Philosophic Stance of Secondary School Science Teachers, Curriculum Experiences, and Children's Understanding of Science: Some Preliminary Findings

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ABSTRACT: This study sought to establish whether teachers' views about the nature of science and scientific inquiry are reflected in their choice and design of learning experiences and, therefore, are significant influences on children's understanding of science. Even those teachers who hold clear and coherent views about science do not plan laboratory-based activities consistently in relation to those views, concentrating instead on the immediate concerns of classroom management and on concept acquisition and development.

KEYWORDS: philosophy of science, children's views, curriculum, laboratory work, teachers' views, teachers' actions

It seems reasonable to suppose that a child's understanding of the nature of science and scientific activity results from the interaction of curriculum experiences and informal learning experiences, including television, movies, magazines, books, advertising, museum visits, and so on. In general terms, curriculum influences are of two kinds: those that are explicitly planned and those that comprise the implicit or "hidden" curriculum. There are explicit messages about science in textbooks (for example, early chapters that give a brief outline of what science involves) and in many Science-Technology-Society-oriented materials. And, on occasions, teachers take steps to emphasize particular features of scientific method during laboratory work and class discussions. More frequently, however, messages about the nature of science are conveyed implicitly, through such things as instructional language, biographical material, and design features of learning experiences — particularly laboratory work and writing tasks.

It seems self-evident that teachers' own views about the nature of science and scientific inquiry will influence substantial aspects of their professional practice, including decisions about the design of learning experiences. For

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example, we would expect there to be a direct correspondence between teachers' views on the nature of scientific inquiry and the ways in which they deal with observation and experimentation in laboratory classes. Teachers' views about the role and status of scientific theory, and the way in which scientific knowledge is produced and validated, would be expected to influence their views about how scientific knowledge is learned and, therefore, how learning experiences should be designed.

Benson's (1986) finding that views about science held by children *within* a class are often remarkably consistent, while those of children in *different* classes can be substantially different, lends support to the contention that children's views are strongly influenced by curriculum experiences and that these, in turn, are determined by teachers' own views about science (their "philosophic stance"). This set of assumed relationships is represented diagrammatically in Figure 1.

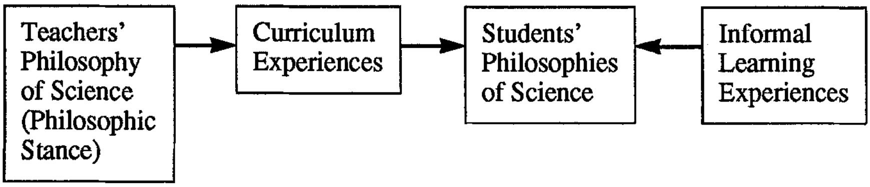

Figure 1. Philosophic Stance and Children's Understanding of Science

There is some further evidence in the science education literature to support such a view. For example, Duschl (1983) found that teachers' beliefs about science (which were largely of a logical positivist nature) influenced their choice of curriculum activities and materials, Lantz and Kass (1987) found that three high school chemistry teachers taught the same content in significantly different ways because of differences in their understanding about the nature of chemistry, and Lederman (1986) concluded that pupils' conceptions of the nature of science are positively influenced by science teachers who model an inquiry or problem-solving approach. Additional evidence is provided by Wolfe's (1989) study of teachers' practices with gifted children and by Zeidler and Lederman's (1987) finding that teacher language (realist or instrumentalist) had a significant effect on students' views about the nature of science. In an experimental study, Dibbs (1982) found that he could impact quite markedly on children's views about scientific method by basing his teaching unambiguously on inductivist, verificationist, or hypothetico-deductivist conceptions of the nature of scientific experiments. More recently, Carey et al. (1989) have shown that a purpose-built "nature of science" teaching unit can effect a shift in the understanding of Grade 7 students on matters relating to the construction of scientific knowledge.

