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ABSTRACT

Conveying an adequate conception of the nature of science to students is considered by many to be implicit in the broader context of what has come to be known as scientific literacy. It has also been demonstrated that possession of valid concepts of the nature of science do not necessarily result in better science teaching. This study examines the possibility that the language teachers use to communicate science content may provide the context (Realist or Instrumental orientations) in which students come to formulate a world view of science. Eighteen high school biology teachers and one randomly selected class from each of their sections (N=409) students were administered pre and post tests at the beginning and end of the fall term using the Nature of Scientific Knowledge Scale (NSKS). Teachers' ordinary language in the presentation of subject matter was found to have significant impact on students' conceptions of the nature of science. These variables represented different contexts (Realist-Instrumental) teachers used to express themselves, scientific information and scientific concepts. (Author/TW)

# The Effect of Teachers' Language on Students' Conceptions of the Nature of Science

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Abstract

Conveying an adequate conception of the nature of science to students is implicit in the broader context of what has come to be known as scientific literacy. However, it has previously been demonstrated that possession of 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. The present study examines the possibility that the language teachers use to communicate science content may provide the context (Realist or Instrumental orientations) in which students come to formulate a world view of science. Eighteen high school biology teachers and one randomly selected class from each of their sections (n = 409 students) were administered pre and post tests at the beginning and end of the fall term using the Nature of Scientific Knowledge Scale (NSKS). Composite scores of the student changes on the Testable, Developmental and Creative subscales were used to compare those six classes that exhibited the greatest change with those six classes that had the least change on the NSKS. Intensive qualitative observations were also conducted on each teacher over the fall semester which resulted in complete transcripts of teacher-student interactions. Qualitative comparisons of classes with respect to six variables related to Realist and Instrumental conceptions of the nature of science were conducted. Teachers' ordinary language

in the presentation of subject matter was found to have significant impact on students' conceptions of the nature of science. These variables represented different contexts (Realist-Instrumental) teachers used to express themselves, scientific information and concepts. Determining the extent to which teachers language had impact on changes in students' conception of the nature of science has direct bearing on all science teacher preparation programs.

The Effect of Teachers' Language on Students' Conceptions of the Nature of Science

## Purpose and Theoretical Basis for Study

Conveying an adequate conception of the nature of science to students is implicit in the broader context of what science educators and national organizations have referred to as scientific literacy (Collette & Chiappetta, 1984; NSTA, 1983; Showalter, 1974; Klopfer & Cooley, 1963). A logical assumption, therefore, in teacher training programs was that improving teachers' conceptions of the nature of science would alter their teaching behaviors in a manner which would enable them to vicariously impart their conception to students. This intuitive assumption concerning the relationship between teachers' conceptions and their classroom behavior has persisted through three decades of research (Cotham & Smith, 1981; Robinson, 1972; Hurd, 1969). Recently, that assumption was tested and found to be unwarranted. Lederman and Zeidler (1986) found that classroom variables specifically related to the nature of science (e.g. Amoral, Creative, Developmental, Parsimony, Testable, and Unified) did not statistically differentiate between the practices of teachers with varying conceptions of the nature of science. It was concluded 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. This leaves open the possibility that conveyance of teachers' conceptions of the nature of science might simply be communicated through ordinary discourse in the presentation of subject matter.

The notion that different conceptions of science may be derived from the language of scientific communication was elucidated by Munby (1976). Munby draws heavily on the works of Toulmin (1960) and Rozak (1968) to describe a subtle but powerful distinction between the language used to convey scientific content and the subsequent understanding of the nature of scientific knowledge by students. That distinction should be a fundamental concern for every science teacher inasmuch as students conceptions of the nature of science may be influenced by it. Munby (1976) reminds us of the "Myth of Objective Consciousness" (Rozak, 1968); a Realist conception which views scientific knowledge as true, real, existing independently of personal experience where scientific objects (atoms, light, ions) have the same ontological status as ordinary sense objects (chair, table).

> 'Cars travel along highways' is an emperical claim: its truth can be assessed by an inspection of the world. But that strategy is not available for the statement, 'Light travels in straight lines,' for this statement is not claiming anything about the way the world is. Instead, it is claiming something about a way of conceptualizing certain phenomena (Munby, 1976, p. 117).

