conceptions of the nature of science among our science students.

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APPENDIX A

Derived Classroom Variables

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1. ANECDOTAL (TG) - Teacher uses (does not use) stories, analogies & examples to illustrate concepts
2. DYNAMIC (TG) - Teacher's presentation is (is not) energetic & theatrical with good voice inflections
3. ROTE MEMORY/RECALL (TG) - Material is (is not) presented at the factual or knowledge level
4. LECTURING (TG) - Teacher talk does (does not) monopolize class time with little student involvement
5. FREQUENT QUESTIONING (TG) - Teacher asks (does not ask) frequent questions
6. FRAGMENTED (TG) - Teacher's presentation is (is not) "free-flowing" and logically sequential
7. HIGHER LEVEL QUESTIONS (TG) - Higher level questions (Bloom's Taxonomy) are (are not) used frequently
8. INSTRUCTIONAL DIGRESSION (TG) - Topics peripherally related to main concept are (are not) pursued
9. PACING (TG) - Teacher does (does not) continually assess class understanding and adjusts pace accordingly
10. PERIODIC REVIEW (TG) - Class time is (is not) used to review/drill students on previously presented material
11. PREDICTABLE (TG) - Mode of presentation is (is not) inflexible irrespective of content
12. PROBLEM SOLVING (TG) - Open ended questions and/or discrepant events are (are not) used
13. RECEPTIVE (TG) - Teacher is (is not) receptive to student-initiated questions
14. RUSHING (TG) - Teacher does (does not) attempt to quickly cover a predetermined amount of material
15. SEAT WORK (TG) - Class time is (is not) allocated for written exercises or textbook reading
16. PROBING (TG) - Follow-up questions to student responses are (are not) used
17. SUPPORTIVE (TG) - Positive encouragement is (is not) often used
18. HUMOR (TG) - Teacher does (does not) interject jokes and/or humorous histrionics during instructional presentation
19. VARIETY OF MEDIA (TG) - Diverse instructional materials are (are not) used in presentation of content
20. AMORAL (TC) - Scientific knowledge is (is not) presented as amoral
21. ANTHROPOMORPHIC LANGUAGE (TC) - Anthropomorphic language is (is not) used and accepted by the teacher
22. ARBITRARY CONSTRUCTS (TC) - Arbitrary nature and utility of scientific constructs are (are not) stressed
23. CREATIVITY (TC) - Scientific knowledge is (is not) presented as a product of human imagination and creativity
24. DEVELOPMENTAL (TC) - Scientific knowledge is (is not) presented as being tentative
25. FALLIBILITY (TC) - Teacher does (does not) admit uncertainty with respect to content
26. LANGUAGE ACCURACY (TC) - Exact definitions of terminology are (are not) stressed
27. MISINFORMATION (TC) - Teacher does (does not) present misinformation
28. MORAL/ETHICAL IMPLICATIONS (TC) - Moral & ethical implications created by science are (are not) emphasized

29. PARSIMONY (TC) - Scientific knowledge is (is not) presented as being comprehensive as opposed to specific
30. QUANTITY OF MATERIAL (TC) - An inordinately large amount of subject matter is (is not) presented
31. RELEVANCY (TC) - Practical nature of subject matter is (is not) emphasized
32. SUPERFICIALITY (TC) - Teacher's explanations of phenomena are correct but inadequate
33. TESTABLE (TC) - The importance of empirical validation of subject matter is (is not) stressed
34. UNIFIED (TC) - The interrelationship of various science disciplines is (is not) emphasized
35. DEMEANOR (TA) - The teacher is (is not) pleasant
36. IMPERSONAL (TA) - The teacher does (does not) attempt to socialize with students before or after class
37. NON-INSTRUCTIONAL DIGRESSIONS (TA) - The teacher does (does not) tell stories totally unrelated to content being presented
38. ACTIVE ENGAGEMENT (S) - Students are (are not) actually participating in lesson
39. ATTENTIVE (S) - Students are (are not) on task for most of the class period
40. UNSOLICITED QUESTIONS (S) - Students ask (do not ask) unsolicited questions
41. DISCIPLINE (C) - Classroom atmosphere is (is not) highly structured and discipline oriented
42. DOWN TIME (C) - Class time is (is not) often characterized by students waiting for next activity
43. LOW ANXIETY (C) - Classroom atmosphere is (is not) comfortable with little anxiety
44. RAPPORT (C) - Teacher and students do (do not) socialize and interact in a friendly manner

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Variable categories: TG: Teacher's general instructional approach; TC: Teacher's content-specific characteristics; TA: Teacher's non-instructional characteristics; S: Student characteristics; C: Classroom atmosphere.