Ascertaining Views

The traditional way of ascertaining teachers' and students' views about science is by means of questionnaire and survey instruments using multiple choice items or Likert scales. A number of such instruments have been developed. In fact, a survey by Mayer and Richmond (1982) identified at least 32, among which the best known and most widely used are the Test on Understanding Science (TOUS)(Cooley & Klopfer, 1961), the Nature of Science Scale (NOSS) (Kimball, 1967), and the Nature of Scientific Knowledge Scale (NSKS) (Rubba & Anderson, 1978). Instruments dealing with the processes of science, such as the Science Process Inventory (SPI) (Welch, 1969a), the Wisconsin Inventory of Science Processes (WISP) (Welch, 1969b), and the Test of Integrated Process Skills (TIPS) (Burns et al., 1985; Dillashaw & Okey, 1980) could also be regarded as providing information on children's understanding of science.

In general, these instruments are constructed in accordance with a *particular* philosophical perspective and are predicated on the assumption that all scientists behave in the same way. Hence, student responses that don't correspond to the model of science assumed in the test are adjudged to be "incorrect." Moreover, as the publication dates reveal, many of these instruments pre-date significant work in the philosophy and sociology of science and so are of limited value for the 1990s.

In adopting TOUS for use in British schools, Coxhead and Whitfield (1975) updated it, shortened it, and reduced its linguistic complexity, producing a 20-item Science Understanding Measure (SUM). However, SUM still "approves" a particular view of science — in this case, a Popperian methodology. Dibbs (1982) modified SUM so that student and teacher responses could be scored in terms of three alternative views: verificationist, inductivist, and hypothetico-deductivist. By using quotations from the work of Popper and Kuhn, Rowell and Cawthron (1982) developed a technique for use with Australian university students that enabled them to gain an understanding of the extent to which Kuhnian views had penetrated science education. Interestingly, the technique enabled students to express views both about what science *should be* as well as what science *is*. More recently, Koulaides and Ogborn (1988, 1989) have used a 16-item instrument, with an elaborate scoring system, to identify the disposition of an individual within what they claim are 'the five main trends in the philosophy of science': inductivism, hypothetico-deductivism, contextualism (rationalist version), contextualism (relativist version) and relativism.

However, despite these developments and modifications, a major problem of questionnaire methods remains unsolved: students don't always perceive and interpret test statements in the way that test designers intend, or, as Lederman and O'Malley (1990) put it, "language is often used differently by students and researchers." In the design of *Views on Science-Technology-Society* (VOSTS), this problem was circumvented by using empirically derived (from student writing and interviews) multiple choice items (Aikenhead, Fleming & Ryan, 1987; Aikenhead & Ryan, 1989; Aikenhead, Ryan & Fleming, 1989). It is the flexibility of VOSTS, and the wide range of aspects covered (Definitions, Influence of Society on Science/Technology, Influence of Science/Technology on Society, Influence of School Science on Society, Characteristics of Scientists, Social Construction of Scientific Knowledge, Social Construction of Technology, Nature of Scientific Knowledge), that give it such enormous research potential and make it the most sophisticated questionnaire instrument yet developed in the field.

A radically different approach, which can be particularly useful with younger students, is the use of open-ended methods such as Chambers' Draw-a-Scientist Test (DAST)(Chambers, 1983). A significant problem with DAST is that it isn't always clear whether children are just supplying the expected stereotype (as a kind of "dramatic device") or giving us insight into what they really believe. Children do "compartmentalize" their knowledge (Claxton, 1990), and so may have at least three "versions" of the scientist at their disposal: the everyday (movie) image of the scientist, the school image of the scientist, their own image of the scientist. It is sometimes unclear which one DAST is accessing.

One way to get around the problem is to talk with children about their drawings and the thinking behind them. In such circumstances, it seems reasonable to ask whether it makes a difference if discussion is conducted in a science lesson rather than elsewhere in the curriculum. In other words, does the stimulus of being in a school science lesson make a difference to children's responses? In the present study, it is becoming increasingly clear that children's responses are not stable and consistent. When asked to write (in an open-ended way) about science, scientists and scientific discoveries, they produce different kinds of responses in different "academic settings." The nature of these differences is currently being explored.

