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ABSTRACT

This study is a qualitative investigation into a teenager's view of the nature of science. This thesis draws on arguments from various philosophies of science and describes the data collection techniques employed. The data are presented in eight categories which are assumed to be related to the notion of "truth" that is central to this teenager's view of science. Generally it was found that the teenager believes that the primary task of science is the same as that of the scientist--to find cures for diseases such as cancer and AIDS. The individual regards science as "truth" and believes that it is necessary to know what is inside a substance in order to explain how it works. The student's respect for science and for her science teacher suggests that her view of truth is a function of the relationship she has with the source of the information, since she uses the two categories of "truth" and "lie" to sort out her notion of truth. It is also suggested that gender may be intimately related to how students regard the truth of statements. Several questions about students' views of science are raised and are suggested to be the basis of further research. (Author/TW)

A TEENAGER'S VIEW OF THE NATURE OF SCIENCE

by

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Abstract

This study is a qualitative investigation into a teenager's view of the nature of science. It draws on arguments from the philosophy of science and recent research findings to develop a rationale for this type of inquiry, then it describes the particular data collecting strategies that are employed. The data are presented in eight categories which seem to be related to the notion of "Truth" that is so central to this teenager's view of science. Generally it is found that Susan believes the primary task of science like that of scientists, is to find cures for disease such as cancer and AIDS. She regards science as truth and believes that it is necessary to know what is inside a substance in order to explain how it works. She also believes the contents of the *National Geographic* magazine as truth but dismisses the *Enquirer* as "garbage." Her respect for scientists and for her science teacher suggests that her view of truth is a function of the relationship she has with the source of the information, since she uses two categories "Truth" and "Lie" to sort out her notion of truth. The thesis discusses Susan's notion of truth, and speculates about why she holds this particular view. These findings raise important questions about students' views of science which could be the basis for further research.

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Finally I thank God for giving me the strength to bring this work to completion. More importantly I thank Him for teaching me about Himself as I prepared this thesis. May this work be used to His honour and to His glory.

Dedication

To my mother

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CHAPTER 1

INTRODUCTION

This study is a qualitative investigation into a teenager's view of the nature of science. It draws on arguments from the philosophy of science and recent research findings to develop a rationale for this type of inquiry, then it presents the interview data and examines them in the light of current research findings. The study concludes by issuing a call to science educators to conduct more studies of this type, since they have the potential for providing rich information about students' views of the nature of science. It also raises some important questions about this individual's view which could be the basis for further research on students' views on the nature of science.

THE PROBLEM

There appears to be a growing disquiet among science educators that students are not understanding some of the basic concepts about science. Take the case of Jim and Keith described below.

Observer: What are you doing at the moment?

Jim: Um... that one there (points to step 3 in a book) No. 3

Observer: What is that?

Jim: (Looks at partner who offers no comment, then picks up book.)

Observer: Can you tell me without reading it?

Jim: I've forgotten

Observer: What is the whole experiment about?

Jim: (No response; grins)

Later that day the same two pupils were heating a yellow solid.

Observer: What are you doing now?

Keith:	Heating this
Observer:	I see, what for?
Keith:	Well... (races off to desk on the other side of room bringing back book) we are doing No. 5
Observer:	What did you do before you started heating it?
Keith:	These ones here (Points to No. 3 and 4 of instructions).
Observer:	Can you tell me what you have found out?
Keith:	We got this yellow stuff
Observer:	Can you tell me the purpose of this activity?
Keith:	No... not really (Osborne & Freyberg, 1985, pp. 72-73).

It is clear that Jim and Keith do not understand what they are doing. They are merely following instructions "cookbook style!" If they were the only two students who lacked understanding of what they were doing, there would be little cause for concern, but the recent data on children's ideas in science (Driver, Guesne & Tiberghien, 1985) indicate that most students do not understand what is going on in their science classes, and in instances where they do, their understandings are often different to those of scientists. If students do not hold the same views as scientists, exactly what are their views about science? This is the problem to which this study now turns.

PURPOSE OF THE STUDY

The main purpose of this study is to investigate and describe in detail a teenager's view of the nature of science. A related purpose is to demonstrate the power of this research method in providing detailed information on this individual's view of science. Finally the study becomes the vehicle for making public this type of data which would otherwise be unavailable.

Since the concept "nature of science" is central to this research, it needs to be clearly defined. In this study an individual's view of the nature of science is interpreted as that person's perception of science. This is very different from scientific concepts, such as energy and chemical equilibrium, which are theoretical products of the discipline. The distinction can be made clearer if the study is viewed as an "end chasing exercise" in which scientific concepts are the means, and the individual's view of the nature of science, is the end being chased. Thus although the study focuses on the nature of science rather than scientific concepts, talk of the former inevitably involves the latter. Within this framework, this study seeks to determine one individual's view of the nature of science.

SIGNIFICANCE AND LIMITATIONS OF THE STUDY

The significance of this study to science education research is discussed at length in Chapter 2. This study is also significant to the teenager involved in the research since it was the first time she had ever been involved in a study of this kind. Besides affording her the opportunity to hold lengthy discussions with an adult, which she admitted was something that she rarely did, the discussions helped her to clarify some of her thoughts about what she did and did not understand about science.

Any attempt to describe an individual's view of the nature of science is influenced to some extent by factors such as the investigator's theories about learning, knowledge, and the nature of science. This study is no exception. It also reflects some of the weaknesses of a novice researcher since I missed some opportunities to further investigate this teenager's view of science due to my lack of experience in conducting research. This only became apparent when the interview tapes were transcribed. It is important to point out that this study is not an empirical claim about teenagers' views of the nature of science since it describes only one individual's view of science.

Chapter 2 provides the rationale and theoretical framework for the study. It is followed in Chapter 3 by a detailed description of the particular data collecting strategies that were used. The data are presented in Chapter 4 and the study concludes in Chapter 5 with a discussion of the research findings and the implications of these findings for science education.

CHAPTER 2

RATIONALE

The rationale for the study begins with the assumption that understanding the nature of science is a significant science educational aim. This chapter first presents background information on the nature of science, then it reviews studies which indicate that all is not well in Canadian schools with respect to this particular aim. The move to a thorough investigation of one student's view of the nature of science draws support in the third section of the chapter from recent data on children's ideas in science. Here a brief review of the literature shows the importance of understanding how students view various scientific concepts. This is followed by arguments from the philosophy of science that support this research. The last section reports on previous approaches to this type of inquiry, and points out the inadequacy of using quantitative methods for obtaining such information. These interrelated discussions converge on the use of qualitative procedures to investigate one individual's view of the nature of science.

THE NATURE OF SCIENCE

Understanding the nature of science is not a new aim of science education. It was especially important to the science education reform of the 1960's and it resulted in the development of new curricula such as PSSC Physics, CHEMStudy, and BSCS Biology (Robinson, 1968). Today, more than two decades later, this aim still figures prominently as one of the desired outcomes of science teaching in Canadian schools (Orpwood & Souque, 1984) yet despite its salience, there are indications that all is not well concerning this particular aim.

RESEARCH FINDINGS

In response to growing criticisms about the state of science education in Canada, the Science Council of Canada embarked on a nationwide investigation in October 1979, to determine just how serious the problem was. The criticisms for the most part seemed to revolve around two major issues: dissatisfaction with the way science was being taught in schools, and lack of appreciation among students for the personal, social or national relevance of science. During the long investigation that followed, the researchers discovered that several areas were in urgent need of attention.

During the first phase of the Science Council study, Orpwood and Souque (1984) found that in almost all the provinces, understanding the nature of science figured prominently as a goal of science education in the curricula set out for the Middle and Senior Years. They also noted that of the 34 textbooks examined in the study, 22 made reference to the nature of science in either a specific or a general context. Yet, in almost all these texts, messages about the nature of science appeared in the form of definitions of science and the scientific method.

In another phase of this same study, Orpwood and Alam (1984) undertook a detailed investigation of 6,865 elementary and secondary school science teachers drawn from all over Canada. They found that the teachers did not consider understanding the nature of science a very important aim of science education. Moreover these teachers complained that this aim was difficult since it could only be achieved by very "bright" students.

Olson and Russell (1984) contributed to the Science Council's study with a detailed report on case studies of science teaching in eight Canadian schools. The results were less than encouraging. Generally, they found that the teachers' main concern was "to get the material covered" in the allotted time. This they achieved in most instances, but it was frequently at the expense of a better understanding of science by their students.

Most teachers were aware that their students were experiencing difficulty in understanding science, but they were reluctant to try different strategies and cited lack of time as the main reason. At "Prairie High" one teacher complained that nature of science topics took up too much time, while another said that this type of work didn't "sink in."

Almost two decades ago, Ausubel (1968) observed:

> The most important single factor influencing learning is what the learner already knows; ascertain this and teach him accordingly (p. iv).

Since the Science Council study did not investigate students' views of the nature of science, this advice is particularly relevant given the present state of science education in Canada. The current inquiry into children's ideas in science is an indication that some researchers are heeding Ausubel's advice and their research has so far uncovered some disturbing facts about students' understandings of science. Some of these are presented below.

CHILDREN'S IDEAS IN SCIENCE

Until recently, the major thrust of research in science education was on the learner's assimilation of knowledge and the implementation of curricula (White & Tisher, 1985). Since the late 1970's however, there has been a shift in emphasis as researchers began turning their attention to investigating students' understandings of natural phenomena. This rapidly expanding field of inquiry has attracted international interest and to date several studies have been done on students' understandings of various scientific concepts. Some of these are documented in the following table.

Topic	Researcher(s)
Dynamics	Champagne, Klopfer & Anderson (1980) Clement (1982) Di Sessa (1981) McCloskey (1983) Sjøberg & Lie (1981) Trowbridge & McDermott (1981) Viennot (1979)
Gravity	Gilbert, Watts & Osborne (1982) Gunstone & White (1981) Stead & Osborne (1981)
Heat	Anderson (1980) Driver & Russell (1982) Engel (1982) Erickson (1979) Erickson (1980) Tiberghien (1980)
Light	Guesne (1985) Stead & Osborne (1980)
Particulate Theory	Novick & Nussbaum (1978)
Density	Rowell & Dawson (1983)
Electricity	Fredette & Lockhead (1980) Osborne (1981) Russell (1980)
Air and air pressure	Engel (1982) Engel & Driver (1981) Séré (1982)

Table 1. Studies of students' understandings of natural phenomena.

Driver (1983) is among the many who have argued that when a pupil enters school his or her mind is not a *tabula rasa* waiting to be filled with teacher's science. The child already has some preconceived ideas about the subject. Sometimes these ideas can easily be replaced by those of the teacher, but there is accumulating evidence showing that children cling to their ideas very strongly despite science teaching (Novick & Nussbaum, 1978). These views and ideas that children hold have been given a variety of names in the literature: "alternative frameworks" (Driver, 1983), "misconceptions" (Helm, 1980), "preconceptions" (Ausubel, 1968), "children's science" (Gilbert, Osborne & Fensham, 1982), and "commonsense views" (Hills, 1983). It has been found that such views and ideas are "amazingly tenacious and resistant to extinction" (Ausubel, 1968) and this gives rise to the interpretation by adults that children hold misconceptions and misunderstandings of science.

According to Gilbert, Osborne & Fensham (1982), for over a century science educators have either dismissed children's ideas as "wrong" and therefore in need of correction, or else failed to take notice of them. These researchers lament that for too long the *tabula rasa* and teacher directed approaches have underpinned science curricula, and they issue a call to science educators to pay serious attention to the student's own view of science. This call for change had been advocated earlier by Driver and Easley (1978) and it would appear that some researchers are taking up the challenge, as indicated by the large number of studies reported in this area over the past five years. This research has resulted in a growing awareness among people involved in science education that some of the basic ideas of science are difficult for children to understand, and that their views frequently differ from that held by scientists. This is illustrated by the following example.

Pupils in a secondary school who were familiar with the terms "atom" and "molecule" were asked, "What do you think an atom is like?" The following responses which are reproduced here exactly as written, were received from some second-year pupils.

> An atom is like a kind of bomb its size is a long round thing and it has gas inside and if you light a match it will have flames all around and it may explode.
>
> An atom is a very small and microscopic black round thing which everything is made of. And if split it will be exploed.
>
> Little round things with stems going of of them joining on to another round thing. 10's of thousands of an inch big (Watson, 1974, p. 31).

This is not an isolated incident. Urevbu (1984) reports similar difficulty among his Nigerian students as they attempt to explain the concept of energy.

In another incident, Driver (1983) reports the case of two 11-year old boys, Tim and Ricky, who are doing simple experiments on the extension of springs when loaded. One end of the spring is supported in a clamp, and a polystyrene cup is hanging from the other end. Following instructions they investigate the extension of the spring as they add ball bearings to the polystyrene cup. Ricky adds the ball bearings one at a time and measures the length of the spring after each addition. Suddenly Tim interrupts. "How far is that off the ground? Pull it up and see if the spring does not move any."

Ricky unclamps the spring, raises it higher up the stand and again measures its length. Apparently satisfied that the length is the same, he continues with the activity. Later when Tim is asked the reason for his suggestion, he explains that he thought the weight of the cup of ball bearings would increase if it were raised. To explain his reasoning, he picks up two marbles and holds one up higher than the other:

> Tim: This is farther up and gravity is pulling it down harder. I mean the gravity is still the same but it turns out it is pulling harder the farther away. The higher it gets, the more effect gravity will have on it because, like if you just stood over there and someone dropped a pebble on him, it would just sting him, it wouldn't hurt him. But like if I dropped it from an aeroplane, it would be accelerating faster and faster and when it hit someone on the head, it would kill him. (pp. 5-6).

These excerpts give some indication of the kinds of understandings that are commonly held by students as they try to make sense of the world about them. It is obvious that their explanations are very different from what would commonly be acc as scientific explanations. Why is this? Possible answers may be found in the way science is taught at school, the use of language in science, and in the nature of scientific knowledge.

