THE DEVELOPMENT OF A TYPOLOGY OF SCIENCE TEACHERS' VIEWS ON THE NATURE OF SCIENCE AND SCIENCE PRACTICAL WORK: AN EVALUATIVE PILOT STUDY

THESIS

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ABSTRACT

Many theories on the nature of science and the nature of learning have been proposed. In particular, two theoretical orientations have been identified as having a decisive impact on activities in the school science classroom, namely "Inductivism" and "Constructivism".

Inductivism views observations as objective, facts as constants and knowledge as being obtained from a fixed external reality. The constructivist view sees all knowledge as "reality" reconstructed in the mind of the learner.

Each view predisposes certain orientations towards the science curriculum and within it particularly to assessment. It is postulated that teachers' views on science will influence how they teach and assess it. An "inductivist" teacher is more likely to reward certain approved responses from learners whereas a "constructivist" teacher is more likely to attend to learners' unique observations as evidence of their thinking.

In this study a questionnaire was developed in an attempt classify science teachers according to their views on the nature of science and learning, and during this process encourage them to reflect on these views. It is hoped that the instrument could measure any changes in teacher's views as a result of the teachers becoming more reflective practitioners over time.

Research indicates that the majority of teachers have a predominantly inductivist view of science. The study confirmed the results of other researchers by showing that a majority of non-tertiary science educators could be classified as being strongly inductivist. However, the overall proportion of these teachers was not as high as expected.

Of possible concern was the indication that the strongly constructivist group showed very strong inductivist tendencies when assessing written tests which involved pupils' responses to laboratory observations.

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CHAPTER 1

INTRODUCTION

It is common cause that South African education is in the throes of a crisis. According to Andrews (1993):

> I have no doubt that our education system is failing miserably. And the reason is that the people who manage the system are working with an outdated, cumbersome philosophy that is not responsive to the needs of the global economy. The world is changing rapidly, but our syllabi and methods of teaching are obsolete.

Rational human activity is underpinned by a theory and according to Hlebowitsh (1993:92):

> Every behaviour and action undertaken in the school and the classroom is rooted, to varying degrees of consistency, in a set of preferences and values that one might cautiously call a philosophical pattern.

The particular theory or world view (Lythcott & Duschl,1990:456) underpinning a particular set of actions does not have to be overtly stated for it to exist and the lack of a stated theory does not imply its absence. Lythcott & Duschl claim that world views, such as inductivism and constructivism, often guide our arguments, sometimes without us even being aware of what they are. This is supported by Hlebowitsh (1993:93) who claims that it is very difficult, if not impossible, to think of any pedagogical act that is purely neutral. All scientific activities must therefore be based on a particular view of the natures of knowledge, science and learning.

The researcher obviously subscribed to a particular view, or combination of views, of the nature of science during his first years of teaching practice. He would, however, have been hard-pressed to spell out a coherent statement of these views. It was while marking external science examinations that he first became consciously aware of the existence of a philosophy underpinning some of the examiner's questions.

In the absence of an external assessment of practical laboratory work in most South African schools, so-called practical work has been examined in written theory examinations. One method employed by the examiner is to ask the question: "What do you observe when...?"

The researcher, at that time, was not aware that two dichotomous approaches to observation could be discerned, namely the traditional or inductivist view and an alternate view, often referred to as the constructivist view.

The inductivist view argues that "... the validity of observational statements are independent of the opinions and expectations of the observer and can be confirmed by direct use of the senses." (Hodson,1986a:18). The implication that all observations are unprejudiced is what Hodson (1986a:17) refers to as the traditional view of the scientific method.

The alternative, or constructivist view, requires that sense data enters our consciousness in terms of prior knowledge, beliefs, expectations and previous experience (Hodson,1986a:19). This constructivist view has evolved out of developments in the psychology of learning that has become the dominant theoretical orientation in science education in the UK and the USA (Novak,1976; Driver,1983; Saunders,1992). The essential feature of the constructivist view of learning is that we learn by constructing new knowledge in terms of our existing knowledge. Woolnough (1983:61) notes that "... without an appropriate conceptual framework, no meaningful observation can take place." Because what we observe is influenced by what we already know, different people can see the same object or event but make different observations (Hanson,1979; Gott & Welford,1987). In the constructivist view observations are not "unprejudiced" as the inductivist view implies.

Because direct observation is a central element in science, it should, according to Gott & Welford (1987:217), appear in all policy statements on science. Broadly two types of observations can be made: quantitative observations (e.g. readings from scales, and counting events or objects) and qualitative observations (e.g. when some object or event is described). Problems arise in qualitative observations if the teacher's pedagogy is based solely upon the inductivist view. Such a teacher might wish pupils to make only those observational statements that are based solely on what they ought "correctly" to detect with their senses and may discourage any uncatered for deductions based on prior knowledge. For instance, when demonstrating the reaction between zinc and copper sulphate in solution the observation which the "inductivist" teacher would wish the pupil to make is that a BROWN PRECIPITATE forms. The pupil who says that COPPER IS DEPOSITED may be penalised, either because in this reaction copper is not being observed in its common form or because the teacher wishes to inculcate the "respectable" (inductivist) habit of collecting as many primary observations as possible before inferring some generalisation. Following the constructivist view it is quite respectable for the pupil to say that it is copper being deposited by inferring from the equation of the reaction.

The external examiner tended to award marks only for observational statements that were in agreement with the inductivist view, (the researcher's personal experience of marking Cape Education Department physical science papers). If this view is adopted by the teacher then according to Lederman & Druger (1985:649) the most "successful" teaching will occur when students exhibit the greatest conceptual change towards the viewpoint held by the teacher, irrespective of the "adequacy" of the teacher's viewpoint.

It was obvious to the researcher that pupils must have realised or adopted the same view on the nature of science as the examiner if they were to perform well in the examination. The South African examination system is often characterised as a case where the "proverbial tail wags the dog." Thus South African teachers, if they are to prepare pupils for success in the external examination system, must teach to the epistemology of the external examiner.

Common belief has it that South African pupils are not so much examined on what they are taught, as taught in a way that will enable them to succeed in a particular external examination. If we wish to change the focus of science education by the next century then we must evaluate our view of science as manifested in the school curriculum.

Abimbola (1983:189) claims that practising teachers should take courses in the philosophy and history of science so that they will be in a position to "...ask appropriate questions about the science curriculum and to come to decisions concerning them." The researcher's concern was that he had no appropriate knowledge of the philosophy of science to call upon to defend or support any of the views of the nature of science that surfaced during the marking process. The examiner had similar difficulties, resorting in the end to the unsubstantiated claim that unbiased observations were the origin of "good" science. According to Hodson (1988:20) this is not unusual, because:

> ...despite a rapidly growing literature dealing with the implications of the philosophy of science for science education, science teachers remain surprisingly ill informed about basic issues in the philosophy of science.

Etchberger & Shaw (1992:412) suggest a number of interrelated requisites for a teacher to move towards a more constructivist approach to teaching. The teacher has to be dissatisfied or uneasy with the way things are. This is followed by an awareness of a need to change and then some form of action must follow, but above all "...reflection throughout the change process is vital for continued teacher change." (Etchberger & Shaw,1992:412)

The motivation for this research is an attempt to address the problem of inadequate knowledge of the philosophy of science on the part of teachers. The aim of the research is to develop a simple, concise, and as far as it is possible to do, valid instrument, in the form of a questionnaire, that could be utilised by practising teachers to: firstly give them an indication of different views of science that impact on their daily practice and secondly to help them clarify their own position vis-à-vis the nature of science. If the questionnaire were only used in this personal individual manner then there is no guarantee of conceptual change on the part of the teacher. A more effective use would be to use the questionnaire to provide a framework around which in-service workshops on the nature of science could be developed. Support for the viability of this option comes from Carey & Strauss (in Hodson,1988:21) who claim that a teacher's view of the nature of science can be considerably improved by appropriate in-service education. Lederman (1992:341), however, challenges this viewpoint, claiming that attempts to change teachers' concepts of the nature of science using academic-year institutes (in-service courses) have met with little success in changing teachers' general understanding of the nature of science. These contrasting claims necessitate that the initial goal of workshops, based on this questionnaire, should not be to change teachers' views, but to encourage them to become reflective practitioners. According to Kyle et al (1991:416), reflective thinking improves practices and our understanding of practices. This would help to achieve what must be the ultimate goal of all science teachers; to ensure that students receive the very best science education that can be offered. (Kyle et al,1991:418).