With older students, these problems appear to be absent, so that Aguirre et al. (1989), for example, were able to use written responses to open-ended questions, such as "What does the word science mean to you?", to gain insight into the views of students embarking on pre-service teacher education courses. Even more versatile and flexible and, therefore, even better suited to eliciting respondents' particular (idiosyncratic) views is the non-directive interview. Basically, this was the method employed in this study for ascertaining *teachers'* views. However, because the study had a particular focus of interest (the ways in which teachers' views about science impact on curriculum decision-making and, therefore, on their students' views about science), an interview protocol was adopted that permitted teachers to express their own views and allowed directed questions to be used to focus attention quite specifically on the ways in which they "translate" their philosophy of science into curriculum experiences — in particular, into laboratory work. Similar approaches using both open and directed questions have been employed with students in research studies by Benson and Jacknicke (1989), Carey et al. (1989) and Larochelle and Desautels (1991a).

The Interviews and the Teachers

Given the importance afforded to laboratory work in contemporary science education, and the fairly close correspondence one might anticipate between teachers' views about the nature of experiments (in particular, the relationships between observation, theory, and experiment) and the kinds of laboratory work employed, it was decided to focus interviews with teachers on matters relating to the conduct of experiments in the construction of scientific knowledge. Responses to principal questions such as "What is the purpose of experiments in science?" and "What do you think makes *scientific* knowledge different from other kinds of knowledge?" were probed by using whatever additional questions were deemed necessary to clarify each teacher's views regarding the way(s) in which experiments are conducted, the purpose(s) they have, the way(s) in which conclusions are drawn, the reliability of observational data, and so on. The student responses in the VOSTS studies reported by Aikenhead and his co-workers and the questionnaire devised by Koulaides and Ogborn (1988) were particularly helpful in thinking about the kinds of supplementary questions that might be required. The purpose of the subsidiary questioning was to try to establish whether the views expressed constituted a coherent, consistent "philosophic stance." Coherent views were classified as *inductivist* (emphasizing the priority of observation), *verificationist* (claiming that experiments are used to verify or "prove" theories), *hypothetico-deductivist* (prioritizing theory and emphasizing falsification by critical experimentation), and *contextualist* (asserting that scientists employ whatever investigative strategy they deem appropriate to the circumstances — i.e., there is no *one* method of science).

To date, 12 teachers (8 women, 4 men), with teaching experience ranging from 2 years to 23 years, have been interviewed. All teach across the three major sciences in secondary schools in New Zealand. The research is not intended to provide a survey of the philosophic stances exhibited by New Zealand's teachers — the sample is too small, and no attempt was made to ensure a representative sampling. Five of the teachers made contradictory statements which revealed substantial areas of confusion and uncertainty about scientific experiments, and so could not readily be said to subscribe to a particular philosophic stance. However, a number of teachers did express reasonably consistent views along inductivist (2), hypothetico-deductivist (3), and "contextual"(2) lines.

Following Brickhouse (1989, 1990), only teachers with a coherent, clearly identifiable and consistent philosophic stance have so far been involved in the second stage of the research, involving a close examination of curriculum plans, worksheets, student lab books, assessment and evaluation materials, and observation of lessons (especially laboratory work). Each of the five teachers — two Inductivists (Margaret and George), two Hypothetico-deductivists (Marilyn and Linda), one Contextualist (John) — was observed for about 15 hours over a period of several weeks. Whenever possible, post-lesson interviews were conducted immediately after the lesson. Teachers were asked about the purposes of the lesson they had designed, what features they regarded as significant, whether it had gone as planned, the extent to which they believed it to have been successful, and so on.