SCIENCE AS TAUGHT IN SCHOOLS

In a Science Council of Canada discussion paper, Nadeau and Désautels (1984) argue that:

> By giving insufficient thought to the nature of scientific knowledge and the conditions under which it has been developed, science teaching reinforces beliefs and myths that are inherent in the scientistic ideology (p. 8).

They suggest that this particular ideology, which is widely promulgated in schools, creates an illusory image of scientific practice that results in most students holding unrealistic views of science such as:

naive realism -	that scientific knowledge is a reflection of things as they really are
blissful empiricism -	that all scientific knowledge derives directly from observation of phenomena
credulous experimentalism -	that experimentation makes possible conclusive verification of hypotheses
blind idealism -	that the scientist is a completely disinterested objective being
excessive rationalism -	that science brings us gradually nearer the truth

Nadeau and Désautels (1984) claim that these views give students a false idea of science and they issue an urgent call to all science teachers to adopt an epistemologically analytical approach in their teaching, so as to develop in students a more realistic view of science.

LANGUAGE IN SCIENCE

Another possible explanation for the lack of congruence between students' understanding of science and that of scientists could be the difficulties that arise with language. Wilson (1956) defines a language as "an immensely complex system of signs which depend on each other for their significance" (p. 16). In the case of human language the verbal signs are words, which of themselves have no meaning, but rather have uses that are largely determined by the rules of the language. Words then are tools for our communication, but in order for us to understand and be understood by others, we must have some common agreement on the uses of the different words. Since one word can be the bearer of more than one concept, the special use of everyday language in science can lead to differences in scientists' and students' understandings of science.

In science two main types of words are used: technical words, which are exclusive to the discipline, and everyday words, which are used and interpreted in a new and scientific context. Roberts (1972) states that scientific writing usually contains built in clues that indicate to the reader that there is a "shift" in the language, and that an "everyday language" interpretation of the text is inappropriate. However, these clues can only be detected by persons who understand that language is used in a different way in science. If students lack this understanding, their interpretation of everyday words in science will conflict with that of their teachers, as illustrated in the following excerpt from a Grade 4 science lesson.

The teacher has been introducing a classification system and has arrived at a distinction between living and non-living things. She continues.

Teacher: Now we are going to leave the non-living things for later and study just the living things.
(Writes "living" on the board)
Now, let's divide all the living things into two divisions. Into what two divisions can we divide every living thing? Every living thing is either a ________ or a ________? Lucy, give me one division.

Lucy: People?

Teacher: People are just part of one of the two divisions

Peter: Plants and animals.

Teacher: Good for you, Peter. That's right. Every living thing in this world is either a plant or an animal. People, Lucy, are animals, so they fit in this division.

Lucy: People aren't animals, they're humans.

Teacher: People are animals, the same as dogs and cats and so on.

(Much laughter and several loud objections by a large number of children speaking simultaneously. It appears that they disagree with this last statement.)
People are animals. What's wrong with that. They're not plants, are they?

Jimmy: But people talk, and have two legs and arms, and move and can think. Animals aren't like that
(Laughter)

Teacher: People do think and this makes them one of the highest forms of animals, but they are still animals ... And other animals communicate with one another.
(Several children are noisy and visibly disturbed)
That's enough. People are animals ...
(And the lesson continues) (Munby, 1982, pp. 19-20).

This incident is not to be dismissed lightly as it points to a problem far deeper than a conflict between Lucy and her teacher over the use of the word "animal." It is representative of an increasing number of studies that document students' lack of awareness about the the different way that language is used in science. As this point is central to the study, the rest of the chapter presents arguments meant to show that a person's view of the nature of science is directly influenced by that individual's understanding of language in science. Since these arguments are built on the idea that language is observation dependent, it seems important to first examine the nature of observations in science, before proceeding with discussions on the role of language in science.

OBSERVATIONS IN SCIENCE

There is general consensus among science educators that observation is one of the fundamental processes of science. Whether on a field trip or in the science laboratory students are constantly instructed to make "observations" of one kind or another. But what does it mean to observe something in science? The discussions that follow are intended to point out that in science the term "observation" is interpreted in a sense that is very different from the everyday meaning of the word.

The theoretical background, experience and training of an individual are important factors that influence what a person is said to observe. Physicists' understanding of the atomic theory enables them to "see" the white lines in the cloud chamber as the passage of a subatomic particle through supersaturated vapour. Similarly, chemists' knowledge of indicators and acid-base theory enables them to "see" the different colour changes of the indicator as changes in the pH of the solution. This dependence of observations on theoretical knowledge is common in science and it distinguishes a layperson's observations from that of a scientist. This is not to suggest that the layperson has no theoretical basis for his or her observations. On the contrary, one may use several theories to make a single observation. The difference, however, lies in the individual's understanding of language in science, and the kinds of theories that this person holds, since those of laypersons are very different from that of scientists. These disparities become even more evident in the science classroom, where children hold their own theories about the world and how it "works" while the teacher usually holds another. This can become the source of much conflict, as in the case with Lucy and her teacher over the use of the word "animal."

What is it about scientific theories that sets them apart from the everyday theories that a layperson holds? A leading clue can be found in the nature of scientific knowledge that is embodied in all scientific theories. To explain this point further, it is necessary to return to the dialogue between Lucy and her teacher.

It is obvious that Lucy's concept of the word "animal" does not include humans. Her view is shared by Jimmy who explains that people aren't animals since they have two legs and arms, and can move and talk and think. Yet their teacher keeps insisting that people **are** animals. Clearly something has "gone wrong" in this science lesson!

Munby (1982, p. 21) states that the essence of the disagreement is that apparently neither Lucy nor her teacher seems to realise that the word "animal" is part of **two** different taxonomies: a scientific one and an "everyday one." Since the taxonomies are different, they give different meanings to the word "animal," so Lucy's taxonomy sorts out the world, as she sees it, and the teacher's taxonomy sorts out the world according to how science sees it. Thus they are both right although each is unknowingly drawing on different taxonomies.

This incident shows that an understanding of the use of language in science is an important prerequisite for understanding science. Had Lucy been made aware of the nature of scientific knowledge, she would understand that in science language is used differently and that her teacher's classification of humans as animals, is not "wrong." Since she lacks this understanding, she is quite likely to view science as some eternal, unchanging truth handed to us by Nature. Almost half a century ago Einstein and Infeld (1938) cautioned against this type of thinking when they wrote:

> Science is not just a collection of laws, a catalogue of facts. It is a creation of the human mind with its freely invented ideas and concepts. Physical theories try to form a picture of reality and to establish its connections with the wide world of sense impressions (p. 310).

This advice is particularly relevant today given the disturbing findings on children's ideas in science. If science educators are serious about developing more realistic views of science in students, they should provide opportunities for these students to understand the nature of scientific knowledge.

THE NATURE OF SCIENTIFIC KNOWLEDGE

Thus far, the argument has shown that language is central to one's understanding of science. In what follows, four views of science are presented: constructivism, inductivism, realism, and instrumentalism. While the first two give useful accounts of the nature of science, the realist and instrumentalist views show how different understandings of the role of language in science could lead to different views of the nature of science.

CONSTRUCTIVIST VIEW

Toulmin (1960) is among many who support the Constructivist view of science. According to this position, scientific knowledge is perceived as a very specific and disciplined way by which humans construct the world so as to enable them to make sense of it. It is perceived as a product of our imagination in which we create our own realities in order to explain and predict natural phenomena. In this view the various principles, concepts, theories and explanations that are used in science are man made, and as such they are subject to change.

This way of viewing science allows one to understand that theories and explanations are not, strictly speaking, true or false. Instead they are evaluated on their usefulness to predict and explain natural phenomena about the world in which we live. Therefore when a theory is discarded, it is not that it is wrong, but rather that it is no longer useful in predicting and explaining the phenomena for which it was created in the first place. It follows that present-day theories should at best be regarded as tentative. In making provision for the uncertainty of science, this view dispels the notion of science as revealed truth to be accepted and learned without question.

INDUCTIVIST VIEW

The Inductivist position claims that all knowledge is based on observation, and scientific laws are reached by a process of induction from sense data. So the task of science is to produce a steady growth of knowledge from objective observations, while revealing the truth about the natural world over time. Although some science educators have traded this idea for the constructivist view of science, current research shows that the inductivist view is still prevalent among students (Driver, 1983).

According to Aikenhead (1980) most students regard science as a giant jigsaw puzzle in which the pieces are put together as knowledge becomes available and even though there is much that still remains to be discovered, it is only a matter of time before scientists will discover the truth about everything. They believe that science is "truth," that experimental results "prove" theories right, and that science can solve any problem given the right conditions. Since they lack a basic understanding about the nature of scientific knowledge, they are unaware of the different use of language in science and readily believe in the reality of electrons, atoms, and other "unobservables."

These views on the nature of scientific knowledge arise out of different understandings on the nature of scientific theories. Nagel (1961) identifies three different views on the cognitive status of theories: the Descriptive view, the Realist view, and the Instrumentalist view. Since the Descriptive view is not useful to this research, it is omitted. This study does not attempt to give a detailed treatise on the other two positions but instead points out some important language differences between them.

THE COGNITIVE STATUS OF THEORIES

REALIST VIEW

In the Realist view of science, theories are regarded as either true or false in the same way that one would acknowledge everyday statements to be true or false. So, the scientific objects referred to by the theory, must be regarded as possessing a physical reality like everyday objects. Nagel sums it up as follows:

> Theories are generally either true of false; and, although a theory can at best be established only as "probable," it is as significant to ask whether a theory is true or false as it is to ask a similar question about a statement concerning some individual matter of fact, such as the statement 'Krakatoa was destroyed by a volcanic eruption in 1883.' A corollary often drawn from this view is that when a theory is well supported by empirical evidence, the objects ostensibly postulated by the theory (e.g. atoms, in the case of an atomic theory) must be regarded as possessing a physical reality at least on par with the physical reality commonly ascribed to familiar objects such as sticks and stones (pp. 117-118).

INSTRUMENTALIST VIEW

This view maintains that theories are neither summary descriptions nor generalized statements of relations between observable data. Instead they are primarily logical instruments for organizing our experience and for ordering experimental laws. Accordingly, in this view "the pertinent question about theories is not whether they are true or false but whether they are effective techniques for representing and inferring experimental phenomena" (Nagel 1961, p.133).

Munby (1976) takes the discussion further by drawing on the distinctions earlier made by Nagel between the Instrumentalist and Realist views of theories. He suggests that if science instruction is given in a scientific context but understood in an everyday sense, an individual is more likely to hold the Realist view, believing that the theories, constructs and laws of science are in fact true descriptions of the world. In contrast, science instruction given and understood in a scientific context is more likely to result in an individual holding an Instrumentalist view in which he or she views science as an invention created by man to provide explanations of data.

This researcher strongly opines that the Instrumentalist view provides a more useful way of looking at science and for understanding abstract concepts such as "black holes," "electrons," "magnetic fields," and other "postulated entities." Central to this view of science, is an understanding of the different role of language in science. Roberts, (1972) sums it up as follows:

> To talk about postulated entities is to use language in a different way from the way we use language in talking about states-of-affairs. You have to shift from the "observable realm" to the "explanatory realm" (p. 4).

This transfer is possible only if one understands something of the nature of scientific discoveries.

DISCOVERIES IN THE PHYSICAL SCIENCES

Using the principle of the rectilinear propagation of light, Toulmin (1960) explains the differences between "discoveries" in the physical sciences and other discoveries such as the one made by Robinson Crusoe when he discovered footprints on the beach of his island.

Toulmin argues that Crusoe reached his novel conclusion, "Footprint! Footprints mean man! Therefore man!" by applying **familiar** inference to **new** data. Moreover at any moment Crusoe could verify his conclusions by actually coming face to face with the man who was responsible for the footprint. Toulmin claims that this type of argument will not hold for geometrical optics because it is not possible for someone to come face to face with the light that is "responsible" for the shadows, in the same way that Crusoe confronted Man Friday. Besides,

> the discovery that light travels in straight lines is not therefore, the discovery that, where previously nothing had been thought to be, in any ordinary sense, travelling, there turned out on closer inspection to be something travelling - namely light ... nor is it the discovery that whatever is travelling in the everyday sense, is doing so in one way rather than another, along great circles rather than parallels of latitude, or straight lines rather than spirals (p. 20).

Instead it is the discovery that one can now begin to think and talk of light as travelling in the first place. In other words the individual is led to "see" **familiar** phenomena such as light, in a **new** way. By adopting this view, the physicist now has a new way of explaining natural phenomena such as why shadows are reversed as the sun moves across the sky, or why they become shorter the higher the sun rises in the sky. In short, this discovery increases the explanatory power of science.

EXPLANATIONS IN SCIENCE

Several philosophers agree that one major function of science is to provide explanations for natural phenomena (Nagel 1961, Martin 1972). This position is grounded in the Instrumentalist view of theories. Toulmin makes it clear that the discovery that light travels in straight lines, is a way of explaining the phenomenon of light. He does not suggest that it is the only way, or that it is the best. It is simply one way by which a scientist could understand and make sense of everyday experiences such as light and shadows.

This is an important point which deserves further attention as science educators may fail to make students aware that science is but one of several explanatory systems available. Roberts (1972) cites two other modes, religion and magic, that are often used to explain. He states that although science can explain, there are some instances in which it is limited as an explanatory mode. Moreover, these limitations are rarely made explicit to students at school with the result that the latter erroneously conclude that science can solve any problem so long as the right conditions are present. It follows that if science is a way of explaining phenomena, science educators are responsible for providing students with authentic explanations of the nature of science.

The preceeding arguments have shown that an understanding of language in science ultimately affects one's view of the nature of science. Since most students are unaware of the different role of language in science, conflicts such as the one between Lucy and her teacher are likely to erupt in science classes. It seems important therefore to investigate students' views of the nature of science, by paying particular attention to their use of language in science. Such a task is attempted in this study.