According to Lederman (1992:339) if we are to improve teachers' conceptions of the nature of science we have to assess their conceptions. This aim of the research would involve the gathering of data that would assist in the structuring of workshops aimed at sensitising teachers to the different views on the nature of science. At no stage is a high degree of external validity claimed, but some understanding of the different possible views held by teachers who attend such workshops, may be gleamed from this study.

The questionnaire assumes that it is possible to identify key tenets of the different views of the nature of science, and that it is possible, on the basis of ten "key" statements, to at least place teachers on a continuum ranging from traditional views to alternate views of the nature of science.

The review of the literature in chapter 2 had to be broad enough to do justice to the complex and extensive field referred to as the nature of science, while at the same time focusing on a particular concept that could adequately illustrate the impact a particular view of the nature of science could have on classroom practice. Before different views of the nature of science could be discussed, the term "nature of science" had to be circumscribed in terms that made its relevance to science education clear. Two major philosophical perspectives have attempted to account for the development of scientific knowledge: namely positivism and post-positivism (Garrison in Glasson & Lalik,1993:187). Inductivism, which encapsulates most of the main concepts of the positivist theories, and constructivism which can be singled out as illustrating most of the ideas surrounding the post-positivist theories are discussed in detail (Glasson & Lalik,1993:188).

All participants involved in science education have definite views on the nature of science, although some participants may have difficulty in succinctly verbalising them. It is important that the origins of these views are identified and their impact assessed, before positive changes can be brought about.

In order to create the necessary focus for a meaningful discussion on the impact of the nature of science on classroom practice, one area, practical work and the role of observation, was singled out. According to Ganiel & Hofstein (1982:581) and Lynch (1987:31) the idea that practical work in science is important, is largely undisputed. However, Woolnough (1983:61) claims that the aims and objectives for practical work can be disputed. These aims and objectives are determined by, amongst other things, the view of science held by the curriculum designers. For instance, according to Daniels (1974:65) "...the structure and content of a curriculum will depend to a large degree on the theory of learning accepted,..." Once the aims and objectives have been clarified, and because the curriculum, in its broad sense, includes a view on the form of assessment, the problem of assessment of practical work has to be addressed. The role that observation plays in practical work depends on the view of science subscribed to, and as such the decision of what is acceptable varies depending on the view of science adopted.

Chapter 2 concludes with a discussion of the viability of teacher workshops to challenge teachers' views on the nature of science.

The research methodology employed is set out in chapter 3 and concentrates on the strengths and weaknesses inherent in the questionnaire. The constant areas of concern identified in many "attitude type" instruments, namely validity, and to a lesser degree, reliability, are addressed (Munby,1983).

The research was conducted over two years. The development of the 1993 survey (discussed in chapter 4), raised certain issues that needed to be reassessed and this necessitated a follow-up survey that is discussed in chapter 5.

The discussion of results (chapter 6) illustrates how the original survey was used to categorise the respondents as having a predominantly inductivist or constructivist approach to the nature of science. On reflection this "either/or" approach was not adequate to do justice to the extremely complex concept of teacher conceptions towards the nature of science and this resulted in the 1994 surveys being refined in both structure and method of analysis to enable respondents to be placed on a continuum that ranged from a strongly positivist to a more post-positivist view of the nature of science.

According to Olivier (1989:10) "Theory is like a lens through which one views the facts; it influences what one sees and what one does not see." This same view is expressed by Hanson (1979) and is a comment on the role of theory in science. Teachers' concepts of the nature of "scientific theory" will influence and might even determine, what, how and why they teach and assess a particular topic. The concluding chapter attempts to show the merit of using the questionnaire as a tool for individual teachers to assess their own standpoints on particular philosophical issues related to science education and for providing a structure around which some of the main ideas of the different views can be debated with regard to their impact on the pupil in the classroom.

CHAPTER 2

REVIEW OF THE LITERATURE

Chapter outline.

According to Munby (in Shaw,1992:14) gaining a truly accurate description of the teaching process requires researchers to go beyond the realms of behaviour and knowledge, they have to study teacher beliefs because, as Yager & Lunetta (1985:62) claim, "To be effective in introducing students to science, science teachers must be familiar with more than the concepts of science. They must understand the nature of science in rich philosophic, historic, and human perspective."

The concept, the nature of science, is first addressed in terms of working definitions and its importance to science education is considered before particular theories on the nature of science and the nature of learning that underpin science education are considered. Two main theories are highlighted, namely: inductivism and constructivism. Each theory predisposes conflicting claims on the status of observation in practical work. Inductivism sees observation as the secure base from which all scientific knowledge is advanced, while constructivism considers all observations to be dependent on the observer's prior knowledge.

A number of sources that influence teachers' views on the nature of science can be identified, namely the curriculum, textbooks, school environment, journals, and in-service training.

Practical work, considered a central element of science education, is discussed with respect to the two dominant theories on the nature of science. The role of observation is highlighted because it brings to the fore the essential difference in approach adopted by exponents of different views of the nature of science. The impact of different views on the nature of science held by different roleplayers is examined before the chapter concludes with a consideration of what, if anything, can be done to bring about conceptual change in teachers.

The nature of science.

The nature of science is a complex concept that requires working definitions for it to be of use. According to Lederman (1992:332) the early part of this century saw the nature of science as defined in terms of the scientific method, during the 1960s the definition revolved around the processes of science, and now in the 1990s the definition encompasses scientific literacy. Ogunniyi (1982:25) has also provided a definition, but it is Lederman's definition, couched in practically applicable terms, that is used in this chapter. He defines the nature of science as "...the values and assumptions inherent in scientific knowledge (e.g., tentativeness, parsimony, empirically based, amoral, etc.)" (Lederman,1992:332). This succinct definition is distilled from his 1986 attempt at defining the nature of science in usable terms (Lederman,1986:4).

When teachers consciously and critically reflect on these values and assumptions inherent in the scientific enterprise they are working in the realm of "the nature of science". Geary (1983:142) claims that a clarification of an understanding of the nature of science influences the behaviour of the enlightened teacher.

The importance of the nature of science to science education.

The importance of student perception of the nature of science is illustrated by Edmondson & Novak (1993:555) "Students' conceptions of the nature of scientific knowledge influence their learning; their choice of learning strategy affects the depth of their understanding." According to Waterman (in Edmondson & Novak,1993:547) if science is seen as a body of proven facts, then it is studied by memorizing facts, if it seen as an ongoing process, then the person may learn concepts.

Piburn & Baker (1993:393) claim that there is a decline in attitude towards science as pupils progress through school, but it is left to King (1991:135) to ask the question: "Why do so many students avoid science?" The answer appears to revolve around the ideas that science is not interesting, that it is perceived as being difficult (Solomon,1991:97), and pupils' decisions <u>are</u> influenced by teacher's attitudes and the implicit philosophy of the curriculum. Hodson (in King,1991:135) claims that it is the implicit messages conveyed by the curriculum about what science is that is ultimately responsible for forming children's attitude and beliefs. A number of researchers (Abimbola,1983; Duschl,1988; Hodson, 1982a & 1982b) claim that problems of motivation in science stem from the scientistic method in which it is presented. A most disturbing consequence of conveying an inappropriate image of science to pupils has been detected by Ryan & Aikenhead (1992:577) who claim "...that traditional school science is actually discouraging bright students..." Ryan & Aikenhead's (1992:577) study supports the claim "...that if science instruction is going to convey accurate and appropriate images of science, it must be brought into line with contemporary epistemology."