Rhetoric-Practice Mismatch

One of the basic questions underpinning the research is whether the expressed philosophic stance of the science teachers is reflected in their choice and design of classroom activity. The short answer appears to be "no." For example, an inductivist approach (claimed as their philosophic stance by only two of the group) was much the most common in practice, and a verificationist stance on the role of experiments — a view not claimed or admitted to by any of the teachers during interview — was, nonetheless, much in evidence in the classroom. More interestingly, perhaps, teachers appear to *change* their stance in response to changes in subject matter and perceived ability of the class, being more inclined towards an inductivist stance with biology topics and with those students regarded as lower in ability.

The most intriguing case of rhetoric-practice mismatch is that of the teacher (John) who expressed strongly contextualist views in interview. In practice, he displayed a remarkable *consistency* in his approach. Following a brief discussion of the purpose of the proposed activity (usually expressed in terms of "Today, we want to find out what happens when ..."), groups of two or three students were provided with brief written instructions on procedure to be adopted and observations to be made, via a worksheet or on the blackboard. After 25-30 minutes, results would be "discussed," patterns and trends would be identified, and the students would be invited to speculate on likely explanations. If none was forthcoming, or discussion appeared to be "off track," the "correct" explanation would be provided. What was most striking was John's reluctance to entertain alternative explanations and the casual way in which he dismissed data that seemed to indicate different patterns, trends, and categories. His lessons were littered with comments such as "It [the experiment] seems to have gone wrong," "Why don't you use Michelle's results?", and "I think that may be an error on your part, can you check it?" These from a teacher who professed a firm commitment to children "finding out for themselves" and to a view of science in which scientists do whatever they deem appropriate in the circumstances. In practice, what John's students were learning is that science has a "right answer" and that the purpose of laboratory work is to identify it, by means of a clearly prescribed method.

Post-lesson discussions with the teachers gave some insight into the reasons for these inconsistencies and mismatches. Just as many of Rowell and Cawthron's (1982) university students perceived a difference between science as it *is* and science as it *should be*, so teachers seem to have an "ideal model" of science (what they perceive science ought to be like) and a model of what is possible in a school laboratory, given the constraints of time, resources, pressure of the syllabus and examinations. Some teachers mentioned the considerable management and organizational problems involved in laboratory work, especially when technician support is unavailable. (It is rare for New Zealand schools to have laboratory technicians.) It might be expected that these factors will be fairly constant over time and so will constitute a fairly predictable *loss of integrity* in a particular teacher's philosophic stance.

Changes in Philosophic Stance

Other influences seem to be more situationally dependent and might, therefore, be regarded more as features or causes of *instability* in the teacher's translation of philosophic stance into educational practice. Prominent among these are specific lesson content and perceptions of the ability level of the students. In general, inductivism is seen to be "easier." A number of teachers shared George's view that less able students need "lots of data before they can generalize." What these teachers seem to be saying is that inductivism is easier to use as a model of *learning*, rather than easier to understand or more appropriate as a model of *science*. Concern with concept acquisition and development is seen as a major priority for *all* students, but with higher ability students, as one teacher (Marilyn) says, "we can afford to take some time out to look at scientific method." She goes on to comment: "With these [lower ability students], I'm just happy if I can get the basic stuff across reasonably well." None of the teachers in this study said that learning about science is less important for lower ability than for higher ability students. Indeed, if anything, they say that content is *less* important for slow leaners than it is for quick learners. However, they believe that they have to put more emphasis on it in class in order to "get it across" — a situation that is quite genuinely paradoxical for them, and a matter of some consternation.

The issue seems to hinge on the question of teacher-directed versus student-directed learning. In general, this group of teachers is less inclined to cede control to students perceived as less able. All have the view that learning in science is difficult, "especially for most of these kids" (Margaret). As a consequence, "experiments have to work" and students need "good clear conclusions." In effect, teachers have to "lead them by the nose," as John put it. Thus, in planning laboratory work, all else is subordinated to the content issue and to getting the right results from experiments.