It is quite possible that when teachers use ordinary language without qualifications to describe scientific content, students will come to understand that content in the context of a Realist conception of science. This would tend to foster the positivistic philosophy of science, which may further lead to confusion among quantitative data (implied as having low fallibility) and qualitative data (implied as having high fallibility), and scientific description viewed as empirical truths embedded in atheoretical pure objective sentences (Howe, 1985).

The alternate conception of science that Munby (1976) describes is the Instrumental view in which scientific description represents statements of practical utility. Such a conception emphasizes scientific knowledge as a product of human imagination and creativity, used in a theoretical fashion to allow us to make inferences and construct arbitrary models to explain the behavior of physical phenomena. This conception stresses the tentative nature of scientific knowledge and is consistent with a post-positivistic view. Howe (1985) stresses the significance of this alternative conception:

> ... the post positivistic viewpoint entails that quantitative evidence can never be interpreted independent of extra-theoretical (qualitative) considerations that help define both the theory in question and the broader conceptual scheme in which the theory is embedded; quantification does not eliminate qualitative judgements and therefore is not an alternative to them (p. 15).

It would seem plausible that the language teachers use to communicate science content may provide the context (Realist or Instrumental) in which students come to formulate a conception of the nature of science. However, that reasonable assumption remains untested (Munby, 1976). The purpose of the present study is to determine to what extent teachers' language may influence students' conceptions of the nature of science. Specifically, the question of whether the language used (syntax) and the manner in which it is expressed may, in fact, provide the context (Realist or Instrumental) in which it is understood. Determining to what extent teachers language may have impact on changes in students' conceptions of the nature of science has direct bearing on all science teacher training curricula.

Procedure of Study

The sample consisted of 18 high school biology teachers and the students (n = 409) from one randomly selected tenth grade class of each teacher. The student sample was heterogenous with respect to race, sex and socioeconomic status representing urban, rural and suburban populations.

The Nature of Scientific Knowledge Scale (NSKS: Rubba, 1976) was administered to each teacher and their students at the beginning and end of the fall semester. Validity and reliability information for the NSKS have previously been cited by Rubba and Anderson (1978) and Lederman and Druger (1985). Composite scores of student change for three of the NSKS subscales were used in the present study. The subscales are as follows: Testable (scientific knowlege is [is not] capable of empirical test), Developmental (scientific knowledge is [is not] tentative) and Creative (scientific knowledge is [is not] partially a product of human creative imagination).

One of the researchers who was unaware of students' or teachers' outcomes on the pretest of the NSKS conducted intensive qualitative observations of each classroom prior to the post-test. Complete transcripts of teacher/class verbalizations, records of chalkboard notes, handouts, assignments, teacher mannerisms, nonverbal cues and physical plan were obtained. Each teacher was observed three times throughout the fall semester and approximately 90 pages of field notes were collected for each teacher and their class. This procedure produced approximately 1600 pages of field notes.

Six variables that reflected Munby's (1976) distinction between Realist and Instrumental language were established and operational definitions were constructed (Table 1). Accordingly, these variables reflected implicit conceptions of realist and instrumental philosophies of science. The variables were, in part, derived from a larger set of 44 classroom variables (Lederman and Druger, 1985). Preliminary observations suggested these variables, in conjunction with other classroom factors, conveyed teachers' viewpoints on the nature of scientific knowledge (Lederman, 1985). It should be emphasized that the six variables represent teachers' conceptions of the nature of science by way of the language teachers use to convey subject matter.

Systematic pairwise qualitative comparisons were performed on the field notes between the six classes yielding the greatest change on the composite score for the developmental, tentative and creative subscales and those six classes exhibiting the least change (Table 2). The task of each researcher was to describe which teachers exhibited "more" or "less" of each variable. Thus, the data generated by the comparison of the field notes were perceived as a series of dichotomous variables and their statistical significance tested using an appropriate nonparametric binomial test (SPSS$^x$, 1983). Past inter-rater reliabilities for similar data comparisons have been established (Lederman & Zeidler, 1986) with agreement levels exceeding 96 per cent. A total of 36 comparisons (six classes with the highest change scores on composite subscales with the six lowest change scores on composite subscales) with respect to the six variables were conducted by the researchers. The researchers were "blind" as to the nature of class changes on composite scores with respect to the teacher. Inter-rater reliability on three randomly chosen class comparisons exceeded 94 per cent in the present study.