RATIONALE FOR QUALITATIVE RESEARCH METHOD

If one of the goals of science education is to bring about some understanding of the nature of science in students, then it is reasonable to expect that they would be evaluated for their competence in achieving this goal. Since the 1960's various instruments have been developed to obtain this kind of information, for example Cooley and Klopfer's "Test of Understanding Science" (1961) and Kimball's "Nature of Science Scale" (1967). However these instruments are inappropriate for purposes of this study because they yield quantitative data which cannot fully capture the students' views of science.

Since the purpose of this research is to obtain a detailed account of one individual's view of the nature of science, it is important that this information be obtained by the use of qualitative methods. This researcher is of the firm belief that lengthy statements given in the student's own words can more fully present a holistic account of that person's view of science, than that which could be obtained by pencil and paper tests. To this end, an ideographic study of this individual's view of of the nature of science is appropriate.

CHAPTER 3

METHOD

As indicated in the last chapter, this study uses qualitative research methods to obtain information on one individual's view of the nature of science. The present chapter provides a detailed description of these methods.

THE SUBJECT

As this study focussed exclusively on the views of a single individual, the selection of a suitable subject was of crucial importance. Therefore using the criteria suggested by Spradley (1979) for locating a good informant, I set about the task of identifying a suitable subject. After much searching a potential interviewee was found. She was a fourteen year old high school student who had been highly recommended to me by a colleague.

Goetz and Le Compte (1984) emphasize the importance of building and maintaining a harmonious relationship between the participants from the start, for without this atmosphere of mutual trust and respect the exercise is doomed to failure. Therefore being fully aware of the fragile nature of a relationship in its early stages, it was with some measure of caution that I attempted to establish and maintain a congenial relationship with Susan.

Susan (not her real name) is a fourteen year old adolescent who lives with her parents and younger brother in a small city in eastern Ontario. In my first encounter with her, she appeared a bit shy and nervous but once we got talking, this initial shyness quickly disappeared. I found her to be a cheerful, optimistic teenager with an obvious zest and enthusiasm for life. She has a warm and friendly personality and her relaxed easy-going nature makes it a pleasure to converse with her. When I spoke with her, she had recently completed Grade 9 at a local high school so she had some background in science.

During this preliminary meeting, I explained to her that the purpose of this study was to obtain **her** view of the nature of science. She was assured that it was not a test and that I was not seeking right or wrong answers, but rather **her** understanding of various scientific concepts and the rationale underlying those understandings. I carefully explained to her the various data collecting strategies for the study and I reassured her that the data would be confidential as her identity would not be disclosed in the final report. Moreover, she would have access to the final report when the study was completed. Since she showed such an interest in the project and was quite candid in her responses to my questions, she readily qualified as a suitable interviewee. However, she still had to be formally asked whether she would participate in the project or not. Once her formal consent was obtained, data collection commenced in the summer of 1986.

DATA COLLECTING STRATEGIES

The qualitative data collecting strategies used to obtain information for this study were: audio recorded interviews, participant observation, and construction of field notes. Each is detailed below.

AUDIO RECORDED INTERVIEWS

This was the primary means of obtaining information for the study. Commencing in June 1986, eight interviews were conducted over a four-month period at times and places appointed by the interviewee. Each interview lasted approximately one hour and was recorded with Susan's permission on cassette tape for subsequent transcription and analysis.

The interview questions were carefully worded so as to make their meaning clear to Susan. Therefore prior to each interview a list of possible questions was drawn up. I knew that these questions might not be used during the actual sessions as it was not possible to predict Susan's responses. Nevertheless they were constructed so that they could be used to guide the interview if the need arose. In practice, some of the prepared questions were asked, but the majority had to be constructed as the interview progressed. This is typical of qualitative studies in which non-standardized interview methods are used and it further illustrates the inappropriateness of using questionnaires or other standardized instruments to obtain this type of information. Two kinds of interview techniques were used: Interview-about-Instances and Interview-about-Events.

INTERVIEW-ABOUT-INSTANCES TECHNIQUE

Interview-about-Instances (I.A.I.) is a technique developed by Osborne & Gilbert (1979) for investigating students' understandings of various scientific concepts. In this method, the individual is presented with several cards each of which depicts a line drawing of a familiar situation. These drawings represent instances and non-instances of various scientific concepts. The individual is asked to identify those cards which in his or her opinion represent instances of the particular concept, and to provide reasons for such choices. This technique is built on the major premise that:

> the concept(s) a child associates with a particular word is considered as a disposition to act in a fairly consistent manner with respect to distinguishing between instances and non-instances (Bell 1981, p. 213).

By attempting to elicit from the individual his or her reasons for acting in a particular way, the researcher hopes to gain some insights into some of the criteria that the person is using to make the distinction. Bell contends that only when the person can give reasons that are similar to those of a scientist, can one safely state that a scientific conceptual rationale lies behind the individual's choices. This method of investigation has been successfully used in a number of studies exploring children's meanings for different concepts, such as "electric current" (Osborne, 1981), "gravity" (Stead & Osborne, 1981), and "animal" (Bell, 1981).

In this study, Susan was presented with several cards depicting instances and non-instances of various scientific concepts for example force, magnetism and static electricity. Each card measured 8.5 x 10.5cm and was numbered in the top right hand corner for easy identification during the interview. (A sample is provided in the Appendix). For each concept under investigation, she was presented with six cards and asked to sort them into groups. She was then asked the reasons for the categories that she created and asked her meanings for the concept and wherever possible, I used her language in subsequent interviews to further explore her ideas.

In a slightly modified version of the I.A.I. approach, Susan was presented with cards which had words instead of drawings. Again she was asked to sort them into groups and the reasons for her distinctions were elicited by the use of both open and closed questions. In the following excerpt which illustrates a typical Interview-about-Instances, Susan is given six cards to sort. Each card has the name of an occupation printed on it . The names are: Teacher, Baker, Family Doctor, Scientist, Newspaper Vendor, Dressmaker. Susan sorts the cards into two groups.

Researcher: You've got two groups. In one group you have Family Doctor, Scientist, and Teacher, and in the other group you have Newspaper Vendor, Dressmaker, and Baker. Could you explain to me why you grouped them like that?

Susan: Well all six of them are occupations and I put the Doctor, Scientist and Teacher together because I felt that em... the occupations like the three sets that I put together are different em... very different because the Family Doctor, Scientist, and Teacher they all sort of use em... smart em... you have to be smarter to do these jobs than a Dressmaker, Newspaper Vendor, Baker... they're all sort of regular jobs like em... the Doctor, Teacher, and Scientist, you have to go to school to be able to be one of them em ... like university and you have to be more experienced.
(Interview #6: 16 September, 1986)

These introductory remarks of Susan's served as a stimulus for me to further explore her ideas. She was asked questions such as:

What do you mean when you say that a person is smart?

What sort of person do you think a dressmaker is?

Would you consider a family doctor to be a scientist?

What sort of person do you think a scientist is?

What sort of work do you think a scientist does?

Would you consider yourself to be a scientist?

By deliberately probing her meanings and explanations, I sought to obtain an inside view of Susan's understanding of science and to see things as it were through her "conceptual lenses."

Osborne and Bell (1981) caution that the interviewer's tone of voice, expression, emphasis and intonation are important variables to consider in I.A.I., as they need to be encouraging but not suggestive of any particular answer. Spradley (1979) also warns that this type of interview task should not be attempted in the early stages of data collection, since the relationship must be well established before the informant is asked to perform tasks such as drawing a map or sorting cards (p. 59). Therefore special care was taken not to convey messages to the student other than those intended, and this technique was used only in the later stages of data collection.

INTERVIEW-ABOUT-EVENTS TECHNIQUE

The Interview-about-Events technique (I.A.E.) was developed by Osborne (1980) for exploring children's understanding of natural phenomena. It is based on the same principle as that of the I.A.I. approach but the methods are different. In this case the individual is required to perform a number of simple demonstrations built around specific concepts, to describe what he or she sees happening, and to provide explanations for the events that occur. Cosgrove and Osborne (1980) report much success in using this method to investigate children's views on physical change. Happs (1981) also used it to investigate students' understanding of the particulate nature of matter.

In this study, I.A.E. technique was used to explore Susan's understanding of magnetism and static electricity. The following excerpt is illustrative.

> For this activity Susan is given two bar magnets, a glass plate, some iron filings, and the following instructions:
> Place the two magnets alongside each other so that the short sides are close to but not touching each other.
> Place the glass plate on top of the magnets.
> Sprinkle some iron filings onto the glass plate and observe what happens.

The discussions in most of these interviews were guided by two main questions: What did you observe? and why do you think that happened? Although these techniques provided much insight into Susan's way of thinking, additional data collecting strategies were used so as to obtain a comprehensive picture of her view of the nature of science.

In order to enhance the trustworthiness of a study such as this and to safeguard against loss of credibility, Guba & Lincoln (1982) recommend triangulation of different data sources. This advice was particularly relevant since I sought to obtain both verbal and non-verbal information from Susan in order to infer her view of science. Since non-verbal behaviour cannot be recorded on audio cassette, it was necessary to employ two other data collecting strategies. These were participant observation and construction of field notes.

PARTICIPANT OBSERVATION AND CONSTRUCTION OF FIELD NOTES

These two data collecting strategies greatly enriched the data for the study by providing "slice of life" episodes of the interviewee's non-verbal behaviour. Field notes were constructed during or immediately following the interview from observation of Susan's actions and facial expressions. A special effort was made to record these observations as accurately as possible, and at the same time to provide vivid, detailed descriptions of the events as they occurred. The following excerpt is from the field notes constructed immediately after a discussion of static electricity.

> Susan wiped the knife several times on her blouse. I wonder why she did that? When I asked her she said "just to see if anything did affect it" or something like that. (She had previously rubbed the knife with wool). She became flushed when

I probed her to tell me what she was wiping off, and said in a loud voice "I don't know. I am just doing it."
I dropped the subject. I didn't want her to feel threatened. Pity I couldn't get her to continue. It might have led to some interesting discussions.
I also recall her looking carefully at the glass rod turning it over several times in her hand as if trying to remember which end she had rubbed with the silk. Must pick up on this up next time.
(Field Notes from Interview #3: 25 August, 1986)

Bogdan & Biklen (1982) suggest that besides providing accurate description of what has occurred in the field, field notes can provide a personal account of the researcher's feelings, problems, ideas, hunches, impressions and prejudices about the study. They could also be the place in which mistakes are identified, techniques refined, and future strategies developed. For this researcher, the field notes served as a place for brainstorming ideas, reflecting on completed interviews, and planning strategies for subsequent ones.

TRANSCRIPTION OF THE INTERVIEW

The tapes were transcribed immediately after each interview since there was a greater likelihood of remembering the discussion where the tape was indistinct. First the date, number, time, and venue of each interview was recorded at the top of each transcript. Then the transcript page was divided into three columns. The left hand column denoted line numbers as well as the identity of the different speakers e.g. S for Susan, T for the researcher; the middle section contained the transcribed dialogue; and the margin on the right was reserved for comments of the transcript when the analysis was conducted. Each transcript page was numbered. Short pauses in the dialogue were indicated by three periods ... and longer pauses were noted in parentheses as (long pause). In some instances, comments from the field notes were incorporated into the transcript. These were enclosed in square brackets [ ] and placed on a separate line immediately following the relevant part of the dialogue. Once the transcription was completed, the data were analyzed.

DATA ANALYSIS

Several different strategies were attempted in order to make sense of the data. Some had to be abandoned because they were not very helpful; others proved to be slightly more useful. Without question, pattern analysis was the most useful.

The technique of pattern analysis is used extensively in clinical supervision (Goldhammer, 1969; Cogan, 1973) where it proved to be of great value in the analysis of teaching. Pattern analysis can be applied to situations other than teaching, since it assumes that one's general behaviour contains regularities which can be rationally analyzed. Unlike standardized instruments such as checklists and observation schemes, pattern analysis allows any type of behaviour to be identified as long as it is consistently repeated over a period of time, and forms a pattern.

> Patterns are always stated in descriptive language to keep them as non-evaluative as possible; assumptions about the interviews and effects of behaviour patterns are avoided. The actual intentions and behaviour patterns are the subject of subsequent inquiry after patterns have been identified (Russell, 1980, p. 47).

Since this analytical tool proved invaluable in "unpacking" the data, the following sections provide a detailed account of how it was used in this study. The analysis proceeded in three phases: pattern identification, grouping of patterns, and interpretation of patterns.

PATTERN IDENTIFICATION

I read each transcribed dialogue at least three times to become thoroughly familiar with the data. Then I carefully studied each interview in order to identify explicitly any patterns relevant to the investigation. Once detected, I recorded them in simple, descriptive language for interpretation in the third phase of the analysis.

GROUPING OF PATTERNS

Once the patterns were identified, I grouped them into categories according to their similarities. Goetz & Le Compte (1984, p. 170) suggest that "similarities permit the identification of a category, the delineation of attributes of a category and the specification of conditions under which categories are found." Therefore two strategies were tried: grouping by topic and grouping by salient features.

GROUPING BY TOPIC

This was done across interviews for topics such as Metals, Magnetism, Static Electricity, Truth, and Energy. After selecting a topic, the relevant bits of the dialogue from the different transcripts were collated so as to create a single account of the interviewee's ideas. Despite the crude form of presentation, it advanced the analysis considerably because at a glance it gave one a "bird's eye view" of Susan's understanding of a specific concept. At the same time the groupings presented the data in a compact form in which new patterns could now be detected. It also allowed one to see that Susan's ideas persist over time since some views that she expressed in earlier interviews were repeated in identical form in later sessions.

GROUPING BY SALIENT FEATURES

"Salient features" are interpreted as any part of the data that appeared more prominent than the rest and immediately caught my attention. Whether it was a particular expression that Susan frequently used such as "What's inside it" or some other aspect of the data that was striking, it captured in a unique way some of the idiosyncrasies of her language and often provided insight into her way of thinking. At times there was no clear distinction between these two groupings since some patterns could be placed in either category. However, once the data had been categorized, the next task was to interpret their significance.

At this point it would be futile to discuss the significance of the data without presenting the actual research findings. Therefore the next chapter presents the findings of this study and the interpretation of the data is done in Chapter 5.