It is the priority afforded to learning *content* that triggers other shifts in philosophic stance. The teachers so far observed seem to be fairly consistent in presenting biology as predominantly inductivist and chemistry and physics as more hypothetico-deductivist. However, the shift in philosophic stance between subjects seems to reflect the learning opportunities presented by the particular topics being taught, rather than a belief in a clear demarcation between the methodology of different sciences. In one sense, this could be a philosophically legitimate position to adopt. Those who subscribe to a "contextualist" view, for example, argue that science has no one method, that the particular approach to an investigation is determined by the specific nature of the problem, the conceptual understanding of the investigator, the experimental facilities available, and so on. However, as will become apparent in the following section, changes in the approach of these teachers are prompted by "learning opportunities" related more to concept acquisition than to the nature of scientific inquiry. Thus, important insights into the "contextualist" nature of scientific inquiry are lost or confused.

Priorities in Planning

In retrospect (i.e., in post-lesson interviews), teachers justified their choice of laboratory work because it illustrated a theory, got a point across, motivated students, or enabled students to be active. Although, in the earlier interviews, these teachers had expressed a view that teaching students about science and about the nature of experimentation in scientific practice is important, and that laboratory work is the best vehicle for doing so, they did not cite what children had learned about science as a criterion of evaluation *after* the lesson. Considerations relating to teaching *about* science had disappeared almost entirely from post-lesson rationalizations. Concerns about discipline and organization, what approach best suits the content, concern with experiments and demonstrations that "work," and with ensuring a good variety and sequence of instructional activities ("I work on a 20 minute rule: every 20 minutes or so I *change* activities," said Margaret) invariably took precedence over whatever teachers' personal philosophy of science might tell them about what constitutes a good scientific investigation or a good experiment. Quite simply, when it comes down to the "nitty gritty" of planning lessons, philosophical issues are "on the back burner" (Marilyn). As King (1991) comments: "something happens ... that causes (teachers) to revert to scientistic ways of thinking ... it is extremely difficult to fly in the face of encyclopedic textbooks, budgets and class size constraints, and standardized achievement tests which stress fact acquisition."

In this study, curriculum decisions were retrospectively rationalized by the teachers in terms of three broad categories of concern. In order of decreasing importance, these are:

- management and organizational principles
- considerations about concept acquisition and concept development
- considerations about the nature of science and scientific activity

Results so far obtained seem to reinforce Lederman and Zeidler's (1987) conclusion that "a teacher's classroom behavior does not vary as a direct result of his/her conceptions [about the nature of science]" and that "simply possessing valid conceptions of the nature of science does not necessarily result in the performance of those teaching behaviors which are related to improved student conceptions." In general, activities relating to learning about science are largely *unplanned.*

Some Consequences for Students

It seems reasonable to assume that students will interpret what goes on in a lesson labelled "science" as representing scientific activity. What has become clear through this research is that even when they hold clear and coherent views about science and scientific inquiry, teachers do not plan laboratory-based lessons consistently or carefully in relation to those views, concentrating instead on organizational issues and activities designed to assist concept acquisition and development. Laboratory work is seen primarily as a *teaching device,* the purpose of which is to ensure that students gather evidence that leads convincingly to the particular view the teacher wants to "get across" (see also Gallagher, 1991). If students don't obtain those data, the experiment is deemed to have "gone wrong" or the students are told they haven't been "careful enough" and are instructed to consult the textbook for the "right result." So despite the prominence given to "experiments," teachers easily dismiss their findings if they don't fit their immediate instructional intentions. The situation is further complicated and confused by the fact that teachers have many other goals for laboratory work: motivation, skills acquisition, development of social skills, and so on. Sometimes these point to design features that are in conflict with those that would give a good understanding of the nature of experiments in science (Hodson, 1988; 1992).