Meichtry (1993:429) claims a large degree of agreement exists among scientists, science educators and policy-makers that the nature of science is multifaceted and an important component of scientific literacy. Scientific literacy is often stated as a goal of science education and according to Lederman & Zeidler (1987:721) "Improving the scientific literacy of the public is one of the most compelling challenges facing science educators". They claim that "...an adequate conception of the nature of science is considered to be a distinguishing attribute of the scientifically literate individual." Teachers have a responsibility to convey to their students, both implicitly and explicitly, an appropriate conception of the nature of science. (Lederman & Druger,1985:649; Zeidler & Lederman,1989:771). Lederman & Druger (1985:650) point out that research indicates that teachers have inadequate conceptions of science. Do teachers have the knowledge to carry out their responsibility?

Views on the nature of scientific knowledge.

Ryan & Aikenhead (1992:560) claim that "The nature of scientific knowledge..., can be viewed from many perspectives." Each view has profound implications for the curriculum, its implementation and assessment.

Garrison (in Glasson & Lalik,1993:187) proposed two major philosophical perspectives that can be used to account for the development of scientific knowledge: positivism and post-positivism. Abimbola (1983:183) supports this simplification by contending that two dominant doctrines can be discerned in the philosophy of science: empiricism and a "new" philosophy of science. Abimbola (1983:183) views positivism as a strict form of classical empiricism. Ryan & Aikenhead (1992:561) propose that views that converge with the newer philosophies of the nature of science can be referred to as representing a "worldly perspective" while views which diverge from the contemporary literature can be thought of as naive. Naive views can be identified with logical positivism.

Ryan & Aikenhead (1992:564) pose a question, the answer to which can allocate a particular philosophical perspective to a particular doctrine.

> Does scientific knowledge tell us what is really out there in the universe (ontology) or is scientific knowledge "mind stuff" (epistemology)?

If a particular perspective on the nature of science claims to to revolve around the study of being or existence (ontology) then it is at home in the positivist camp, but if it claims to study or investigate a theory of human knowledge (epistemology) then it forms part of the post-positivist doctrine. From an ontological perspective, empiricism, logical positivism scientism, naive realism, idealism, traditionalism, and inductivism all qualify for a positivist classification. If, however, epistemological claims dominate, the perspective belongs to the post-positivist category. Many contemporary views of the nature of science, e.g. relativism, deductivism, non-traditionalism, constructivism, and Abimbola's "new" philosophy can be categorised as post-positivist.

Abimbola (1983:185) attributes a transitional doctrine, lying between logical empiricism and post-positivist philosophies, to Popper's falsificationism perspective: a theory is only "scientific" if it can be falsified by experience. This may point towards a continuum of perspectives, rather that diametrically opposed points of view.

Abimbola's (1983:183) "new" philosophy of science developed as a challenge to logical empiricism and it is therefore not surprising that there exists a tension between these two competing philosophical perspectives.

According to Glasson & Lalik (1993:187) positivists "believe it is possible to use theory, together with value-independent observation and logic to discover phenomena that purportedly exist in the real world." The main thesis is that only knowledge claims that are rooted in direct experience can be genuine, consequently, observations and facts must precede theories and observations must be unbiased (Edmondson & Novak, 1993:548). According to Aikenhead (in Ryan & Aikenhead,1992:561), logical positivism contends that scientific knowledge is directly linked to reality and that science is the means of finding absolute truth.

Post-positivists claim that knowledge is a human construction and that observations are theory-laden (Glasson & Lalik,1993:188). According to Abimbola (1983:186) the "new" philosophy of science represents different philosophical viewpoints with some common threads running through them. Formal logic as the primary tool of analysis of science is rejected and there is an emphasis on a continuing research programme rather than accepted results as the core of scientific discovery. Apparently valid theories of learning are reflected in the emerging post-positivist philosophy.

It is when philosophers of science begin to ask the question: "Should we present scientific theory as an attempt to account for and explain the real world or as a tool to enable us to predict certain events?" (Hodson,1982a:644) that the debate between realists and instrumentalists emerges.

Nott & Wellington (1993:111) define realism as involving:

> ...statements about a world that exists in space and time independent of the scientists perceptions. Correct theories describe things which are really there...

while instrumentalism claims that:

> ...scientific theories and ideas are fine if they work, that is they allow correct predictions to be made. They are instruments which we can use but they say nothing about an independent reality or their own truth.

Statements on realism and instrumentalism by Zeidler & Lederman (1989:774), Hodson (1982a:645) and Munby (1983:150) are summarised in table 2.1.

Table 2.1
A tabulation of the main characteristics of realism and instrumentalism.

Realism's characteristics	Instrumentalism's characteristics
*Direct empirical validation is stressed. *Scientific knowledge is fixed or absolute. *Scientific knowledge does not involve human creativity and or imagination. It is independent of the knower. *Models represent actual behaviour.	*Indirect validation and logical analysis is acceptable. *Scientific knowledge is tentative. *Scientific knowledge is presented as products of human creativity and imagination. *Models are used to predict the behaviour of objects or events.

According to the statements in table 2.1 it would be tempting to place realism in the positivist camp and instrumentalism in the post-positive camp, i.e. to see realism as being part of the traditional domain and instrumentalism indicating a more modern approach to the nature of science.

Hodson (1982b:25), however, does not see these two perspectives as mutually exclusive. Both have a part to play in the development of scientific knowledge. He proposes a compromise view that is both realist and instrumentalist. He claims:

> Theories <u>are</u> instruments for calculating and predicting, but we hope that they are also descriptions and explanations of reality - though we may subsequently find that they are not. A realist can be a realist about some theory (those which he believes to be true) and instrumentalist about others, which he finds to be useful but not true (i.e. theoretical models), whereas an instrumentalist is always an instrumentalist and blurs the distinction between theory and model.

Hodson (1982b:26) claims "It is quite a common situation in school science to have a realist theory (for explanation) and an instrumentalist theory (for prediction) for the same phenomenon." Teachers may find it difficult to identify exclusively with either one of the perspectives unless they are presented with a specific situation. A possible solution is to provide a continuum on which one can place oneself depending on the circumstances.

Hodson (1982b:28) supports this idea:

> Scientific concepts are subject to change as the theories they comprise change and develop, but the physical world remains constant. Consequently, scientific practice - the process by which this change in theory is brought about - must also change. Thus, it would seem that there is no single scientific practice applicable to all science at all times.

Scientific theories move from instrumental beginnings to realist positions in which they have objective existence independent of the individual consciousness.

Educational literature highlights two main views: inductivism and constructivism. The inductivist view was the dominant view of the nature of science until the 1970's. The constructivist view has influenced science education for some time now, but it is only recently that it has started to have an effect on South African science classrooms.

Philosophers of science education, when considering the so-called traditional or inductivist view, have asked these questions: Is this really how science is practised? Is this the way that scientific knowledge is advanced? Is this the way that pupils learn science? Does this view enhance the understanding of science? Can the inductivist view for the advancement of science be justified in terms of logic and experience?

To answer these questions they have reconceptualised how scientific knowledge has developed. They have also applied the cognitive psychological view of the nature of learning. The results of these investigations have prompted a reappraisal of the inductivist view and the constructivist view has emerged as a new attempt to explain the natures of learning and science.

Stanton (1990:29) posed the following question: "Do we obtain our knowledge externally through reality or internally through our minds?" (my emphasis). One's answer will indicate to which view of scientific knowledge they are inclined.

The inductivist view of the nature of science.

The inductivist view belongs to the epistemology referred to as empiricism. Stanton (1990:29) claims that in this paradigm observations are objective, facts immutable and scientific knowledge grows by accretion and that knowledge is obtained externally through reality.

For many years science has been highly regarded by society. In science and its methods, society has seen something special, something that other fields of study do not offer. Siegel (1985:517) claims that the traditional view of science sees it as the possessor of a special method and as the epitome or apex of rationality. According to Duschl (1988:56) "Scientistic ideology portrays an image of science which places the cognitive foundation of scientific knowledge beyond reproach since any criticism of scientific knowledge must itself be scientifically based."