CHAPTER 4

PRESENTATION OF DATA

The previous chapter has shown that data from the eight interviews were carefully treated in order to reveal something of Susan's view of the nature of science. As a result they were organized into categories that were salient and frequent, and that seemed to best illustrate her view. The purpose of this chapter is to present these categories and the data associated with them. The categories have been ordered as follows:

Truth

Scientists

What is science?

What's inside it?

Explanations

I don't know

Undifferentiated concepts

Other features

Although this order is imposed upon the data, it does more than provide the reader with a coherent way to access Susan's view. The categories themselves seem to fall logically from the first, "Truth," which seems so central to her view of science.

In the presentation that follows, each category is illustrated with examples from the data, and each example is identified with the number and date of the interview. This device allows the reader to see that the data supporting each category are not incidental but persist over time. The large amount of data presented here serves additional purposes: it permits the reader to develop a sense of the relationship between the interviewer and Susan, and it provides a reasonable amount of information about the way Susan answers questions about science.

MAGAZINES AS SOURCES OF TRUTH

In one of the interviews, Susan is given cards to sort. Each card has the name of a magazine printed on it. The names are *Newsweek*, *Enquirer*, *People*, *National Geographic*, *Time*, and *Vogue*.

T: You should have six cards here. [Susan checks the cards. Laughter from Susan] Why are you laughing? [More laughter from Susan] Sort them any way you wish and then you'll explain why you sorted them that way [Susan sorts the cards into four groups. She puts *Newsweek*, *People*, and *Time* into one group, and each of the remaining three cards she leaves on its own.]

T: What about *Enquirer*? You were rather tickled with this one

S: It's a joke

T: Why do you say it's a joke?

S: It's garbage. I mean they make up things

T: You don't believe what you read?

S: No. It's so funny! like I mean they'll say a man gives birth to a baby... that's ridiculous! [T and Susan both laugh]

T: And *National Geographic* is that garbage also?

S: No far from it em... they tell about... well it's a monthly magazine they've been doing it for years and years em... It's just... they talk about different tribes quite a bit, different animals, em... different countries stuff like that (Interview #6: 16 September, 1986)

This dialogue immediately gives one some insight into the sorts of things Susan considers as truth. She has scant respect for the *Enquirer* magazine and quickly dismisses it as "garbage." In contrast the *National Geographic* earns her respect as a credible magazine. In another interview conducted some five weeks later, her views about *Enquirer* magazine remain unchanged.

T: Would you consider something as *Enquirer* magazine as truth?

S: No [In loud voice]

T: You're definite on that one eh!

S: Yes I'm definite

T: What was the reason you gave me the last time?

T: Just total rubbish they write like a man has a baby or whatever. They might be able to do that someday but I really doubt it. I just don't trust it like it's just got this reputation for being not true. (Interview #8: 24 October, 1986)

So far the data have not indicated why Susan believes the contents of the *National Geographic* magazine to be true. In the excerpt which follows, these reasons become apparent.

T: I noticed that in several interviews you mentioned this article from the *National Geographic*. It must have impressed you very much?

S: Um hum

T: What about it that struck you?

S: The pictures i guess. They're just so amazing that something so small could be that interesting

T: Did you believe what you read?

S: I guess so

T: Why would you believe something like this article on the Immune system in the *National Geographic* (June '86 issue) and not believe something say that you read in *Enquirer*?

S: Well the *Enquirer*... like people have stood up and said that this is not true. They make things up like they're so... so unbelievable! I just don't believe it... it's sort of like trash. And the *National Geographic*, it's a very sort of like prominent magazine. They write the truth because they have no need to lie.

T: How do you know it's the truth they are writing?

S: Em... I just believe that it's the truth. I don't actually know for sure, but why would they not want to tell the truth? I never really thought of them lying so I just accepted it (Interview #7: 03 October, 1986)

Susan apparently places a lot of trust in this magazine and accepts what it says as true because she has been given no reason to believe otherwise.

TEXTBOOKS AS SOURCES OF TRUTH

She also regards the content of her textbooks as truth.

T: Did you believe everything you read in your textbooks?

S: Yes

T: Why did you believe it?

S: I guess 'cause it's the only thing I really had to know em... I didn't have anybody to em... my parents aren't scientists or anything so I guess, what it said, I believed. It was the only source I had to know.

T: Suppose there were other sources for you to know about science, what could some of these sources be?

S: Old science books, library books, maybe magazines like *National Geographic* (Interview #1: 25 June, 1986)

The data so far indicate that Susan considers *National Geographic* magazines and textbooks as sources of truth. In the discussion which follows, she expands this category to include her science teacher whom she also regards as a source of truth.

HER SCIENCE TEACHER

When Susan speaks of her science teacher she acknowledges that she unquestioningly accepts what he says, even though he does not provide reasons to support his claims. The following excerpt reflects this attitude.

T: When your teacher comes into the classroom and teaches you, do you question what he teaches you, or do you just accept it?

S: Well sometimes if the book says one thing and the teacher well says another thing, then we'll question it but usually I just accept and believe what he says because I mean he's been teaching, and he's been teaching things to so many people that I don't think he would lie. And also the school board, they really would not have people lying to us because we are there to learn

T: How do you think your teacher knows the information that he passes onto you?

S: Well he's learned it from someone else

T: Such as?

S: Another teacher or scientist

T: And how do you think the other teacher or scientist came to know the things that they know?

S: Well if you're a teacher, you've been taught these things or you've learned it from a course or something and I would assume that if you've been taught, it would be true because a teacher is there to tell the truth.

T: Do teachers always tell the truth?

S: Well there was one case up in Alberta a guy was saying all sorts of things about the Nazis that never happened em... I guess there are cases where people are em... so screwed up that they don't tell the truth

T: Was that person a teacher?

S: Yes

T: How did people find out that what he was saying wasn't true?

S: Well they ... like this guy (a student) well he was just so pro Nazi that he said it never happened and that the Nazis were good and everything. He (the teacher) taught students like in Grade 12 or Grade 11 so they (the students) knew that these things weren't true so they reported it and this guy (the teacher) was taken to court but I don't really know what happened. (Interview #7: 03 October, 1986)

This attitude of trust in her science teacher is also evident in an interview conducted three months earlier.

T: Did you believe the things your teacher told you?

S: Yes

T: Why?

S: Because we just assume that he knows and what he knows is right. You don't really think when you're doing it whether you should believe or not. You just assume that it's right.

T: In his teaching did he give you reasons for the different things or did he just tell them to you?

S: Sometimes he would but sometimes... I guess he didn't really

T: Could you remember any instance where he gave you a reason for something?

S: Em... (long pause) not really (Interview #1: 25 June, 1986)

The kind of relationship between Susan and her teacher helps in understanding her view of science. Osborne & Freyberg (1985) argue that the relationships that develop between science teachers and their students, could greatly affect those students' understandings of science because for most children the science teacher is the only "scientist" they know. They quote a Science Department Head as saying:

> The most important thing for students, particularly of average ability, is their relationship with the teacher... Ask them what they think of science and invariably you get a comment back on what they think of the teacher (p. 54).

This is clearly reflected in part of Susan's written response to the question "What is science?"

> I like science when I understand what is being said by the teacher and students. Otherwise I just get confused and do poorly in tests. Last year when I read over in the texts what I had done during the day, I knew and understood most of what was said. In my class last year about 20 - 30% of the students got involved with the discussion most of the time and he (her science teacher) basically focussed on those people. So that made me feel even more frustrated and confused because if I put my hand up about a question I did not understand, the people who knew what they were doing would make me feel inferior to them. This happened with a lot of my friends also. He (the teacher) spoke about two levels above me so that made it even more difficult. He basically focussed on the boys because they were usually the ones who got involved. (Interview #7: 03 October, 1986)

This statement clearly shows that Susan's understanding of science is affected by the kind of relationship that she has with her teacher. Although Susan reacts negatively to these situations and experiences feelings of confusion and low self esteem, she still believes in her science teacher and regards what he says as true.

A similar view appears as Susan begins to talk of her idea of a scientist. She talks about this in so many interviews and in such detail, that one concludes this issue to be very relevant to her. Her descriptions are vivid and consistent from one interview to the next.

SCIENTISTS

PHYSICAL CHARACTERISTICS OF A SCIENTIST

As early as the first interview Susan begins to talk about the physical characteristics of a scientist.

T: If I should ask you to describe a typical scientist, what would this person look like?

S: Smart person in a lab coat (laughter). Em.. I usually think of people with em... glasses, not that other people aren't smart, but because people who are smart usually wear glasses. Em... grey hair, tall, I don't know why but that's just what I think of

T: Would that person be a male or female?

S: I usually think of a male, but that's just my picture. I mean I know there's female ones

T: Would that person be old, young, or middleaged?

S: Em...fifty (Interview #1: 25 June, 1986)

Three months later she remains firmly wedded to the concept of a scientist as a very intelligent, (smart) man about fifty years old.

T: Now what about a scientist. What sort of person do you think a scientist is?

S: Well I think of men. Ladies can be scientists but the picture I get in my mind is a man em... an old man em...

T: When you say old around what age are you talking about?

S: Fifty

T: Okay

S: Em... they're kind of quiet em... very intelligent, em... that's about it

T: Why do you get a mental image of a scientist as a quiet person?

S: Em.. I just don't know it's just the way it is (Interview #6: 15 September, 1986)

QUALIFICATIONS TO BE A SCIENTIST

Susan appears to have no doubt concerning the requirements for becoming a scientist. She believes that one has to be very smart (intelligent) and knowledgeable in order to pursue such a career. She develops this idea in the following discussion. During this interview Susan is given six cards to sort. Each card has the name of an occupation printed on it. The names are: Family Doctor, Dressmaker, Baker, Scientist, Teacher and Newspaper Vendor. Susan sorts the cards.

T: Okay. You've got two groups. In one group you have family doctor, scientist, and teacher, and in the other group you have dressmaker, newspaper vendor, and baker. Could you explain to me why you grouped them like that?

S: Well all six of them are occupations and I put the doctor, teacher and scientist together because I felt that em... they all sort of use em... smart... you have to be smarter to do these jobs than a dressmaker, newspaper vendor or baker - they're sort of regular jobs. The doctor, scientist and teacher you have to go to school to be able to be one of them like university and you have to be more experienced

T: Are you suggesting that you don't have to be smart to be a dressmaker or baker?

S: Well like em... the doctor, scientist, teacher you have to be very intelligent. And for this one (the baker) you have to be em... smart enough to do it but em... you don't really have to have all the brains like the other ones would.

T: Would you consider yourself to be a scientist?

S: No

T: Why not?

S: Well I just consider scientist to be like a profession and I just don't think that I know enough about science to say that I am a scientist so I don't consider myself to be a scientist (Interview #6: 16 September, 1986)

At this point the data become more complex as Susan explains the sorts of things that a scientist would know. Inevitably this leads to a discussion of the kind of work he does.

WHAT A SCIENTIST DOES

During the first interview, she suggests that a scientist would know what's inside a starch. The discussion continues:

T: How do they know that?

S: 'cause they've done tests or studies I guess

T: Is that all a scientist does - tests and studies?

S: No they try to find cures for things like using a cell or something to see if it will fight against another cell or something to kill the other cells like cancer cells

T: What sort of work do you think a scientist does?

S: They study cells and make medicines to help people em... they usually do studies on different things like em... maybe the effects of acid rain on people or the environment usually trying to figure out things and trying to find ways to help (Interview #1: 25 June, 1986)

Here she focuses on the social aspects of science and sees the work of a scientist primarily as finding a cure for disease, particularly cancer. She suggests that sometimes his job may entail dealing with environmental issues, but his main task seems to be rooted in the medical field: he makes medicines, or does tests and studies to discover a cure for cancer. Apparently she views a scientist as a "good" person because he is always trying to find ways to help. Susan's view of what scientists do as conveyed by these early statements reappear consistently in subsequent interviews. The following dialogue is illustrative.

T: What sort of job do you think a scientist does?

S: Well they could either be a teacher or biologist or anything that has to do with a science. They work in a lab trying to find like something to kill off cancer em... or do research all kinds of stuff like that

T: You mentioned that a scientist does research. What do you mean by research?

S: Well they study a topic and research about finding a cure for something or they test things like cells which could fight off cancer or something like that em... they do tests

T: What kind of tests do you think they do?

S: Well they really have a lot to do with trying to find cures for diseases (Interview #6: 16 September, 1986)

As the discussion progresses, one gets a clearer insight into the criteria Susan uses to distinguish between scientists and non-scientists.

T: Do you know the name of any famous scientist?

S: Einstein

T: Do you know of any reason why he's famous?

S: He invented something but I'm not sure I can't really say what

T: Suppose if someone does not find a cure for something and does not invent something and is not involved in testing of any kind, would you consider such a person to be a scientist?

S: Well what would they do instead?

T: Well that's what I would like to find out. Are there other things that they could do instead?

S: Em... teach science

T: So if they teach science, you would consider them a scientist?

S: Yes. Some of them write books about science. I guess a scientist would have to know... like a scientist would write a book em... I guess.. that's about it

T: If the person is involved in writing a book about science, what sort of things would you expect or do you think could possibly be in that book?

S: I guess they could write about different cells

T: What about them?

S: What different cells do em.. what say they cause, what they could fight against em.. they could also write about animals like the inside of human beings like the way an animal or human being is working inside. The scientist sort of study like the smaller things ... they work to find things to help people but they don't work directly with people (Interview #6: 16 September, 1986)

Here she expands her notion of a scientist to incorporate teachers but only if they are actively involved in the field of science. Their work would entail trying to find out what different cells could fight against or how the human body works inside. All the while she relates their work to the medical profession. In this dialogue, she also introduces the notion of a scientist as someone who tries to figure out how things work. This idea prominently reappears in other interviews.

The "good image" of a scientist also comes out strongly in this interview. She makes an important distinction though. A scientist is a helper but he does not work directly with people. This idea of a scientist as a "good person" is repeated in the following interview.

T: Do you think that scientists are people that know what they're talking about?