Results and Conclusions

The results of the binomial comparisons clearly demonstrate differences in the language teachers use to convey subject matter. It would appear to be the case that teachers' language reveal implicit conceptions of the nature of science which, through ordinary discourse, is subsequently conveyed to their students. Table 3 displays the results of the paired comparisons between the six classes yielding the greatest change (toward more instrumental orientations) on the composite score of the posttest with the six classes exhibiting the least change (in this case, moving away from instrumental orientation toward realist conceptions). This technique produced a total of 36 comparisons for each variable. Each teacher was rated as to who demonstrated more of the language consistent with communicating instrumental conceptions associated with that variable.

The results reveal that the variables Testable, Developmental, Arbitrary Constructs, Anthropomorphic Language, Creativity and Subjective were highly significant (in all cases $p < .005$) in distinguishing between instrumental and realist conceptions of the nature of science with respect to teachers' language and subsequent changes in students orientation. For example, considering the variable Developmental, there were 33 comparisons which related teachers whose class had shifted towards a more instrumental orientation as exhibiting more instances of verbal language through ordinary discourse that reflected that orientation. In contrast, there were only 3 instances in which teachers with the least class change (toward instrumental orientations) were rated as exhibiting more verbal behaviors associated with that orientation ($p < .0000$). In practice, the teachers' classes with the least change toward instrumental orientations were found to actually move away from that orientation towards more realist conceptions (again, refer to Table 2). Therefore, by examining each of the variables in this manner it is concluded that the ordinary language teachers use to communicate science content does provide the context in which students formulate their own conceptions of the nature of science.

It is also interesting to examine examples of teachers' language to determine how their language may actually be conveying instrumental (Table 4) or realist (Table 5) conceptions of science. One can explore the potential impact of teachers' language in painting various scenarios in their students' minds as to how scientific knowledge is to be understood and interpreted. For example, in examining the variables Developmental and Arbitrary Constructs/Models, in Table 4, the teachers stress and emphasize the arbitrary nature of models and usually either qualify their use of anthropomorphic language or use it in such a manner that students are prone to understand that it is being used to represent arbitrary examples (models) to convey a point (instrumental orientation). However, in examining the same variables in Table 5, the teachers are presenting subject matter in a manner that implies that models are always equivalent to the actual objects or events they depict and their use of anthropomorphic language suggests that the teachers are factually describing various events. When one examines other variables, it is easily conceivable to imagine how such scenarios are constantly reinforced throughout the school year and to understand why students scores change toward particular scientific orientations to the extent that they were found to change in Table 2.

TABLE 1
Operational Definition of Variables Related to Teachers' Language

| Variables | Realist | Instrumental |
|---|---|---|
| 1. Testable | Importance of empirical validation of subject matter is stressed. | Other approaches to validation of data are presented (qualitative and logical analysis). |
| 2. Developmental | Scientific knowledge is presented being fixed or absolute. | Scientific knowledge is presented as being tentative. |
| 3. Arbitrary Constructs/Models | Models which represent the actual behaviors of objects are stressed. Models are equivalent to and hold the same sense status as the objects and events they depict. | Arbitrary nature and utility of scientific constructs are stressed. Models are used to predict the behavior of objects or events and only suggest how they may be viewed. |
| 4. Anthropomorphic Language | Anthropomorphic language is not accepted by the teacher (or such language is used while implying factual descriptions). | Anthropomorphic language is accepted by the teacher (when such statements are understood in the arbitrary constructive model as above). |
| 5. Creative | Scientific knowledge does not involve human creativity and imagination; it is independent of the knower. | Scientific knowledge is presented as being a product of human creativity and imagination. |
| 6. Objective/Subjective | Objective knowledge exists because we simply reveal what is always present in natural phenomena and consequently must be the case. | Subjective knowledge exists because we always choose how to examine and interpret natural phenomena which may vary with time, place and person. |