What is it in the Scientific Method that gives science a special kind of reliability? The empiricist assumption is that all input via the senses should, and can be unbiased and therefore objective. This provides an objective collection of "immutable facts" on which the rest of the Scientific Method is based. This empiricist view proposes that science is based on experience or observation coupled with reason, as distinct from theory (Waring,1979:20; Driver,1983:4; Stanton,1990,29).

According to Chalmers (1982:xv - 1) the naming of some claim, or line of reasoning, or piece of research as "scientific", is done in a way that is intended to imply some kind of merit or special kind of reliability. The elevated status given to the Scientific Method has created the impression that, if the method is followed correctly, truth, with its implied objectivity, would emerge. It is this objectivity that has appealed to both scientist and non-scientist alike. According to Siegel (1985:525), however, certain formulations of the Scientific Method are clearly untenable. Baconian inductivism and the mechanical method of employing the Scientific Method are indefensible. "There is no algorithm for discovery." (Siegel,1985:525). In supporting this Ryan & Aikenhead (1992:573) claim that the Scientific Method" should be replaced by "...any method that might get favourable results." Hodson (1988:28) cautions that because we cannot defend one particular method does not imply that there are no methods of doing science. According to Hodson (1988:28) "Scientific method, like the knowledge it produces, changes and develops in response to the context of inquiry."

One of the consequences, according to Hodson (1986b:391; & 1988:23), of the inductivist-empiricist view of the nature of science is the "...projection of a distorted image of science as value-free and independent of socio-historical and economic influences." Storey & Carter (1992:20) support this concept, claiming that "...we teach the myth of certainty and fact, when actually science is a varied process that provides our best explanation of data, obtained by experiment or observation at that particular time." The importance attached to the Scientific Method has concealed the reality of doing science. Real scientific work probably adheres only approximately to this strict rule-following method.

The Scientific Method has been offered as a neat summary of what does not really happen. As Millar (1989:55) argues:

> Gaining scientific knowledge is more like pulling oneself up by one's bootstraps, building an edifice of ideas on best guesses and hunches, which can be tested for their usefulness in explaining and predicting. This is skilful work, not rule following.

As Hemple (1966:11) cogently points out, if a scientific investigation starts with the inductivist premise of observing and recording all the facts, it will never get off the ground. Collection of all the facts would have to await the end of the world. In an attempt to escape this harsh reality, we can insert the word "relevant" before "facts", but then we are saying that the facts or observations must be relevant to something - a theory or previous knowledge. Observations then become biased and theory dependent. Hemple (1966:15) claims that "Scientific hypotheses and theories are not derived from observed facts, but invented to account for them." These observations must be made under a variety of conditions and no observational statement may conflict with the theory.

Observation is regarded as one of the cornerstones of the inductivist view. Two problems have been identified with this view. The first, the theory-laden characteristic of observations will be discussed in the section on observation. The second problem revolves around the validity of the process of induction to provide validity to theories, statements and laws. The process of induction occurs when a large number of singular observational statements are replaced by a single, general and universal statement. The inductivists, according to Chalmers (1982:13-17), have two approaches they can use to justify the use of inductivist reasoning to provide reliable and true scientific knowledge. The one is logic and the other is to resort to experience.

According to Chalmers (1982:14), "Valid logical arguments are characterised by the fact that, if the premise of the argument is true, then the conclusion must be true." Inductivist arguments are not logically valid. If, after a number of observations, a conclusion or universal statement is made, it is possible for the conclusion to be false and the premise to be true, without a contradiction (Waring,1979:21; Chalmers,1982:14). Chalmer's (1982:14) example illustrates this point:

> Suppose, for example, that up until today I have observed a large number of ravens under a wide variety of circumstances and have observed all of them to have been black and that, on that basis, I conclude, "All ravens are black". This is a perfectly legitimate inductive inference. The premises of the inference are a large number of statements of the kind, "Raven x was observed to be black at time t", and all of these we take to be true.

There is no logical reason why the next raven could not be a different colour to black. In this case the conclusion "All ravens are black", would be false. Chalmers (1982:14) concludes, "The principle of induction cannot be justified merely by an appeal to logic."

The inductivist may now revert to experience to justify the process of induction as being legitimate and valid. He could argue that induction has proved correct in so many cases that the principle of induction can be justified on the basis of experience. The "problem of induction", according to Hume, (in Chalmers,1982:15) is that one cannot revert to experience to justify the principle of induction.

The principle of induction worked successfully on occasion x_1
The principle of induction worked successfully on occasion x_2
The principle of induction always works.

The argument is itself an inductivist one. The inductivist is attempting to justify the principle of induction by using the principle of induction and this provides a misplaced faith in inductivism that stems from the fact that every time it is employed it works (Abimbola,1983:184)

The "rational" view of the nature of science is based on the inductivist approach. The principle of induction cannot be justified by resorting to logic or experience; therefore science cannot be rationally justified.

Other problems that will continue to plague the inductivist method are: How many observations are necessary and how wide a variety of conditions are sufficient?

It can be seen that the inductivist view of science has limited use because the principles on which it is based, objective observations and the principle of induction, cannot stand up to logical argument.

Hodson (1986b:391) argues that:

> The objectivity of science is not guaranteed by requiring that individuals are free of personal preferences and interests, as the inductivists claim, but by insisting that hypotheses are open to testing by others.

It is this testing of hypotheses by others that has lead to a view proposed by Popper; the falsificationist view. This view denies that science is based on induction at all. It proposes that all theories must be open to falsification.

Various researchers (Driver,1983; Osborne & Freyberg,1985; Millar & Driver,1987) have shown that the empirical process outlined above does not model childrens' learning. According to Millar (1989:50) "Knowledge,...does not simply emerge from objective and detailed observation." Children construct their knowledge.

A student, (quoted in Rowe & Holland,1990:87), comments on the suitability of observation as a sound base on which to build scientific knowledge:

> What is this game that scientists play? They tell me that if I give something a push it will just keep on going forever or until something pushes it back to me. Anybody can see that this is not true. If you don't keep pushing, things stop. Then they say it would be true if the world were without friction, but it isn't, and if there weren't any friction how could I push it in the first place? It seems like they just change the rules all the time.

This type of mismatch between scientists' science and pupils' science is highlighted by Johnstone (1985:15):

> Pupils get to the point of asking, "Do you want the real answer or do you want the school answer?" This has serious repercussions for the teaching of science. Common sense is a powerful friend, but a fearsome adversary.

The constructivist view of the nature of science.

A current view on learning has been referred to as the Constructivist Learning Model (CLM). According to Yager (1991:53) much cognitive research that has been undertaken in the past few decades has underpinned and supported this new approach to learning. (Posner et al,1982; Driver,1983; Driver et al,1989; Lythcott & Duschl,1990:445; Laverty & McGarvey,1991). Hodson (1988:28) compares the view that scientific concepts are subject to modification and growth to how children modify their own conceptual frameworks.

> Thus, acceptance of this view of progressive conceptual differentiation in science and of constructivist views of the nature of learning ensures harmony between the philosophical and psychological principles underpinning the curriculum.

Bodner (1989b:D4) sums up the constructivist theory of knowledge and learning in one sentence: "Knowledge is constructed in the mind of the learner." Mahoney, (in Watts & Pope,1989:327) says that "Constructivism refers to a family of theories that share the assertion that human knowledge and experience entail the active participation of the individual." Watts & Pope (1989:326) claim that for them "...constructivism adds some shape to what is otherwise a hotch-potch of ideas and ways of working."

A constructivist's answer to Stanton's earlier question is that knowledge is obtained internally through our minds. According to Norris (1984:130) this is not a new idea. Over 300 years ago the French philosopher, Descartes, claimed that we have no way of knowing for sure if what we conceive of as the external world actually exists. This contrasts with the empiricist view that knowledge is internalised from outside the learner. According to many researchers (Driver,1983; Driver et al,1989; Hodson & Reid,1988; Johnstone,1985; Yager,1991) the "transmission" view, where the learner is a passive absorber of information is no longer a viable view of the nature of learning. According to Watts & Pope (1989:327), "People are restlessly proactive - they set about interpreting their own world, they are not just passive recipients of someone else's knowledge."