S: Um hum

T: Do you find it contradictory that they're supposed to know yet they're engaged in doing research and tests to find out what they don't know?

S: Em... I don't find that contradictory because it's like they know enough how to find a cure for something at least they know how the procedure goes. I think that's not contradicting it because it can be something good.

T: What do you mean by good?

S: Well like trying to find a cure for disease to help people. I don't think there's a contradiction (Interview #7: 03 October, 1986)

Susan believes that the scientist's concern for the well being of mankind motivates him to set about finding cures for diseases. She develops this idea in the following discussion.

T: What do you think motivates scientists to try to find out what they don't know?

S: They're maybe just interested in it. They just want to know for themselves personally, or else they just have to find out.

T: Why would they have to?

S: Well if it's a job or something they have to do this. They have to find out

T: What do you think would prompt a scientist to set out to find say a cure for cancer?

S: Em... well like maybe if they know somebody with the disease em... they've heard about another person having it, or it's becoming a very big problem. That's some of the reasons.

T: But suppose the scientist doesn't know anybody with the disease for example no close relations or friends, do you think the scientist would still be interested in finding a cure?

S: Yes

T: Why do you think so?

S: Well you know about AIDS. It has become so big that I guess scientists would want to get involved because they just sort of want to get rid of it. Em... it's very big em... like it's growing. I mean the disease, so I guess scientists don't really have to know somebody. They could just like be aware that this is happening and want to do something about it, or it could be that they're just being paid by the government to do it.

T: So you're suggesting that it could be a job that they're just working at, or it could be that they recognize it as a problem and they want to control it. Is that what you're saying?

S: Um hum. (Interview #7: 03 October, 1986).

The following excerpt confirms previous findings that for Susan a scientist is a very knowledgeable person who finds cures for diseases.

T: Would you consider a teacher to be a scientist?

S: No

T: Why not?

S: Because ...they're not really helping to find a cure or em.. they just sort of teach people

T: If someone is actively engaged in teaching science, would you consider that person to be a scientist?

S: Yes

T: Why?

S: Because they had to train just as a scientist would in order to become a teacher like they know everything a scientist would about something

T: If someone was actively involved in writing papers or books on science, would you consider that person to be a scientist?

S: Yes

T: Why?

S: Because like I said before they have to know about science what they're talking about em... say someone like geologists they wouldn't sort of really know about science or anything about it em.. well they have to be a scientist in order to write about it

T: Could science be considered anything other than a subject?

S: Well I guess scientists working for new cures (Interview #6: 16 September, 1986)

One striking aspect of the data is that in all Susan's talk about a scientist's work, she dwells only on the positive aspects of science. There is no mention whatsoever about any negative aspects of science neither in this interview, nor in any of the interviews that were conducted for this study. This says a lot about her view of science. She trusts science and perceives it only in a positive light because as far as she is concerned it deals with finding new cures for disease. The statement which follows, clearly attests to this fact. It is part of Susan's written response to the question "What is science?" In it she reiterates her notion of science being concerned with finding cures for disease.

WHAT IS SCIENCE?

> Science is everything that is happening in the world around us such as the workings of the human body, a disease such as cancer or AIDS, why the sun shines, what is in our air and other things that involve our world and space. It is also discovering cures and new inventions that would make life easier from day to day. When I think of science, I think of scientists in lab coats experimenting with different chemicals to find out how something works or why it is there (Susan's writing Interview #7: 03 October, 1986)

This notion of a scientist as a seeker of cures for disease comes out so strongly in the interviews that it's prominence cannot be ignored. The following excerpt reinforces this point.

In this interview, Susan is given six cards to sort. Each card has a statement printed on it. The statements are:

A way of explaining things about the world
Finding a cure for disease
Writing a book about science
What scientists have discovered
An ongoing process
Something that we do at school

Susan sorts the cards.

T: You have them three in one group and the other three are all separate. In that bottom group you have writing a book about science, finding a cure for disease, and what scientists have discovered.

T: Explain to me what group that is

S: The scientific group having to do with science, what scientists do

T: Okay what do you mean when you say having to do with science? Is that what you think science is about?

S: Yes (Interview #6: 16 September, 1986)

SCIENCE AS TRUTH

The data so far suggest that Susan regards science as truth. She trusts its authority and believes in it, possibly because she has been given no reason to doubt. This is confirmed in the following interview.

T: Would you consider science as truth?

S: Yes

T: Why?

S: Because people have tried things like saying the world is round things like that em... they've tried and they've proved them. So I guess like if you can prove something, like doing experiments and things like that I believe that way. (Interview #8: 24 October, 1986)

She does suggest however that some things in science might not be necessarily true, but cannot cite any instance to support her claim. She also believes that science brings us a little closer to the truth and it's only a matter of time before the truth will be finally discovered. She discusses these ideas in the following excerpt.

T: Do you think that there are instances where scientists may not understand what is happening or what is going on?

S: Sometimes they just can't figure it out but I'm sure they will one day like if they don't know something but they're still trying to figure it out

T: And you feel that it's just a matter or time that they would come up with it?

S: Um hum (Interview #6: 16 September, 1986)

This is directly related to her notion of the *National Geographic* magazine as truth. It follows, that if science is truth and the books about science are to be believed, then the scientists who write these books must also represent truth. Thus their job is to reveal the truth by discovering cures for disease, investigating how things work, and finding out what's inside substances.

WHAT'S INSIDE IT?

One intriguing feature of the data is Susan's firm belief that one must know what substances are made of, or what is inside them in order to explain how they work. Even more intriguing, is the way that she speaks about these substances. Whether she is referring to cells or starches, metals, magnets or meteorites, she appears to believe that all one has to do is simply to break them down and look inside to see what they are made of, in order to explain how they work.

In this interview, Susan sorts different substances into groups according to whether they are magnetic or non-magnetic.

T: For those substances that are attracted to a magnet, what do you think makes them attract to it?

S: I think maybe because they might have the same material you know

T: The same material?

S: Yes the same substance in it

T: The same substance as what the magnet is made up of?

S: Yes maybe like just something in them that attracts to it

T: Do you have any idea what this something might be?

S: Em (Long pause) well I think that if you broke it down you'd have to be able to see it like you can see this piece of metal here [Pointing to a strip of metal]

T: So you should be able to see it if you broke it down?

S: Yes (Interview #4: 29 August, 1986)

In another situation, when talking about the differences between a protein and a starch she laments,

S: I know that it's a starch but I don't think I know what it contains or what's inside it

T: Do you think a scientist might know this?

S: Probably

T: Why?

S: Because they know basically all there is to know about it. They know how it is broken down, where it goes, probably know what's inside it, so they'd know how it's used inside us I guess (Interview #1: 25 June, 1986)

Susan appears to regard all matter as closed containers, and science as the means of opening them. Thus all one requires is an attentive eye to see what is inside. Apparently she has not been made aware that in science, observing is a process that differs from simply looking at things and that we "see" phenomena as it were through a scientist's "conceptual spectacles."

EXPLANATIONS

The disparity between Susan's understanding of science and that of a scientist, becomes even more obvious when one examines the kinds of explanations that she gives. The dialogue below is illustrative.

T: Now I am giving you some magnets and I want you to put them on this pencil [Susan does the activity.]

S: Oh! [in surprised tone - puzzled look on her face. Two of the magnets are suspended midway on the pencil]

T: What's that?

S: They're not attaching like they were before when they were off the pencil

T: Why?

S: Maybe the lead in the pencil is em... affecting the magnet's magnetism in some way so that the magnets won't come together
[Susan had earlier stated in this same interview, that lead is a non-magnetic substance]

T: Affecting it in what way?

T: Well before we did the lead, we tried to attach it to the piece of magnet but it wouldn't attach. So I think maybe the lead in the pencil is stopping the magnets from attaching by em... just getting in it's way like

T: Suppose if you take out those two magnets there - the two top ones. Now put them back onto the pencil. [Susan does the activity. The magnets are now firmly stuck together]

S: Oh come on!... it's not fair... oh! [in a wailing tone]. I have no idea why it did that this time. Em... em... (long pause) Can I check something?

T: Sure go ahead.

[Susan turns the magnets over and thoroughly inspects them, then she repeats the activities on her own. In one instance she gets the magnets suspended above each other, then she turns them over and replaces them on the pencil. The magnets are now firmly stuck together]

S: I think maybe the sides of the magnets are made of ... I don't know if this would be the same but ... ions negative and positive

T: What about them?

S: Well there might be positive charges coming from one side and negative charges coming from the other and on all of them maybe

T: Take your time

S: Oh! em...[Susan is getting confused and becoming flushed]

T: It's confusing isn't it?

S: Very (Interview #4: 29 August, 1986)

In another interview during a discussion on respiration Susan suggests that carbon dioxide is always present in our bodies.

T: How do you know that?

S: Well because we're always breathing in oxygen and the carbon dioxide is attached to the oxygen or it's part of the oxygen so we must always have it in us because we're always breathing it in

T: So what happens to the carbon dioxide in the body?

S: Em... I guess when we exhale there is more carbon dioxide ... so maybe em... once all the oxygen is gone, the oxygen turns into carbon dioxide (Interview #2: 30 June, 1986)

Until recently such statements had been treated in the literature as misunderstandings or misconceptions of science ([illegible], 1983). Now that there is a growing awareness that students' explanations usually differ from those of adult scientists, researchers are becoming more interested in investigating students' intuitive ideas about science (Osborne & Freyberg, 1985). This potentially rich source of information which until now has remained virtually untapped, could provide much insight into these students' understanding of science.

I DON'T KNOW

There is a strong suggestion in other parts of the data that Susan's understanding of science is organized into two broad categories: (1) those phenomena that she understands and that she could readily explain, and (2) those that she does not understand and that she would rather not attempt to explain.

Whenever Susan is asked a question about something that she understands, she answers quite readily, speaking in a calm, confident manner while giving detailed explanations for the event or phenomenon. Her speech is fluent and she does not appear agitated in any way. In short, her general appearance reflects composure. One such example is when she describes a scientist and his work. If however the question is about a scientific concept that she knows but does not quite understand, her physical appearance changes instantly. She becomes flushed and laughs nervously while saying in a somewhat defensive tone, "I don't know!" This pattern of behaviour is illustrated by the following incidents that occurred during one interview. In this interview Susan is speculating whether static electricity could be made by rubbing a metal with wool.

S: I think it has to be like a soft and a hard material but I don't think it would work say if you used a piece of metal .... wait maybe it would em...

T: I think there's a knife here. Would you like to try it with a metal?

S: Sure [T gives Susan a stainless steel knife]

T: Okay rub the knife with either the wool or silk and pass it between the styrofoam balls.
[Susan selects the wool]
What do you think is going to happen?

S: Em... [laughter] nothing

T: Okay. We'll see
[Susan does the activity]

S: Yes I was right. Nothing happened.

T: What about if you tried it with the silk?
[Susan wipes the knife on her blouse]
Why did you wipe it on your blouse?

S: Just to see if anything did affect it so that it would be different with the silk... like maybe if the wool did do something to it

T: So you're wiping it off

S: Yes [nervous laughter]

T: What would that be that you'd be wiping off?

S: I don't know [in loud voice] I'm just doing it! [Susan becomes flushed] (Interview #3: 25 August, 1986)

Some time later during this same interview, Susan suggests that static electricity could be just "tiny atoms or particles" but when further questioned as to the nature of these particles, she becomes flushed and hastily replies, "I don't know!" This tactic is used on two other occasions as her defence strategy whenever questions or situations threatened to disrupt her order of the world.

UNDIFFERENTIATED CONCEPTS

Undoubtedly some of these situations are very confusing for Susan. As she tries to provide explanations for the events which occur, she sometimes merges several scientific concepts together without being aware that she is not making any clear distinction among them. The following excerpt is illustrative. During this interview, Susan is given a plastic comb, some wool, tiny bits of paper, and the following instructions.

T: I want you to rub the comb several times with the wool then place the comb just over the paper but without touching it

S: Okay

T: But before you do that, tell me what you think will happen when you rub the comb with the wool and place it just over the pieces of paper?

S: Em... the paper will go right on to the comb... it will be attracted by the comb

T: Do you think so?

S: Um hum

T: Would you like to test your predictions by doing the activity?

S: Sure [Susan does the activity. Squeals of laughter from Susan.]

T: Well what did you observe?

S: The paper came up to the comb

T: Why do you think that happened?

S: Em... because there is sort of like em... friction is sort of built up em... makes it statiky em... magnetic in a way

A little later during this same interview, she repeats the activity this time using salt and pepper instead of the paper.

T: What do you think [illegible] to happen when you rub the comb with the wool and you pass it over the mixture [illegible] the salt and pepper?

S: Em... I think that just the pepper will come up em... (long pause) em... nothing or just the pepper will come up

T: Would you like to try it?

S: Sure [Susan does the activity] The salt and the pepper! [in excited tone]

T: Why do you think the salt and the pepper came up?

S: Em... I guess like what I said before. Rubbing it together makes it sort of like... it becomes magnetic

T: Rubbing the wool and the comb makes it magnetic. What's the it?

S: Makes the comb magnetic

T: So what?

S: Well em... em... like a magnet attracts things so the comb sort of becomes ... it becomes a magnet and this draws in the salt and pepper because it's sort of like a magnet

When Susan repeats the activity using styrofoam balls instead of the salt and pepper, she offers the following explanation.

S: It (the glass rod) affected it (the styrofoam ball) but I'm not sure how because there's nothing really. The glass is solid so nothing could really go off it onto the styrofoam ball and em... and that maybe just like the magnetism of the glass with the styrofoam ball when it gets the plastic, it didn't like react as well with the plastic. Do you understand what I mean?

T: When you say react well, what do you mean?

S: Em... didn't mix with it or it wouldn't... just were against each other like they would not come together em... I don't know how to say it

T: When you say attraction what do you mean?

S: Like being pulled to the object

T: And what would be responsible for this pulling towards the object?