TABLE 2
Classification of Teachers' Classes According to Amount of Pre to Post Test Change on Composite Score (Creative, Developmental, Testable)

| Teacher I.D. Number | Class Change Composite Score | Teachers' Language Orientation |
|---|---|---|
| 20 | 7.42 | Instrumental |
| 16 | 4.67 | Instrumental |
| 10 | 4.13 | Instrumental |
| 13 | 3.17 | Instrumental |
| 15 | 2.70 | Instrumental |
| 7 | 2.70 | Instrumental |
| 8 | 0.36 | Realist |
| 6 | -1.28 | Realist |
| 19 | -1.60 | Realist |
| 12 | -2.06 | Realist |
| 9 | -2.29 | Realist |
| 17 | -10.50 | Realist |

TABLE 3
Binomial Tests of Paired Comparisons

| Variables on Which Comparisons Were Performed | Teacher with Greatest Class Change Exhibiting More | Teacher with Least Class Change Exhibiting More | 2-Tailed Probability (p) |
|---|---|---|---|
| Testable | 27 | 9 | .0046 |
| Developmental | 33 | 3 | .0000 |
| Arbitrary Constructs | 31 | 5 | .0000 |
| Anthropomorphic Language | 28 | 8 | .0015 |
| Creativity | 34 | 2 | .0000 |
| Subjective | 35 | 1 | .0000 |

TABLE 4

Language of Teacher's Conveying
Instrumental Conceptions of Science

| Variable | Teacher Number | Instrumental Orientation |
|---|---|---|
| Testable | 10 | "Many years ago a man named Gram found that when he applied a certain chemical to bacterial cells some turned purple and some turned pinkish or red. He concluded that the bacteria must be different and the difference was probably in the cell wall." |
| | 7 | "Well, why don't we all check on this. Let's get as many different sources as we can. One parent or book can be wrong." |
| Developmental | 15 | "This Big Bang Theory about the universe is believed today by most scientists. But there are still many points missing from the story. Tomorrow we may know more and this theory may be changed. Scientists admit this. They don't want to jump to conclusions. You can never be really sure. Now no matter how weird this theory sounds, most scientists believe it because in their minds it's the best model we have to explain the origin of the universe at this time. That doesn't mean that they won't abandon it tomorrow." |
| | 20 | "So be careful with the measurements. You won't come up with an absolute undebatable answer. And I don't expect you to." |
| Arbitrary Constructs/ Models | 16 | "It comes out that way because some scientist set it up that way. He put all the inert atoms together on purpose...The periodic table is just something created by scientists to organize all the elements...This brings up again another problem that always exists in classification. Remember I told you that living organisms don't always fit into the neat little classifications that we have made up..." |
| | 13 | "So I want you to consider a new mental picture. A new model O.K.? We will equate electrons with hydrogens...Okay, so we will use the following mind set..." |
| Anthropomorphic Language | 15 | "Now with these 2 extra neutrons the carbon becomes overweight and it becomes very unhappy, so it sends out pieces of itself. Now I admit that this is a drastic response to being overweight. But it gets the point across." |
| | 13 | "You know there is a junk yard in the cell. There is a junk yard where all the spare parts and molecules are just lying around. It contains loose ATP, proteins, some carbohydrates, and a whole assortment of useful things just dissolved and floating around in a special part of the cell. Its just like a junk yard because I can go in there and pull out whatever I need." |
| Creative | 10 | "With current techniques in gene splicing or recombinant DNA, bacteria can be induced to perform functions that are important to industry. For example, researchers at G.E. have developed a strain of bacteria that eats oil...Now this is a great thing as far as the environmentalists are concerned because it can be used to help clean up oil spills." |
| | 15 | "So, this theory says that all the material of our universe was blasted out from one central spot. It is a very strange idea. That's because we really have nothing to compare it to in our daily lives. We have never experienced any event even close to it in our life time. So, it's kind of tough to imagine." |
| Subjective | 7 | "Watson and Crick won a Nobel Prize in 1953 for discovering the structure of the DNA molecule. They first used the terminology of 'Double Helix' so at least according to them this is what the DNA molecule looks like"..."The conditions of the primitive earth have been developed from a wide range of experiments and evidence which has been put together from all scientific fields. Of course, none of us was there when the earth first formed so we can't be totally sure what it was like." |
| | 10 | "Alright, viruses must be in contact with other life forms to perform their life functions...If they're off by themselves or not in contact with a living cell they don't act alive at all. This is why I believe that viruses are not alive. I don't consider them to be living organisms. Some books agree with me. Some do not. This is just my personal opinion. I could be right, or I could be wrong." |