Current views on cognitive and learning theory portray the learner as crucial to the learning process. According to Hodson & Reid (1988:159) a guiding principle of current epistemology is to shift the "...locus of control towards the learner."

Tobin (1993:20) claims that one cannot separate knowledge from knowing. He goes on to claim that in the traditional inductivist approach, where knowledge is seen as being separate from knowing, certain characteristics appear: beliefs are based on objectivism; the transmission model dominates; the teacher is in control and; the focus in the classroom is on content.

In contrast Driver, (quoted in Watts & Pope,1989:328), highlights features of constructivist view that impact on schooling: learners are not passive; learning involves an active process on part of learner; knowledge is not "out there" but personally and socially constructed; teachers bring prior conceptions to the learning situation; teaching is not the transmission of knowledge and the curriculum is not that which is to be learnt but a programme of learning tasks from which pupils can construct their own knowledge.

Yager (1991:53) says that in learning today "...the emphasis (is) on the learner, we see that learning is an active process occurring within and influenced by the learner as much as by the instructor and the school."

As Gunstone (1993:6) points out, the constructivist view is student-centred, but it is also strongly teacher-controlled as opposed to teacher-dominated.

The essential feature of the constructivist view of learning is that we learn by constructing new "knowledge" in terms of what we already know. Ausubel et al (1968:iv) sum up the implications:

> If I had to reduce all of educational psychology to just one principle, I would say this: the most important single factor influencing learning is what the learner already knows. Ascertain this and teach him accordingly.

If one takes Ausubel's ideas one step further, a second factor to consider might be what is intuitive to the learner. This is very often what the learner knows, but it is not necessarily the case. It might be more realistic to see science as starting with what is intuitive.

Bodner (1989b:D5) says that according to the traditional view, something is true, (or a fact), if it corresponds to reality. What is reality? Is reality that which is perceived by our senses? He argues that "In the constructivist theory, knowledge is `good' if it works;..." In this theory knowledge either works for us or it doesn't. There is no true or false, correct or incorrect interpretation of knowledge or reality. No true reality exists, only individual interpretations of the world. These interpretations are shaped by experience and social interactions.

According to Bodner (1989b:D6) knowledge is constructed by the learner. The learner is, however, not at liberty to construct random knowledge; the construction must work. It must be open to testing and adoption in the light of new information. Our knowledge is only maintained for as long as it is useful to us. Once the knowledge is of no use it is discarded or adapted. Posner et al (1982:212), using the ideas of Kuhn and Lakatos, believe that learning, which they see as coming to terms with and understanding ideas, can take place in one of two ways. Firstly existing ideas and concepts are used to deal with new phenomena, this they call assimilation. Secondly, when existing ideas are inadequate to grasp the new phenomena, the existing concepts are replaced or reorganised to make the new phenomena acceptable. This has been referred to as accommodation. Stanton (1990:29) uses a slightly different interpretation of these words.

According to Andersson (1986:549) many reports have highlighted the idea that pupils may have preconceptions that may differ from the accepted science concepts. Pupils, because they live in a world that is constantly giving them sensory input, try to make immediate sense of this input. They construct for themselves explanations that work for them. They do not suspend judgement and make unbiased, appropriate observations, and only once all the data from sensory input is obtained, do they follow the process of induction to obtain an explanation (law or theory). It is highly unlikely that a pupil could make an appropriate observation without having some theory or hypothesis to indicate which observations are appropriate and which are not appropriate. Lythcott & Duschl (1990:455) claim that "What one sees is in part determined by what one knows."

The concept of "Childrens' Science" was introduced by Osborne & Freyberg in 1985. They claim that "...children bring to science lessons views of the world and meanings for words which have a significant impact on their learning." Research shows that pupils will try to make sense of new data in terms of existing conceptions. Only when there is a mismatch between the pupils' theories and new information, will pupils start to question their theories. Rowe & Holland (1990:87) emphasise, "These home-grown conceptions are precious to us." Unless there is a really compelling reason to change them, these personal concepts will stay lodged in our brains. They go on to explain that students have to be convinced that each piece of scientific "common sense" is more useful and powerful than their own existing view. This is hard to achieve, since student models are based on real-world experience and science models are often a step or two removed in abstractness. Obviously the more teachers know about possible pupil preconceptions, the better they will be at providing learning experiences that stimulate pupils to modify their initial conceptions. Osborne & Freyberg (1985:13) support this idea: "...unless we know what children think and why they think that way, we have little chance of making any impact with our teaching no matter how skilfully we proceed." Driver (1983:2) concludes, "It is, after all, the coherence as perceived by the pupil that matters in learning."

A number of learning models have been proposed that claim to help teachers to teach for understanding. Wittrock (in Connor,1990:11) proposed the "generative learning" model for changing pupils' ideas. The model has three objectives: clarification of the pupil's existing ideas; modifying these ideas towards the current scientific view; and then consolidating the scientific view within the pupil's background. This model cannot be applied by teachers if science education is based on the inductivist paradigm.

A second model for teaching science whereby pupils can modify or abandon their ideas before adopting scientifically accepted ones has been proposed by Hill et al (1987:46). This five stage learning cycle (figure 2.1) claims to use constructivist principles to promote learning and real understanding.

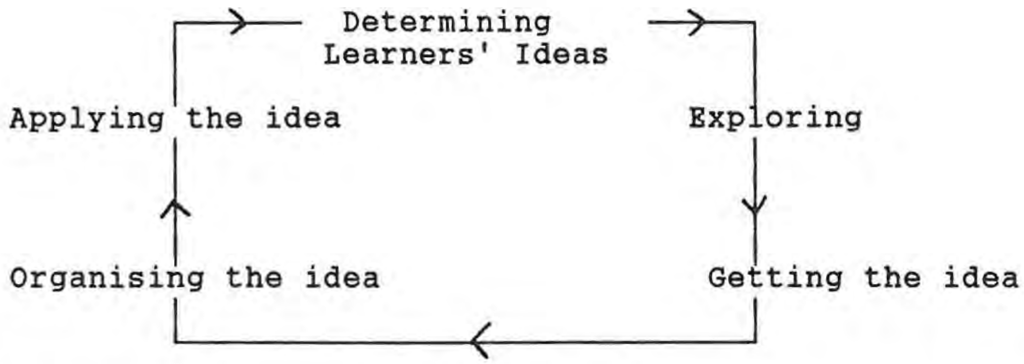


Figure 2.1
The Hill et al five stage learning cycle that enables pupils to adapt or change the concepts that they already hold.

Each stage of the cycle has specific objectives: determing the learners' ideas identifies preconceptions; exploring the idea lets pupils use their own language to express the idea; and getting the idea makes the concept explicit and allows for the introduction of new language and symbols. Organising the idea enables pupils to build a mental scheme of how the idea works, and applying the idea allows for use of the concept in familiar and new circumstances.

According to Yager (1991:54) "..., constructivists do not consider knowledge to be an objective representation of an observer-independent world." Pre-conceived ideas are not regarded as an anathema to the process of scientific discovery. Bodner (1989b:D4) goes on to liken constructivists to pragmatists, in that they do not accept the idea of truth as corresponding with reality. "Modern science does not give us truth; it offers a way for us to interpret events of nature and to cope with the world."

A constructivist teacher teaches in a different way to a behaviourist or inductivist teacher. Constructivist teachers probe pupil answers to find out why they have chosen a particular route. There tend to be fewer right and wrong answers. Correct answers are not "imposed" on pupils. According to Yager (1991:55) "Constructivist teachers would rather explore how students see the problem and why their paths towards solutions seem promising to them." According to Saunders (1992:137-8) "The teacher cannot modify the student's cognitive structure, only the student can." The teacher can assist pupils by providing situations which result in disequilibrium and by helping them to restructure their internal world so it is more consistent with the empirical data from the external world.