S: The em... I guess rubbing the wool and say a piece of plastic together em... em... static electricity

T: Oh interesting! Tell me what you know about static electricity

S: Well it's sort of like rubbing a balloon against your head. It makes it sort of like ... attaches to the wall, or it attaches to things. So rubbing the wool and the piece of plastic together would attract em... the styrofoam ball to it because of the static electricity because static electricity is like magnetic I guess because I tried it before and it attaches to a wall. (Interview #3: 25 August, 1986)

As Susan attempts to make sense of the phenomena she is observing, she uses various concepts interchangeably because apparently she sees no difference among them. First she uses the concept of attraction: "The paper will go right on to the comb... it will be attracted by the comb" Then she incorporates three new concepts: friction, "statiky" (presumably static electricity), and magnetic (magnetism). These three become merged during the interview. When she repeats the activity using the salt and pepper, she selects the concept of magnetism to explain the behaviour of the particles: "Rubbing the comb and the wool together makes it (the comb) magnetic"

When she performs the activity with the styrofoam balls, she introduces the notion of static electricity and suggests that it is magnetic. (This was vaguely referred to as "statiky" in an earlier part of this interview.) These changing frameworks and undifferentiated concepts are seen as Susan's attempts to make sense of puzzling phenomena based on her own experiences and prior knowledge. This pattern is repeated in two other interviews when she talks about heat and warmth, and again when she discusses force, power and energy.

OTHER FEATURES

Included under this rubric of "Other features" are various excerpts from the data that are interesting and are worth noting. The chapter concludes with a brief examination of some of these features.

DIFFERENT LEVELS OF HEAT.

S: Em...it's just ... there's different levels of heat. Some people can be warm and some people just sort of em... em... in between cold and warm I guess but not ... If I was really cold I guess my fingers would sort of be numb because that would mean that the blood would sort of slow down inside of me. (Interview #2: 30 June, 1986)

Here Susan introduces the idea of heat being in layers. She also suggests that the colder it gets, things slow down. These two ideas are repeated in slightly different form, a little later in the same interview.

THE COLDER IT GETS, THINGS SLOW DOWN

T: What do you mean by heat?

S: Em.. The temperature of my body say like the warmth I guess

T: And how does your body acquire this warmth?

S: Em I guess by... well I guess I need to be warm so that everything inside of me that is going on will work because if I get cold, it sort of stops em.. em.. the colder it gets the cells sort of stop working like they slow down (Interview #2: 30 June, 1986)

DIFFERENT LEVELS OF AIR

T: Okay. Have you ever been in an aeroplane?

S: Yes

T: Alright. Is there any particular sensation that you have ever experienced as the aircraft is going up?

S: Yes [laughter]

T: What?

S. Sickness.

T: Sickness where?

S: In my stomach. Yeah. My stomach sort of comes up. My ears also pop

T: Yeah. That has also happened to me. Why so you think it pops?

S: Em... em...

T: Does your ear feel that way throughout the flight?

S: No. It's just.. once you've got level in the air, em but just going up and coming down em..maybe because the difference em.. in the difference in the levels of the air that you're going through because it get's em... em... it might get tighter as you're going up like em..

T: What gets tighter?

S: The air pressure in the airplane or else em... the difference in the amount of oxygen in the air as we're going up and then like getting tighter em... and then when you go down the pressure lets go sort of. Your ears pop when you go down but it's just sort of letting off pressure as you're going down.

T: You mentioned "levels of the air" but I'm not too sure what you mean by levels

S: Em... straight the same place like almost straight (Interview #2: 30 June, 1986)

SUMMARY

The data in this chapter can be described as both rich and voluminous as they provide leading clues about Susan's view of the nature of science. Despite their richness however, they need to be interpreted and presented in a form that would adequately reflect Susan's views. This is done in Chapter 5.

CHAPTER 5

DISCUSSION

This study has used eight interviews with a female adolescent to construct her view of the nature of science. The present chapter describes Susan's image of a scientist and her views of science. It also discusses some implications of the study and it concludes by raising some questions about Susan's views which were not answered by the study. These questions could be the basis for future research on students' views on the nature of science.

SUSAN'S IMAGE OF A SCIENTIST

The data show that Susan holds the stereotyped image of a scientist as a man. This is hardly surprising since research indicates that this particular image is prevalent among students. For example when Chambers' (1983) Draw-a-Scientist-Test was given to 4,807 male and female students, only 28 pupils drew a scientist as a female. Research also shows that this image of a scientist is as persistent as it is popular. Three decades ago, 35,000 teenagers participated in a study of "The image of science and scientists among high school students" (Mead & Metraux, 1957). According to this study, most students perceived a scientist as a bespectacled, intelligent, middle-aged man who wears a white coat and does research in a laboratory. They believed that he is a dedicated man who does not work for money or fame or self glory, but for the benefit of mankind and the welfare of his country. He works in order to create new inventions and discover new cures for disease so that people will be able to live longer, healthier lives, and will have new and better products to make life easier and more pleasant at home.

The similarity between these views and Susan's perception of a scientist is too striking for it to be dismissed as mere coincidence. However, this close correlation should be a cause for concern among science educators since it suggests that the curriculum changes and new teaching methods that were introduced over the past three decades have done little to alter the stereotypical image of a scientist held by Susan.

In addition to the stereotypical image that Susan has of a scientist, she also regards him in a very positive light. This could be due partly to her belief that his job is primarily to find cures for disease. This she considers as something "good." Although she does suggest that a scientist could do other things, such as teaching science or writing a book about science, she constantly reverts to her dominant conception of the scientist as someone working to find cures for disease. This positive image is not limited to Susan's perception of a scientist. It spills over to her view of science and ultimately affects the way that she thinks about science.

SUSAN'S VIEW OF SCIENCE

Susan explicitly states that she likes science only when she understands it; otherwise she gets confused and does poorly in tests. She claims that her science teacher, a male, speaks about two levels above her and focuses mainly on the boys because they mostly are the ones that get involved. To complicate matters, if she asks a question about something which she does not understand, she is made to feel inferior by the students who do understand it. This further heightens her feelings of confusion and insecurity.

If this is typical of what obtains in Susan's science classes, it suggests that the males in this class are receiving preferential treatment from the teacher. Perhaps this is why Susan has the mental image of a scientist as a male, and why she perceives science as a male dominated activity. Whatever the reason, it is known that the differential experiences of males and females within science classes greatly influence their perception of science (Kahle & Lakes, 1983). This could have serious implications for Susan's view of science.

For Susan the word "science" has a range of meanings that vary depending on the context in which it is used. Sometimes she speaks of science in terms of a subject done at school, Biology for example. At other times she uses it as a general term for everything that is happening in the world around us. Science is what her science teacher tells her, or what she reads in textbooks or in the *National Geographic*. She also believes that science is what scientists do: It creates new inventions and discovers cures for diseases like cancer and AIDS. Science too is responsible for figuring out how things work, as well as solving problems such as those caused by environmental pollution and acid rain. Through science, we can find out what is inside a meteorite or how the human body works. In short, science can solve any problem if scientists will only work at it, or so Susan thinks.

She does not make much distinction between the tasks of science and scientists, since in several instances she uses the same job description for both. She believes that the primary task of science, like that of a scientist, is to find cures for disease and help people, and although she admits that scientists are still ignorant of many things, she is convinced that it is only a matter of time before they will discover the truth about everything. This notion of discovery lies at the very core of Susan's belief's about science. It complements the other notion of truth that is so prominent in the data, as shown below.

The data strongly suggest that Susan regards science as truth and that she uses two categories, "Truth" and "Lie" to sort out her world. She unquestioningly accepts what her science teacher says because she believes that "teachers are there to tell the truth." She reasons that since her teacher has been teaching science for so long to so many people, if he were not telling the "truth" someone would have found him out, as in the case she mentions of the teacher in Alberta. She also regards the contents of science textbooks and the *National Geographic* as truth because she cannot think of any reason why they would present lies. She dismisses the *Enquirer* magazine as "rubbish" since it talks about the unimaginable, such as a man giving birth to a baby. In contrast the *National Geographic* deals with "real" life issues such as The Immune System. Furthermore, it provides coloured pictures to support its facts; and Susan concludes that if she could see them, they must be true. If Susan regards science as truth, then her view is entirely consistent with the belief she has in her science teacher and textbooks, as well as her strong conviction that one must know what is inside substances in order to explain how they work.

It is important to notice that there seems to be more than one account of truth operating for Susan. In addition to the propositional notion of truth, in which truth is some function of the proposition itself, Susan seems to be working with a pragmatic notion, in which the truth of a statement is connected in some way to its source. Evidence for this is available in Susan's views of scientists as "good" people who devote their time to finding cures for disease and helping people. In this account of truth, truth becomes truth-telling, as Susan seems to see in the *National Geographic*. The alternative is lying as she implies of the *Enquirer*. This particular notion of truth may well be connected to the kind of relationship that Susan develops with her science teacher and this could explain her view of her teacher as someone who would not tell lies.

IMPLICATIONS AND CONCLUSION

Susan's unique view of science has important implications for professional practice as well as for further research in science education. The implications for professional practice are described first.

It is significant to note that in this case study, some of Susan's ideas are consistent with what has been observed in other studies of students' views of science. This consistency underscores the importance of encouraging science teachers to introduce their students to systematic discussions of the nature of science since at present, science students like Susan seem to be unaware of the specialized use of language in science and lack a basic understanding of the nature of scientific knowledge (Osborne & Freyberg, 1985; Driver & Easley, 1978; Driver, Guesne & Tiberghien, 1985).

Since Susan appears not to have been encouraged to reflect on the nature of science in any systematic way, part of the responsibility for her view of science must be assumed by her science teacher and by the science textbooks she has used. Without an understanding of the nature of scientific knowledge, students such as Susan can be expected to perceive the isolated laws and facts presented to them in science instruction as no more than pieces in an unfinished jigsaw puzzle.

This study also demonstrates the power of qualitative research strategies for capturing the complexity and fullness of a student's view of science. Therefore it is recommended that further studies be conducted using similar methods of data collection. These would provide additional information to science teachers, curriculum developers, and textbook authors about the significance of students' views of science and about the complexity of efforts to inform and otherwise influence the systematic development of views of science.

It is tempting to subscribe to the notion that Susan is "wrong" in her beliefs about science. This would be unfounded. Although her view seems quite similar to the Realist view it would be unfair to characterize her as a Realist on the basis of the particular notion of truth that she holds. Significantly, she believes that the truth of a proposition is directly connected to its source, and she uses the categories "Truth" and "Lie" to judge the credibility of statements. This particular notion of truth is not reflected in any of the epistemological views that were presented in Chapter 2, and so it suggests that factors other than those that science education research has identified are influencing this teenager's view of science. None of the current work on students' views of science reflects this particular notion of truth, consequently the findings of this study have far reaching implications for further research on students' views on the nature of science.

Clearly, the **source** of propositions is important to how Susan and students like her take them to be credible. Also, there is a suggestion that gender may be intimately related to how students regard the truth of statements. The questions that follow reflect the significance of investigating this matter further, and give a clear picture of the implications of Susan's views for further research.

> Are the views of female students influenced by the gender of their science teachers?
>
> How do the views of female students differ from those of their male peers?
>
> Are the views of female students influenced by whether or not they see scientists as "good" persons working to find ways to help people?
>
> Is it possible that girls bring certain inherent feminine attributes to the task of understanding science and that these are significant influences on their views of science?

REFERENCES

Aikenhead, G. (1980). *Science in social issues: Implications for teaching*. Ottawa: Science Council of Canada.

Anderson, B. (1980). Some aspects of children's understanding of boiling point. In W. F. Archenhold, R. H. Driver, A. Orton & C. Wood-Robinson (Eds.). *Cognitive development research in science and mathematics* (pp. 252-260). Leeds: University of Leeds.

Ausubel, D. P. (1968). *Educational psychology: A cognitive view*. New York: Holt, Rinehart & Winston.

Bell, B. F. (1981). When is an animal not an animal? *Journal of Biological Education, 15*, 3.

Bogdan, R. C., & Biklen, S. K. (1982). *Qualitative research for education: An introduction to theory and methods*. Boston, MA: Allyn and Bacon.

Chambers, D. W. (1983). Stereotypic images of the scientist: The draw-a-scientist-test. *Science Education, 67*, 255-265.

Champagne, A., Klopfer, L., & Anderson, J. (1980). Factors influencing learning classical mechanics. *American Journal of Physics, 48*, 1074-1079.

Clement, J. (1982). Student preconceptions in introductory mechanics. *American Journal of Physics, 50*, 66-71.

Cogan, M. (1973). *Clinical Supervision*. Boston, MA: Houghton Mifflin.

Cosgrove, M. & Osborne, R. (1980). *Physical change*. Working Paper of the Learning in Science Project, Hamilton, NZ: University of Waikato.

Cooley, W. W. & Klopfer, L. E. (1961). *Test of understanding science*. Princeton, NJ: Educational Testing Service.

Di Sessa, A. (1981). *Phenomenology and the evolution of intuition*. M.I.T. Working Paper from Division for Study and Research Education. Cambridge, MA: Mass. Institute of Technology.

Driver, R. (1983). *The pupil as a scientist?* Milton Keynes: The Open University Press.

Driver, R., & Easley, J. (1978). Pupils and paradigms: A review of literature related to concept development in adolescent science students. *Studies in Science Education, 5*, 61-84.

Driver, R., Guesne, E., & Tiberghien, A. (Eds.). (1985). *Children's ideas in science*. Milton Keynes: Open University Press.

Driver, R., & Russell, T. (1982). *An investigation of the ideas of heat, temperature and change of state of children aged between 8 and 14 years*. Unpublished paper. University of Leeds.

Einstein, A., & Infeld, L. (1938). *The evolution of physics*. Cambridge: Cambridge University Press.

Engel, E. T. (1982).*The development of understanding of selected aspects of pressure, heat and evolution in pupils aged between 12 and 16 years*. Unpublished doctoral dissertation, University of Leeds.

Engel, E., & Driver, R. (1981). *Investigating pupil's understanding of aspects of pressure*. University of Leeds, Center for Studies in Science Education.