Among teachers in this study, there was considerable emphasis on "making the students active" and "getting the less able students involved" (Marilyn). Active learning is seen as desirable in three related senses: as a motivational device (George: "children enjoy practical work"); as a way of providing a variety of lesson activities (Margaret: "breaking the lesson up"); as a way of enhancing learning (John: "doing it yourself is far more effective than being told"). The last justification is particularly ironic in view of the fact that in many of the lessons observed students were *not* "doing it for themselves." Rather, they were being manipulated by the teacher towards particular pre-determined learning outcomes. Little wonder that they see through the pretence (Driver, 1975; Wellington, 1981). But, in doing so, they gain a distorted view of the nature of scientific experiments and are likely to be confused by the frequent conflicts between explicit messages about science as a tentative human construct and implicit messages that scientific knowledge is "discovered" and certain.

Brickhouse (1990) found that "teachers' views of how scientists construct knowledge were consistent with their beliefs about how students should learn science." As far as experienced teachers are concerned, she reports: "Their classroom instruction was remarkably consistent from one day to the next, and they expressed personal philosophies that were congruent with their actions in the classroom." However, among the teachers studied in this research, there was *in*consistency between their expressed views about how scientific knowledge is constructed and validated within the community of scientists and their views about scientific knowledge implied in the choice of learning experiences.

That inconsistency took two forms. With one teacher (John), there was a persistent mismatch, producing consistently conflicting messages. He consistently presented scientific knowledge to students in (authoritarian) ways that were in direct contradiction to his expressed views concerning the construction of that knowledge by scientists. With other teachers, the relationship kept changing (i.e., it is *unstable*). With two of the teachers (Marilyn and Linda), these "mixed messages" were remarkably wide-ranging: from scientific knowledge presented as absolute truth about the universe, through socially constructed and culturally determined knowledge, to theory as a mere "theoretical fiction." While eclecticism (or contextualism) regarding scientific *method* might be regarded as a "good thing," and in tune with the views of many contemporary theorists, the projection of conflicting (and unexplained) views about the role, status, and origin of the scientific *knowledge* that is produced is a major cause for concern. The problem in these classrooms is that underlying messages neither consistently reinforce nor consistently conflict: they serve merely to confuse.

At the heart of the problem, and the root cause of the persistent mismatch between philosophic stance and curriculum experiences, is the failure to acknowledge the social construction of scientific knowledge in the design of laboratory activities. Because an "experiment" in school is designed primarily to lead students to a particular view, because it is regarded by teachers as a way of convincingly revealing meaning, rather than constituting an element in the negotiation or construction of meaning, the implicit curriculum message is that scientific theory is a body of authoritative knowledge revealed and authenticated by observation and systematic experimentation. Design of laboratory work is not driven by a perception of what constitutes a real scientific experiment in the activity of *doing science*, and certainly not by a desire to get students to reflect on their experiences in the school laboaratory as a way of gaining insight into the nature of knowledge construction in science. Thus, discrepancy between theory and observation is not regarded as an opportunity to discuss the ways in which knowledge is negotiated. Yet, in *talking* about science, these same teachers may promote the view that scientific knowledge is socially constructed, and in many other (nonlaboratory) learning activities they may adopt a constructivist approach. Further discussion of these matters, and the confusions that result, can be found in Benson (1989), Cheung and Taylor (1991), Duschl and Gitomer (1991), Larochelle and Desautels (1991a, b), Russell and Munby (1989), Songer and Linn (1991).

Conclusion

This research was predicated on the grounds of a simple relationship between teachers' views about the nature of science, the design of curriculum experiences (particularly laboratory activities), and students' views about science (Figure 1). The research reported here suggests that this simple linear model should be replaced by a more "realistic" view that takes account of the loss of integrity in translating rhetoric into action, identifies potential areas of conflict with teachers' views about the nature of learning, and recognizes the unstable nature of a teacher's philosophic stance when confronted with the demands of planning worthwhile and effective laboratory activities in the face of financial constraints, insufficient time and the dictates of examinations. More detailed analysis of data from classroom observations and post lesson interviews will assist the development of such a model and may identify some priorities for teacher education and curriculum development.

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