For Watts & Pope (1989:326) constructivism: "...suggests some basis for thinking about the thinking that young people do, and for learning about their learning." Yeany, (in Yager,1991:53), feels that this model may be the means by which all current lines of research in science education may be connected.

Constructivism empowers pupils!

Teachers' views on the nature of science and learning.

An understanding of science requires more than the mere action of acquiring a body of facts and skills. According to Billeh & Malik (1977:559):

> To understand science, one needs to understand its basic philosophy, its underlying assumptions, characteristics of the scientific enterprise, processes through which scientific knowledge is acquired and developed,...

If teachers are to teach science well they must have a clear understanding of the nature of science and have the ability to convey this understanding to their pupils, because according to Edmondson & Novak (1993:555), pupils' concepts of the nature of science influence their understanding. Gallagher (in Ryan & Aikenhead,1992:577) claim that textbooks and teachers' classroom practice - both frequently inaccurate and inappropriate - influence pupils' understanding of the nature of science.

Carey & Strauss (1970:368) emphasise the importance of a teacher's understanding of the nature of science:

> If the teacher's understanding and philosophy of science is not congruent with the current interpretations of the nature of science; if the objectives that he establishes are not congruous with the dynamic spirit of science, then the instructional outcomes will not be representative of science in spite of all the efforts that may be expended by those charged with the development of relevant curricular materials.

This illustrates the consequences of teachers, curriculum designers and examiners not keeping abreast of current developments on the nature of science. It is important that all stake-holders in school science have similar views of the nature of science. External examinations cast a giant backward shadow. The view of science held by the examiner dictates to the teacher, not only what to teach, but how to teach. A teacher who promotes a view of science that is incompatible with the view held by the examiner, cannot adequately prepare pupils for the present South African examining system.

Duschl (1988:51) claims research has shown that teachers' attitudes about the nature of scientific inquiry have distorted the nature of science by presenting scientific knowledge as representing absolute truth in its final form. What is disturbing are Gallagher's (1991:126) findings that even when teachers have a significant depth of understanding about the nature of science and long exposure to programmes supporting a post-positivist approach they still had not given up the view, learned at university, that scientific knowledge is objective. Although both teachers in his study saw science as a tentative, creative activity, they both still adhered to most of the traditional, positivistic views of science. Changing teachers' conceptions about the nature of science is not merely a matter of exposing them to different views. According to Edmondson & Novak (1993:549) the majority of college students and professors hold essentially positivistic views of the nature of science, these were found to be very strongly held, even in after "correcting" instruction.

According to Carey & Strauss (1970:366) science teaching in the USA has consisted of a continual changing of approach with regard to content, methodology, and philosophy. They emphasise that the two most important influences on the science curriculum, and how it is taught at any time, are the prevailing learning theories and the current philosophy of science. Science education should not be static and should evolve and develop as the nature of learning and science develops. A review of the history of science shows how the philosophy underpinning science education has changed with time and according to Carey & Strauss (1970:366) the changing methods of teaching and assessing science reflect these changes in the basic philosophy of science teaching. Unfortunately Abimbola (1983:188) sees developments in science education lagging behind those in the philosophy of science. "Science education may therefore need to adjust to, and adopt some of the basic tenets of the new philosophy of science."

The origin of teachers' views on the nature of science.

Teachers' views on the nature of science can originate from a number of sources. It is not possible to identify any one particular source as being more important than another because the amount of influence would depend on the individual teacher.

The curriculum.

Jansen's 1979 HSRC document "Objectives of Physical Science Teaching at Secondary Schools in the RSA" which can be considered the blueprint for South African science curricula sees the "demands of the discipline of science" heading a list of goals and objectives for science (Jansen,1979:83-89):

1. an introduction to the scientific explanation of natural phenomena;

2. an introduction to the "language" of physical science; and

3. an introduction to the Scientific Method.

It becomes clear from the aims and objectives of many of the syllabuses used by education departments in South Africa that much of the science practised is based on Jansen's 1979 HSRC document. Science education is embedded in the overall educational philosophy of the South African education system which is based on Christian National Education (CNE) principles. Van Wyk's (1993:2) reason for teaching science in school illustrates the impact of CNE on his view of science:

> According to Genesis 1:28 man, as a creature of God, has been appointed as steward of created reality and for this reason it is essential that he should acquire as much knowledge of this reality as possible. In the teaching of Physical Science it is endeavoured to impart to the pupils a knowledge of matter, i.e., the basic building block of created reality, as well as of the natural laws to which matter is subjected. This is accomplished by way of the scientific method.

CNE with its roots firmly based in God, the Creator of reality, creates the impression that there are "facts" out there that have been created by God and the goal of science education is to enable (lead), pupils to discover what God has created. Man must be taught to "uncover" the facts and attempt to understand this externally created reality. This would support Edmondson & Novak (1993:550) claim that a barrier to moving students towards more meaningful learning strategies is a strongly positivistic orientation of the courses and evaluation processes.

Teacher's history.

Trumbull & Kerr (in Baker,1991:337) argue that the major influence on the development of teachers is the way they have been taught. Although it could be argued that this may not be the major factor in the development of a teachers' views it is certainly a factor to be borne in mind.

Textbooks.

Osborne (1990:190-191) claims that what is written in textbooks inculcates in pupils a certain view of the nature of man. The treatment of Newton's Laws dominates physics in schools. "The world view presented is one that is relentlessly deterministic, linear and remote from human action or influence." We talk about ignoring friction, ideal gases and pieces of wires and batteries that have no resistance. Gallagher (1991:122) claims that textbooks influence the content and nature of what is taught especially if the teachers lack time and/or expertise.

According to Gallagher (1991:123) textbooks tell us what we know and give very little information as to how we came to know it. The impression created is that scientific knowledge is revealed truth. Gallagher (1991:125) supports the claim that most textbooks reinforce the teaching role that is familiar to teachers - presenters of factual knowledge. Why should the role of textbooks be presented in a negative light? Saunders (1992:136) claims the many science programs are textbook driven and these textbooks often fail to capitalize on the more effective instructional practices comming out of the constructivist perspective.

School environment.

In schools the heads of science departments wield a large amount of power to influence a teacher's views. These Heads of Department (HODs) not only vet what is being taught by novice teachers, but they influence how it is being taught through teacher evaluations. They are also responsible for the moderation of examination and test question papers set by novice teachers and they moderate how these "inexperienced" teachers should mark scripts. It follows that if the HOD holds a different view of the nature of science to that held by the "inexperienced" teachers, it is the HOD's view that will triumph.

Assessment and examinations.

The giant backward shadow cast by external examinations influence teachers' views on the nature of science. Assessment can and does drive change in education. Examinations may be a major stumbling block to paradigm shifts, but because of their power, they can also be very powerful change agents (Hodson & Reid,1988:164).

In traditional assessments, for example, the emphasis is on "product" rather than on "process" and this according to (Josephy,1986:219) encourages "blind-copying" and rote learning. This impacts on a teacher's teaching methodology. Josephy (1986:220) claims that it is not easy to change long-held views on assessment and as long as the deterministic approach to assessment persists, getting the "right answer" at all costs will be the aim of most pupils and teachers. According to Saunders (1992:140) "Like it or not, many students are strongly motivated to learn what they need to know to pass the test or exam." This heavy emphasis on lower-level knowledge is not conducive to the development of scientific knowledge in students.

The researcher's personal experience of marking CED physical science papers is that the examiners either personally held an inductivist view of science, or were happy to support the predominantly inductivist approach to the concept of observation. This view of the nature of observation dictates that only specific answers related to sensory input were accepted. In the 1993 examiner's report it is obvious that the examiner perceives the "problem" as one of candidates not reading the question properly and not of conflicting views on the nature of science. "...as mentioned in previous reports, candidates need to read questions carefully. For example, when asked `What is observed?`, a theoretical explanation does not earn any marks." (CED,1994:111). There is a totally false concept of the "skill of observation" and according to Wellington (1989:17) "It is therefore of rather more than philosophical concern."