Erickson, G. L. (1979). Children's concepts of heat and temperature. *Science Education*, *63*, 221-230.

Erickson, G. L. (1980). Children's viewpoints about heat: A second look. *Science Education*, *64*, 323-336.

Fredette, N., & Lockhead, J. (1980). Student conceptions of electric current. *The Physics Teacher*, *18*, 194-198.

Gilbert, J. K., Osborne, R. J., & Fensham, P.J. (1982). Children's science and its consequences for teaching. *Science Education*, *66*, 623-633.

Gilbert, J., Watts, D., & Osborne, R. (1982). Student conceptions of ideas in mechanics. *Physics Education*, *17*, 62-66.

Goetz, J. P., & LeCompte, M. D. (1984). *Ethnography and qualitative design in educational research*. Orlando, FL: Academic Press.

Goldhammer, R. (1969). *Clinical supervision: Special methods for the supervision of teachers*. New York: Holt, Rinehart, & Winston.

Guba, E. G., & Lincoln, Y. S. (1982). Epistemological and methodological bases of naturalistic inquiry. *Educational Communication and Technology Journal*, *30*, 233-252.

Guesne, E. (1985). Light. In R. Driver, E. Guesne, & A. Tiberghien (Eds.). *Children's ideas in science* (pp. 10-23). Milton Keynes: Open University Press.

Gunstone, R., & White, R. (1981). Understanding of gravity. *Science Education*, *65*, 291-299.

Haaps, J. (1981). *Students' understanding of the particulate nature of matter*. Working Paper of the Learning in Science Project. Hamilton, NZ: University of Waikato.

Helm, H. (1980). Misconceptions in physics amongst South African students. *Physics Education*, *15*, 92-105.

Hills, G. (1983). Misconceptions misconceived: Using conceptual change to understand some of the problems pupils have in doing science. In H. Helm, & J. D. Novak (Eds.). *Proceedings of the International Seminar: Misconceptions in Science and Mathematics* (pp. 245-265). Ithaca, NY: Cornell University.

Kahle, J., & Lakes, M. (1983). The myth of equality in science classrooms. *Journal of Research in Science Teaching*, *20*, 131-140.

Kimball, M.E. (1967-68). Understanding the nature of science: A comparison of scientists and science teachers. *Journal of Research in Science Teaching*, *5*, 110-120.

Martin, M. (1972). *Concepts of science education: A philosophical analysis*. IL: Scott Foresman.

McCloskey, M. (1983). Intuitive physics. *Scientific American*, *248*, 122-130.

Mead, M., & Metraux, R. (1957). Image of the scientist among high school students. *Science*, *126*, 384-390.

Munby, A. H. (1976). Some implications of language in science education. *Science Education*, *60*, 243-260.

Munby, A. H. (1982). *What is scientific thinking*? Ottawa: Science Council of Canada.

Nadeau, R., & Désautels, J. (1984). *Epistemology and the teaching of science*. Ottawa: Science Council of Canada.

Nagel, E. (1961). *The structure of science*. New York: Harcourt, Brace & World.

Novick, H., & Nussbaum, J. (1978). Junior high school's pupils understanding of the particulate nature of matter: An interview study. *Science Education*, *62*, 273 - 281.

Olson, J. & Russell, T. (Eds.). (1984). *Science education in Canadian schools: Vol. III. Case studies of science teaching*. Ottawa: Science Council of Canada.

Orpwood, G., & Alam, I. (1984). *Science education in Canadian schools: Vol. 11. Statistical database for Canadian science education*. Ottawa: Science Council of Canada.

Orpwood, G. F., & Souque, J. (1984). *Science education in Canadian schools: Vol. I. Introduction and curriculum analyses*. Ottawa: Science Council of Canada.

Osborne, R. J. (1980). Some aspects of students' views of the world. *Research in Science Education*, *10*, 11-18.

Osborne, R. J. (1981). Children's ideas about electric current. *New Zealand Science Teacher*, *29*, 12-19.

Osborne, R., & Gilbert, J. (1979). Investigating students' understandings of basic physics concepts using an interview-about-instance approach. *Research in Science Education*, *9*, 85-93.

Osborne, R., & Bell, B. (1981). *Interviewing children: A checklist for the I.A.I. interviewer*. New Zealand: University of Wikato, Science Education Research Unit. (Eric Document Reproduction Service No. ED 230 594)

Osborne, R., & Freyberg, P. (1985). *Learning in science: The implications of children's science*. Auckland: Heinemann.

Roberts, D. A. (1972). *The mole as an explanatory device: How do you know a mole if you see one?* Ontario: Ontario Institute for Studies in Education.

Robinson, J. T. (1968). *The nature of science and science teaching*. CA: Wadsworth.

Rowell, J., & Dawson, C. (1983). Laboratory counter examples and the growth of understanding in science. *European Journal of Science Education*, *5*, 203-216.

Russell, T. J. (1980). Children's understanding of simple electric circuits. In T. J. Russell, & A. P. Sia (Eds.). *Science and mathematics concept learning of South East Asian children: Second report on phase II* (pp. 67-91). Glogor, Malaysia: SEAMEO _ RESCAM.

Russell, T. L. (1980). Developing teachers' analytical skills. In H. Munby, G. Orpwood, & T. Russell (Eds.). *Seeing curriculum in a new light* (pp. 44-62). Lanham, MD: University Press of America.

Séré, M. (1982). A study of some frameworks used by pupils aged 11 to 13 years in the interpretation of air pressure. *European Journal of Science Education*, *4*, 299-309.

Sjøberg, S., & Lie, S. (1981). *Ideas about force and movement among Norwegian pupils and students*. (Rep. No. 81-11). Norway, Oslo: University of Oslo, Institute of Physics.

Spradley, J. P. (1979). *The ethnographic interview*. New York: Holt, Rinehart & Winston.

Stead, B., & Osborne, R. (1980). Exploring science students' concepts of light. *Australian Science Teachers Journal*, *26*, 84-90.

Stead, K. & Osborne, R. (1981). What is gravity: Some children's ideas. *New Zealand Science Teacher*, *30*, 5-12.

Tiberghien, A. (1980). Modes and conditions of learning - an example: the learning of some aspects of the concept of heat. In W. Archenhold, R. Driver, A. Orton, & C. Wood-Robinson (Eds.). *Cognitive development research in science and mathematics* (pp.283-309). Leeds: University of Leeds.

Toulmin, S. (1960). *The philosophy of science: An introduction*. New York: Harper & Row.

Trowbridge, D., & Mc Dermott, L. (1981). Investigation of student understanding of the concept of acceleration in one dimension. *American Journal of Physics*, *49*, 242-253.

Urevbu, A. O. (1984). Teaching concepts of energy to Nigerian children in the 7-11 year old age range. *Journal of Research in Science Teaching*, *21*, 255-267.

Viennot, L. (1979). Spontaneous reasoning in elementary dynamics. *European Journal of Science Education*, *1*, 205-222.

Watson, F. R. (1974). The pupil's thinking. In J. T. Haysom, & C. R. Sutton (Eds.). *The art of the science teacher* (pp.31-40). London: McGraw Hill.

White, R., & Tisher, R. (1985). Research on natural sciences. In M. Wittrock (Ed.). *Handbook of Research on Teaching* (3rd ed.) (pp. 874-905). New York: Macmillan.

APPENDIX A: INTERVIEW #3

T: Well Susan it's good to see you. How were your holidays?

S: Pretty good. [T and S chat a bit about the vacation]

T: Well we're here for another interview and as I told you before the whole purpose of the interviews is to get your understanding of science. You would recall that I told you previously that this third interview would be slightly different, because I'll be asking you to manipulate simple bits of apparatus. I'll be asking you what you observe and to suggest a possible explanation for your observations. So we're going to begin with Activity #1.
You will observe on the handrest next to you there are several little bits of paper which are cut up.

S: Yes

T: Now I'm going to ask you to take this comb and I'm giving you a bit of wool. I want you to rub the comb vigorously with the wool several times and then you would just place the comb over the paper without touching it.

S: Okay

T: But before you do that tell me what you think would happen when you rub the comb with the wool and place it just over the bits of paper?

S: Em.. the paper will go right on to the comb .. it will be attracted by the comb

T: Okay you think so.

S: Um hum

T: Alright. Would you like to test your predictions by doing the activity?

S: Sure.

T: Okay. Just rub it vigorously up and down several times. That's okay if it gets fuzz. [Scratching sound as Susan rubs the comb with the wool. Squeals of delight from Susan]
Well what did you observe?

S: The paper came up to the comb

T: Why do you think that happened?

S: Em.. because there's sort of like em.. em friction is sort of built up em makes it statiky em... magnetic in a way?

T: Magnetic? so where would this magnetism come from?

S: Rubbing the wool and the comb together.

T: Rubbing the wool and the comb. Do you think if we rubbed the wool onto another material say something like glass, do you think that would happen?

S: No. I think it's just plastic.

T: It's the plastic. Okay. Would you like to try it again to see if the same thing would happen?

S: Sure

T: Okay so take off the paper. See if you could get them all closely together and you try it again.
[Scratching sound as Susan repeats the activity]

T: Okay. Did the same thing happen this time?

S: Yes.

T: Okay. So your explanation that you gave me previously does that still hold?

S: Um hum

T: By um hum do you mean yes?

S: Yes [Laughter]

T: Okay. So we're through with activity #1. We're going to use the comb again but this time we're not using paper. If you could just scrape the bits of paper ... just scrape it onto this card .. you could dump that because you're through with that...
This time Susan, we're going to repeat the activity using salt and pepper. In your hand you have two packs of salt and two packs of pepper. I want you to open those packs and just sprinkle it on the handrest and mix them together for me.

S: Mix them together?

T: Um hum.

S: For all the packs?

T: Yes. Just mix them together.
[Susan opens one pack of salt and one of pepper]
You know that might be enough. You may not even need the other two packs. You could just kind of stir it together. Use this pen cover.
[Scratching sound as Susan mixes the salt and pepper together]
That's okay. Now what do you think is going to happen if you rub the comb with the wool and you pass it over the salt and the pepper ... the mixture of the salt and the pepper?

S: Em... I think that just the pepper will come up

T: Just the pepper will come up?

S: Or if not anything at all em... nothing or just the pepper will attach to the comb

T: Would you like to try it?

S: Sure.

T: Okay go ahead.
[Scratching sound as Susan vigorously rubs the comb with the wool]

S: The salt and the pepper... [in excited tone]

T: The salt and the pepper came up. Why do you think the salt and the pepper came up?

S: Em... I guess just like what I said before. Rubbing it together makes it sort of like... it becomes magnetic

T: Rubbing the comb and the wool make it magnetic? What's the it?

S: Makes the comb magnetic

T: Makes the comb magnetic. Em... could you make a link between this magnetism and the little particles that you have there? Sorry, that's a poor question. Rubbing the comb on the wool makes the comb magnetic. That's your explanation?

S: Yes.

T: Okay so... so what?

S: Well ... em... the em... like a magnet attracts things so the comb sort of becomes... it becomes a magnet and this draws in the salt and pepper because it's sort of like a magnet. Is that what what you want?

T: Well it's your explanation. Em... would the comb be magnetic if it isn't rubbed with the wool?

S: No

T: It has to be...

S: Um hum

T: Okay. Alright. You can scrape that off
[Susan begins to scrape the salt and pepper from off the armrest. T interrupts her]
I think there's something further that we could do with that Susan Just mix it up for me once more.

S: Mix it up?

T: Yes and you're going to repeat it... no, no don't use the comb use this [T hands Susan a pencover] Okay repeat it using the comb Now tap the comb lightly, very lightly. Do you observe anything happening when you tap the comb?

S: Em.. well the salt and the pepper falls off

T: The salt and the pepper fell off

S: Wait it looks like just the salt that's falling off

T: Just the salt is falling off?

S: I'm not sure

T: Okay try it again ... try it again just to verify that
[Susan repeats the activity]

S: Maybe the pepper is falling off too... the black part in the pepper is staying on but the other part of the pepper is falling off.

T: What about the salt?

S: That fell off the first time I tapped it

T: Okay, the first time you tapped it the salt fell off.

S: Yes

T: What about the pepper? Did all the pepper fall off the first time you tapped it?

S: No

T: Why do you think that happened?

S: The pepper I think is em lighter than the salt so it stays on for a longer amount of time

T: Alright. Well we're through with that activity so you could scrape it off

T: Now we're going on to Activity #3. In this instance we're going to use styrofoam balls. If you look on the board you'll see I have a little sketch. Those balls represent styrofoam balls. I'm sure you know what styrofoam balls are.

S: Yes

T: They're suspended on a string and they're attached to some kind of support. Now we're going to bring two rods towards the opposite balls em... in one case we're going to use a glass rod, in the other case, we're going to use a plastic rod. You'd be rubbing them with different materials. The glass rod you will rub with silk, the plastic rod, you will rub with wool. Actually I have it set up here on the side, so if you pull your chair a little closer so you can come around here. Let's make sure that you know what you're doing. You're going to rub the glass rod with silk .. there's the glass rod there

S: Okay

T: And you will rub the plastic rod with wool

S: Okay

T: Now I'm going to ask you a question. What do you think is going to happen when we bring the rods very close to the balls, the glass rod on one side and the plastic rod on the other? What do you think is going to happen?

S: Em... I think that the plastic will attract the em... styrofoam ball and the glass will sort of like it will em... push the styrofoam ball away like it won't attach?

T: So the plastic will attract and the glass will push it away. Is that what you think will happen?

S: Yes

T: Okay go ahead and try it

S: Just rub it like this?

T: Yes just rub it.

S: The whole thing?

T: Um hum rub it vigorously several times.
[Susan does the activity]

S: Oh they both attracted the styrofoam balls.

T: Both were attracted to the styrofoam balls?

S: Um hum

T: Suppose you passed the plastic rod just in between those two balls just in the middle but don't let it touch.... What do you observe happening

S: They both attached to the rod

T: What about if you did it with the glass rod?

S: They both attached to the glass rod.