TABLE 5

Language of Teacher's Conveying Realist Conceptions of Science

| Variable | Teacher Number | Realist Orientation |
|---|---|---|
| Testable | 19 | "Chemical tests for non-organic molecules are usually pretty easy. They usually involve some type of percipitation or obvious color changes like yellows and blacks or something easily seen. And they're usually very accurate and definitive tests. If you use one of these tests and you get a positive result you can be pretty confident that the molecule you're testing is present; providing you've done the test correctly...It usually takes a couple of chemical tests used in combination to be sure that you have a liquid...(their tests) give significant results." |
| | 6 | "Ecologists actually go out and count the number of a particular type of organism found in a certain area at a certain time. The number of organisms counted is called the population density." |
| Developmental | 6 | "This portion of the amino acid is called the amino group. It contains a nitrogen atom and two hydrogens. Always and forever...Exactly, always and forever." |
| | 19 | "There is no doubt that man must have been a cud chewer at one time in his history." |
| | 12 | Student: "What ratio are the hydrogens and oxygens in?"<br>Teacher: "Two to one."<br>Student: "How are we supposed to know that without memorizing it?"<br>Teacher: "You wouldn't, just like you wouldn't have known what at atom is or an element is without memorizing it." |
| Arbitrary Constructs/ Models | 6 | "Watson and Crick described the DNA molecule as a double helix. Three dimensionally, the molecule looks like this" (Hold up molecule to class)..."<br>Teacher: "Some of you found this type of thing out yesterday when you put together dipeptide molecules. What did you find out about keeping them in straight lines?"<br>Student: "You couldn't."<br>Teacher: "That's right because the bonds come off the amino acids at different angles so you couldn't keep the chain absolutely straight." |
| | 9 | Teacher: "The enzyme is what shape?"<br>Student: "The rectangular shape at the right."<br>Teacher: "In diagram B the enzymes remain the same shape before and after but something is different from diagram A. In diagram A the enzyme helped put together two monosaccaride molecules to form a disacchide." |
| Anthropomorphic | 9 | "The genes contain all the information for the form and function of our body. If the genes are upset then something about you will change. Since you're such a finely tuned machine any change would most likely be for the worst." |
| | 6 | "To make energy, to make ATP. That's the only reason they do it. It's not done to make wine or bread or beer. Fermentation is always performed by organisms so they can get energy"..."Your white blood cells and antibodies are always on the lookout for foreign proteins." |
| Creative | 17 | "...You know, not your most exciting line of work. Their (ecologists) idea of a big night out was to count all the organisms in a 12 inch square." |
| | 9 | "...What is cellular respiration? The breakdown of glucose to form ATP. The breakdown of glucose to form ATP. The breakdown of glucose to form ATP...What is aerobic respiration? That portion of cellular respiration that requires oxygen. That portion of cellular respiration that requires oxygen. That portion of cellar respiration that requires oxygen"..."Pretty soon we'll find out that the chromosomes are made of a substance called DNA." |
| Objective | 12 | "If you're really going to understand these two sections you are going to have to see what's really going on."<br>Teacher: "This DNA is a very long and large compound...It's really very interesting because even though it contains so much information, it is really very small. You can't even see it with a microscope."<br>Student: "Then how do you know what it looks like?"<br>Teacher: "They know how it looks from doing tests with chromosomes and seeing what they look like." |
| | 8 | "So, with all this new information about cells and where they came from a new understanding came about...A theory was developed that took all the facts discovered about cells and put them together." |

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