Pallrand (1993:45) claims that newer forms of assessment have a major impact on the way that teachers teach and pupils learn. If assessment does drive the curriculum, then we have to carefully consider how we assess. According to Waring (1979:50):

> Again and again, the advocates of change have been forced to recognize that until examinations can somehow be made to follow and not to lead in the determination of content and approach, and until syllabus decision making is taken out of the hands of those whose primary interest is individual specialisms, little is likely to change.

According to Pallrand (1993:43) we have to ensure that our assessment methods are consistent with our goals and views on the nature of science and learning. If what Pallrand claims is true, then science HODs in schools will ensure that assessment in their schools conforms to their view of science. This view of the nature of science might not conform to the newer trends in the philosophical or the pedagogical aspects of teaching science.

Journals.

Drost (1982:166) claims that subject specialist journals play an important role in the professional development of educators. It is by this means that new developments, that are continuously taking place, are brought to the attention of educators. These journal articles are essential to enable interested persons to remain abreast of the latest developments in their subject area. Of major concern is that many teachers have probably not have read or heard much about the changing nature of science and learning since they began teaching.

In-service education.
This topic is discussed at the end of the chapter but is worthwhile noting that one means of getting teachers to become aware of the latest developments in science education is to encourage them to take part in appropriate in-service education courses. These courses should be presented by presenters who are aware of, and subscribe to the "newer" views on the natures of science and learning.

Professional associations.
Clough (1992:37) claims that there is no way for science education to develop other than to respect the growing body of pedagogical research. He claims that the best way for science educators to achieve their most desired goal - excellence in science teaching - is to use this body of knowledge that is growing daily. The participation of teachers in professional associations (e.g. SAATPS) is useful in exposing teachers to the current developments in science education. They can, via newsletters, meetings, conferences and conventions be exposed to alternative views on the nature of science. These views may differ from the views of the syllabus, HODs, subject advisors and external examinations.

Practical work and its relevance.

The view of the nature of science held by teachers, will influence their approach to practical work and its assessment. Kempa (1986:68) claims that the reasons and justifications for practical work are based on a particular view of the nature of science. According to Tamir et al (1982:42), "Laboratory work has been one of the unique instructional means of teaching science." The importance of practical work is not in question, it is the aims of practical work and what is actually achieved by doing practical work that is in question.

Lynch (1985:4) claims there are three orientations towards the use of practical work in science:

1. as a visual aid - to reinforce understanding of concepts and theory;
2. to promote experimenting - problem solving skills and working as a scientist; and
3. to teach basic laboratory skills and techniques - actually doing, as opposed to knowing how to do.

Woolnough (1983:61) highlights the first orientation, claiming that there is a widely held belief that "...insight and understanding of a phenomenon come as the outcome of successful practical work." This implies that the purpose of doing practical work is to help with the understanding of the theory. Lynch, (in Bryce & Robertson,1985:1) reports that South African surveys reveal that teachers and educators consider that practical work should serve as a means of facilitating learning and understanding. The concept of using practical work to illustrate previously taught theory, rather than for the development of skills, would be supported by the Cape Education Department's (CED) approach in which practical and theory are assessed only in theory examinations. Saunders (1992:138) claims that the traditional or verification aim of practical work is all but useless because its implied passivity will not be able to produce meaningful disequilibrating experiences - the cornerstone of learning in the constructivist perspective. Solomon (1991:97) has documented research that shows that British students have difficulty in connecting their school experimental work with scientific theory. If this is the case, then it might explain Edmondson & Novak's (1993:551) conclusion that a number of studies show the appalling lack of effectiveness of laboratory studies.

Tamir et al (1982:42) supports some combination of all three orientations: "Laboratory work is not conceived as a series of hands-on manipulations which take place for their own sake, but rather as an interaction between ideas and experiments."

A commonly cited justification for including practical experiences in science is that science is an empirical subject and that pupils need to experience the processes of science if they are to understand them. Unfortunately many curriculum projects have implied that the Scientific Method is the only way in which "real" scientists work. This, according to Cross (1990:16), is incorrect:

> We are trying to teach science using a flawed concept of how scientists work. This mistaken perception has frustrated our teaching, hobbled science education, and turned youngsters away from science.

According to Ausubel et al (1968:524), from the time of Bacon through to the 1950's the emphasis had been on the methods of scientific enquiry, particularly on the nature of "unbiased observations and controlled experiments." (Novak,1978:2-3). It was Thomas Kuhn's "The Structure of Scientific Revolutions" in 1962, that gave impetus to a changing view of the nature of knowledge and knowledge production. A "new" epistemology of constructivism was developing. While this new epistemology was being proposed in the scientific community as a more accurate description of the way that scientists worked, the educational community was starting to give priority, according to Hodson & Reid (1988:160), to an epistemology that was fundamentally flawed. This is illustrated by the adoption of the heuristic view of the nature of science in UK schools during the 1960's.

An approach to school practical work which reflects more closely how real scientists work is modelled on constructivist theories. The constructivist viewpoint would propose that practical work be theory driven. Theory would precede the practical (Harris,1990). The inductivist view, in which practical work precedes the theory, envisages the theory as "growing" out of the practical work. The close link between theory and practical is apparent whichever view is held, but theory without practical is of little use, and process without a context and content is meaningless.

Another view of practical work is that "process" should be as important as "product". According to Wellington (1989:7) the move towards "process" science has been a response to the knowledge-led curriculum of the past. This movement has provided a fresh approach to science teaching and has also opened up "...a whole new debate on the nature of science education and of science itself."

Woolnough (1983:61) suggests that we shouldn't use practical work solely to support theory, but that we do practical work for its own sake. This is an expanded version of Lynch's second and third orientations. Woolnough's "new" aims for such a model of practical work would be to:

* develop specific skills, including observation;
* develop a scientific way of working - not necessarily through the much maligned Scientific Method; and
* enable pupils to obtain a "feel for various phenomena".

This view of doing practical work for its own sake has implications for the assessment of practical work. According to Bryce & Robertson (1985:2-5) if practical work is important in its own right, then it would be sensible to assess it directly. They go on to say "There is certainly evidence that practical work is sufficiently distinct from more cognitive aspects of science to merit direct assessment."

If practical work is to help pupils to grasp science concepts and to facilitate the achievement of other non-practical objectives, then a different form of assessment is required to the one mentioned above.

Olsen (in Bryce & Robertson,1985:3) distinguishes between the...:

> ...development of knowledge, (know that), and the development of skills, (know how). Practical science ... may be de-emphasized or de-valued, if one considers it merely as the medium by which the former is learnt.

Practical science is not simply a means to an end. It can be included in the curriculum in its own right.

Observation.

According to Norris (1985:817) "Observation is fundamental to scientific investigation..." The concept of what scientific observation entails for teachers is often not adequate for the important role that it has to play.

> Scientific observation sometimes involves relatively simple activities requiring little preparation and unsophisticated interpretation. At other times, however, scientific observation is an extremely complex activity, indeed among the most challenging enterprises in which human beings engage. The science education field typically portrays only that segment of scientific observation at the simple end of this spectrum. In doing this, there is a risk that students will acquire a distorted image of scientific observation.

The claim that scientific knowledge can only originate from unbiased observations needs to be seriously challenged. The counter-claim that all observations are subjective and necessarily produce subjective, knowledge also requires closer scrutiny.

Observations can be reported in descriptive, lustreless ways: "A brown precipitate was formed." We cannot deny that these are genuine cases of seeing or observing. It would be silly to say that these were not observations. It would, however, be just as unsound, according to Hanson (1979:20), to suggest that these are the only genuine cases of seeing or observing.

Hanson (1979:4) believes that there could be a sense in which two people do not actually see the same thing, do not begin from the same data, even though they have normal eyesight and are visually aware of the same object.