T: Now this time you're going to use the glass rod alone. Just rub the glass rod with the silk and just pass it in between the styrofoam balls don't let it touch and you tell me what you observe

S: Nothing. The styrofoam balls aren't attracting to it or not they're just staying where they were like they aren't attaching to the glass and they're not pushing away from it

T: Suppose if you tried it with the plastic rod and wool?
[Susan examines the glass rod as if trying to remember which end was previously rubbed with the silk]
Any end would do. What do you observe?

T: Em .. well one of them is pushing away from it and the other one is just staying where it is like it's not doing anything.

T: One is definitely pushing away?

S: Yes.

T: Why do you think that is happening?

S: Em (long pause)

T: Is there any difference in the styrofoam balls?

S: No

T: Can you see any difference?

S: No

T: Do you think the type of rod might have something to do with it?

S: Em... the glass and the plastic just.. like maybe the glass sort of em.. is not really in it but affected it the styrofoam ball and the glass and the plastic they might not mix with each other do you know what I mean?

T: When you say it affected it, how would it affect it in what way?

S: Well it touched it so maybe it not really rubbed anything on it but maybe a chemical or something in the glass might have just gone on the styrofoam ball em wait..

T: Take your time

S: It affected it ... but em... I'm not sure how because like there's nothing really. The glass is solid so nothing could really go off it onto the styrofoam ball em.. and that maybe just like the magnetism of the glass with the styrofoam ball when it gets the plastic it didn't like react as well with the plastic do you understand what I mean?

T: When you say react well what do you mean?

S: em...didn't em... em... it didn't... mix with it or it wouldn't just were against each other like they would not come together em... I don't know how to say it

T: You mentioned the term magnetism and you mentioned the term attraction, when you say attraction what do you mean?

S: Like being pulled to the object

T: What would be responsible for this pulling towards the object?

S: The em... I guess rubbing the wool and say a piece of plastic together em... the em static electricity

T: Oh interesting... you're using big terms. Tell me what you know about static electricity

S: Well it's sort of like rubbing a balloon against your head it makes it sort of like attaches to the wall or it attaches to things so rubbing the wool and the piece of plastic together would attract the em... styrofoam ball to it because of the static electricity because the static electricity is like is magnetic I guess because I tried it before and it attaches to the wall.

T: Where does this static electricity come from? Is it there all the time?

S: You make it I guess

T: How would you go about making it?

S: Em heat and like the friction or the rubbing against something

T: Just any material or is it special material?

S: I think it has to be like a soft and a hard material but I don't think it would work if say you used a piece of metal ...wait maybe it would em...

T: I think there's a knife here would you like to try it with a metal?

S: Sure
[T gives Susan a stainless steel knife]

T: Okay try it with any of the materials either the wool or the silk. You'd be rubbing the knife with either the wool or... oh you're using the wool in this case

S: Yes

T: And you can pass it in between the styrofoam balls. What do you think is going to happen?

S: Em.. [laughter] nothing

T: Okay we'll see

S: Yes I was right. Nothing happened.

T: Nothing with the wool.

S: Yes

T: What about if you tried it with the silk
[Susan wipes the knife on her blouse]
Why did you wipe it on your blouse?

S: Just to see if anything did affect it so that it would be different with the silk like if the wool did maybe do something to it.

T: So you're wiping it off?

S: Yes [nervous laughter]

T: What is it that you're wiping off?

S: I don't know I'm just doing it.
[Slightly loud tone. Susan rubs the knife with silk and passes it between the styrofoam balls]
They move like just a little but they don't really attract or go away from the knife

T: Okay so what's your position concerning metals and static electricity?

S: I don't think there really is any with metal like you can't make static electricity with metals

T: Okay but you did mention that it might be a combination of a hard and a soft material

S: Yes

T: Would you include a metal in that category of hard materials?

S: No.

T: No. What would you include in that category of hard materials?

S: Plastic, glass, em.. (long pause)

T: Okay plastic and glass what about the soft materials?

S: Em hair, any kind of clothing because like say if your mother just did the washing and say like the socks you see on commercials the socks are stuck to the clothes so I guess it could be soft materials rubbing together also because like I guess in the dryer the dryer they rub together and em... that makes sort of like static electricity

T: So what is responsible for them sticking together. Is it something like glue?

S: No it's heat and also the rubbing together makes the static electricity

T: You must have rubbing? or do you think that rubbing is crucial to the production of static electricity?

S: Yes. [Very hesitantly and softly]

T: Do you think so?

S: Yes

T: You seem a bit uncertain

S: Well I just thought I ... well... yes...

T: Okay let me ask the question another way. Do you know of any instance in which static electricity was produced without rubbing of some kind?

S: No because like... you can't just bring two things unless they I think they have to be rubbed together to produce the static electricity.

T: Alright. You're using this term a lot this static electricity but I'm still not too sure that I understand what you understand static electricity to be. Could you tell me as simply as possible what is your understanding of static electricity?

S: Em... something produced by ...

T: It's something that's produced which means that it's not there all the time?

S: Yes

T: It is or it is not?

S: No it's not there all the time. It's produced by rubbing two things together. Static electricity is as a result of rubbing two things together but I'm not actually sure like what it is

T: Now you mentioned something like taking the socks out of a dryer and how they stuck together and just tell me again what was your explanation for them being stuck together

S: Em... the heat in the dryer I guess because they rub against each other in the dryer and that builds up static electricity

T: Do the socks remain stuck together all the time?

S: No. If you pull them apart em... like the static electricity eventually goes away.

T: Where does it go?

S: Just... I guess maybe the particles maybe they just break up and go like into the atmosphere

T: Into the air?

S: Yes like they don't really work unless you rub something together to get them

T: So if I understand you correctly you're saying that static electricity could be produced and static electricity could also go away

S: Yes

T: Could you keep it?

S: Em.. you could if you kept ... well... the socks (inaudible) stay together for a long time but eventually like if you pulled em... say they were hanging up together em... they'll eventually break apart because the static electricity will just disappear but if you wanted to make it stay, you'll keep rubbing it together again and just put them up together again and when they start falling just rub them together again and put them back up. But there will always have to be the heat. It will have to be quite warm for them to stay together for a long time.

T: And what do you think would cause this heat?

S: Em.. like a furnace or a dryer or maybe the sun as long as like there is not much wind usually inside I think it will work better.

T: Why do you think it will work better inside than outside?

S: Well because there's less factors affecting it like the air outside, it could get windy or it could cloud over say or get colder but if the sun still stayed out, there will be just I guess like there's always sort of breeze or fresh air or it just sort of make the socks eventually fall apart.

T: So what would the wind be doing?

S: It would sort of em... blowing away ... not really blowing away bust em... em... getting rid of the static electricity by blowing over it it would separate the socks so the static electricity would be disappearing faster I guess because the em... air moving faster around it.

T: When it disappears, where do you think it goes?

S: Em... into the ground...

T: The ground

S: Yes because em...

T: How would it get from the socks to the ground?

S: Gravity

T: Gravity

S: Yes. I don't know

T: But you're just suggesting it could be gravity

S: Yes.

T: You mentioned earlier that the static electricity might be in the air. If it's in the air, do you think it's possible for us to see it?

S: ... just like air you can't see air.

T: D... you know that the static electricity is in the air?

S: No. you rub things together or something like that. I think maybe ... well in the summer there's not static electricity but in the winter like if you take off a sweater, you get shocked from it

T: Why?

S: Em like baked heat em... not baked heat but like the furnace heat or dryer heat or maybe the sun would not really do anything for the static electricity because like I said there really is not much static electricity if you took off the sweater in the summer compared to taking it off in the winter

T: So you're saying that the main difference is the heat.

S: Um hum like we produce heat like it might be our produced heat that might affect it most

T: Are you suggesting that our bodies produce different amounts of heat in the summer as opposed to the winter?

S: No man made heat like heat from a furnace or (incoherent)

T: I know this is a bit difficult Susan but could you just kind of chew it out for me what you understand static electricity to be. You have told me what it does. I am not asking for a definition but em... okay you said it's the static electricity that ...or rather let me change that. In one of the activities you noticed that the styrofoam balls became close together and you said it was the static electricity that was responsible for that I know it's a kind of toughish question and you may not have an answer but could you just articulate it a bit more for me so that I really understand what you mean?

S: Static electricity to be?

T: Um hum.

S: Em....

T: Okay you said the static electricity holds them together

S: Um hum

T: But you can't see it

S: No

T: So what is it?

S: Em... it could just be tiny atoms or particles em...

T: Particles, what kind of particles? what do you mean by particles?

S: I don't know

T: Go ahead what about these particles?

S: Em... like maybe each particle maybe makes up a ...say if they came together to make say a clump they could maybe make static if they're rubbed like ... I don't know

T: Do you think that these particles are the same?

S: Yes

T: Suppose if we had used say plastic balls instead of styrofoam balls, do you think we would have the same or similar results?

S: I think it has to be something usually something I don't know if this is true but something light and something heavier like a styrofoam ball and ...

T: Okay which one would be the lighter one

S: Styrofoam ball

T: And which one would be the heavier?

S: The rod like the plastic rod

T: Em so if for instance we used something like a golf ball

S: It wouldn't work

T: Why do you think it wouldn't work?

S: Em.. well a golf ball is made of plastic at least I think so so I think this is usually true that if two things are the same they can't really attract each other

T: When you say two things are the same what do you mean?

S: Well like the golf ball and the plastic rod, they're both made of plastic

T: So you're suggesting that they have to be of different materials

S: Yes

T: That's interesting. Do you think that the thread had any part to play in it?

S: Em.. No

T: Have you have any experiences with static electricity other than those that you mentioned?

S: Well if you turn off the lights you can see static electricity sometimes. If you turn off the lights and say you're shaking blankets apart, there are flicks of light coming off the blanket

T: And what would that light be?

S: Static electricity

T: So you're suggesting that sometimes you can see it.

S: Yes

T: That's one experience that you have had. Any other?

S: The same with the sweater. Taking off a sweater. I can't think of any more.

T: Is there any other thing that you want to mention or to suggest concerning what we did today?

S: No

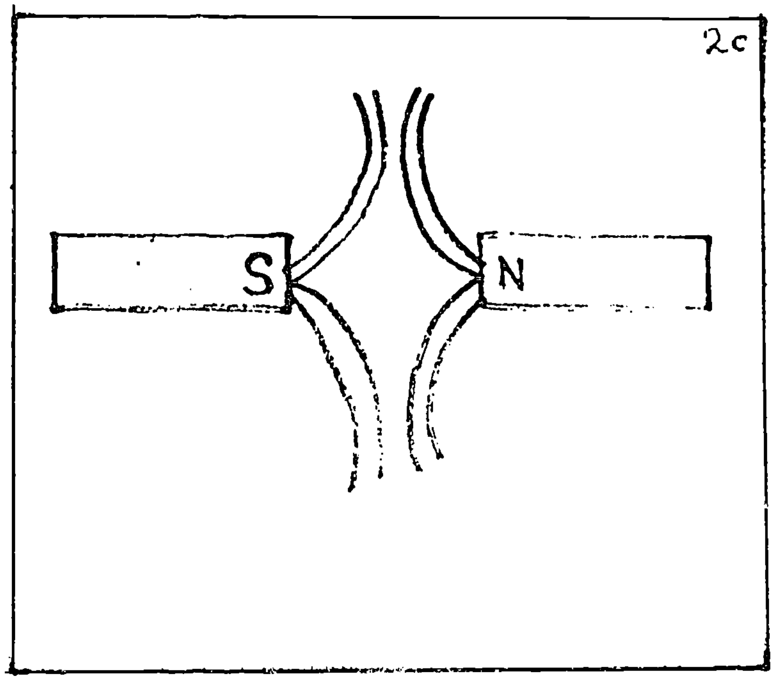
T: Do you have any questions for me?

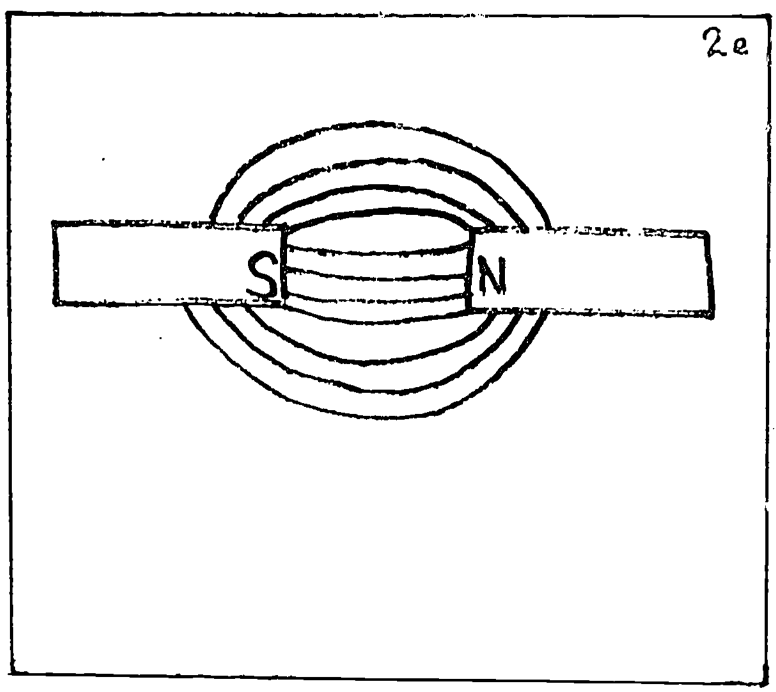
S: No

T: Well you've just completed the third interview. Thank you.
(25 August, 1986)

APPENDIX B: THE INTERVIEW-ABOUT-INSTANCES METHOD

The I.A.I. method is a procedure for establishing a person's understanding of a particular word or the concept(s) a person associates with a particular word. The following are two samples from a set of cards used to explore the concept of magnetism.





Vita

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EDUCATION

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1976 - 1979	University of the West Indies Bachelor of Science (Major: Chemistry)

EXPERIENCE

1986 - 1987	Research Assistant Faculty of Education, Queen's University
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