Hanson (1979:4) uses an example of two microbiologists looking at an Amoeba - a unicellular animal. "What either man regards as significant questions or relevant data can be determined by whether he stresses the first or the last term." The "unicellular" scientist sees a cell with a cell wall, a nucleus, etc. just like any other cell. The "animal" scientist sees the <u>same</u> cell as an animal in its own right. It excretes, reproduces and moves about - more like an animal than a cell.

"Seeing is an experience. ... People, not their eyes, see." (Hanson,1979:6). The mere fact that the same image falls on the retina does not mean that people see the same thing.

When a person sees a bicycle, the image of a bicycle falls on the retina. The person then sees a bicycle. What does <u>not</u> happen is that the person acknowledges the image and only <u>then</u> tries to interpret it, and eventually, by association, comes up with an interpretation, "bicycle". There is in a sense a theory that people use when they see a bicycle. If a person knows about bicycles from experience, they do not, in their minds, first go though options of what the image "bicycle" cannot be, before they come up with seeing a bicycle (Hanson,1979:22). According to Hanson (1979:20):

> First registering observations and then casting about for knowledge of them gives a simple model of how the mind and the eye fit together. The relationship between seeing and the corpus of our knowledge, however, is not a simple one.

Hanson (1979:20) argues that interpretations can simply "be there" in the process of seeing. There is no two step process.

According to Hanson (1979:13) visual experiences become organised in the context in which they occur. Experience also sets the context in which something is seen. Pupils work with copper and copper sulphate during the electroplating exercise in standard 6. In the copper/zinc electrochemical cell exercise performed in standards 8 and 10, pupils could reasonably expect copper to be a product. Context and experience would guide pupils to say that they see copper being deposited. It would be inappropriate for them to ignore their experience, and the context, and to begin by saying that they see a brown precipitate. Pupils simply see copper being deposited. Pupils use the theoretical knowledge that they have gained and attempt to build a more sophisticated theoretical understanding of phenomena (Hodson,1986b:384). Only inexperienced pupils may say they see a brown precipitate. These pupils are not blind, but they would be blind to what the experienced standard 8 pupil would be able to see.

Hanson's (1979:17) example illustrates this point:

> We may not hear the oboe is out of tune, though this will be painfully obvious to the trained musician. Who, incidentally, will not hear the tones and <u>interpret</u> them as being out of tune, but will simply hear the oboe to be out of tune.

According to Hanson (1979:19) "There is a sense, then, in which seeing is a theory-laden undertaking. Observation of `x' is shaped by prior knowledge of `x'." A number of researchers, (Norris,1984; Millar,1989) all argue that the reality of working as a scientist is that we give the strongest justified interpretations to observations. It is only when very good reasons to doubt our theory-laden observations are raised, that we move into the relatively neutral, and "safe" descriptive language of colours and temperature changes etc. There is always a reason to doubt our interpretive, observational statements, but as Hodson (1986a:25) notes, "...we cannot claim scientific knowledge to be certain (we could be mistaken), this does not mean that it is uncertain." Shapere (in Hodson, 1986a:25) argues, "...the mere possibility of doubt arising is not itself a reason for doubt." We don't always have to make observational statements in terms of that which reflects only what is found on the retina and then make interpretations. We can make inferential, observational statements. Norris (1985:817) claims that "...the distinction between observation and inference is context bound, and changes as scientific knowledge changes." Scientific observation is only historically linked to human perception and the paradigm shifts that have occurred in the views on the nature of science should permeate through to the classroom.

Significant or relevant observations depend on what we already know (Hanson,1979:26). An object or event is not intrinsically relevant. If seeing or observing were purely a physical process, an image falling on the retina, then nothing would have significance. Why is the observation of the brown precipitate more important than the chip out of the top of the beaker? What makes the mark on the beaker less significant than the brown precipitate? If we don't have a theoretical framework in which we are making observations, we are simply collecting data, and much of the data may be irrelevant. Pupils, especially at a young age, are looking for the surprise, the different thing. They may see the smudge made by the spilt indicator solution rather than the colour change of the solution. Data which is collected independently of a pre-conceived theory may produce much that is irrelevant. "In practice, observation is carried out to collect particular data in order to support, to refine or to test a theory." (Hodson,1986b:383). Theory precedes data collection.

The answer required by an inductivist examiner assumes that a significant or relevant observation is required. The "unbiased" observation of seeing a brown precipitate is not unbiased, it requires previous knowledge that what happens at the zinc plate is more significant than other sense data that falls on the retina. According to Hodson (1986a:23 & 1986b:382) "Knowing what to observe, knowing how to observe it, observing it and describing the observations are all theory-dependent and therefore fallible and biased." Millar & Driver (1987:47) note that:

> When they are asked to observe an event and explain their observations students tended to make observations which fitted their expectations; ... they gave reasons for not considering disconfirming cases (a strategy not unknown among scientists).

As Hanson (1979:7) so aptly puts it: "...there is more to seeing than meets the eyeball."

According to Geary (1983:144) we sometimes have to deal with observations made by pupils that are in conflict with what we are expecting them to make. If pupils don't see what we expect them to see and we insist, because it supports the all important theory, that they see the "correct" thing, we will not be teaching science. We cannot get pupils to write down something that goes counter to what they "observe" without some satisfactory explanation. There may be a tendency for pupils to think that a "good" observation is one that confirms what the teacher says (Geary,1983:144).

It is easy to undermine the empiricist assumption about observation. Observations do depend on human perceptions and "...human perceptions are not objective." (Chalmers,1990:43). Observational statements about the same data "...will vary from person to person, from culture to culture, and from theoretical school to theoretical school." (Chalmers,1990:43). Observation is undeniably theory-dependent. The extreme relativist could use this argument to destroy all "objective" scientific observation. Is it necessary to use this argument to such extremes that the "objectivity" of science is destroyed?. Probably not. Chalmers (1990:43) regards this emphasis on the "...subjectivity or psychological aspects of perception by individual observers as misplaced, ... and as playing into the hands of the extreme relativist."

According to Chalmers (1990:46-47) scientists accept the subjectivity of observational statements. Their response has been to replace "mere" observation by instrumental measurement (pointer readings, clicks on counters etc.), routine procedures and controlled experiments. In this way some of the subjectivity of human observation may be bypassed. These routines, methods and instruments make quantitative observations more reliable and less dependent on the theoretical framework of the observer. These methods have been able to lend objectivity and give credence to observational reports. It is important to recognise that these methods and instruments are themselves theory dependent and that it is inevitable that all worthwhile scientific observations remain selective. Hodson (1986b:385) claims that "What we choose to observe and the way in which we choose to observe are dependent on our knowledge and our expectations."

If a pupil says that copper is formed in the Zn/Cu cell, then this statement can be substantiated by adding concentrated nitric acid to the copper, and NO_2 will be produced. The "brown fumes" can be tested to show that they are NO_2. Chalmers (1990:49) says that "Acceptable observational statements can be understood as those statements describing observable states of affairs that are able to survive tests involving skilled use of senses." This does not mean that observational statements are infallible, but by using appropriate methods and skills the observation might be able to claim a higher degree of objectivity, but never infallibility.

Chalmers (1990:49) believes that objectivity can be achieved and often is achieved in science, but this is no guarantee that we can always achieve a high degree of objectivity.

According to Hodson (1986b:386) "The key to good observation in science is a sound theoretical frame of reference." This is in contrast to the Scientific Method that says that a person must first make an unbiased observation - i.e. observation precedes theory - rather than stressing the mutual interdependence of observation and theory. This idea is supported by Millar (1989:51). The best scientific observations are not naive like a child's. To observe well, we need adequate training in observing. According to Millar (1989:52) when we talk about observing in science we mean teaching the "skill" of observing closely, and more importantly, making relevant observations. It is impossible to know which observations are relevant unless we already have in mind what we are supposed to be doing or looking for i.e. we already have a theory. Observation therefore depends on a theory.

The lack of objectivity and the theory dependence of observations are not insurmountable problems. Observations can be objectified to some extent, but when they are made more objective they must still be open to revision and they certainly do not provide the secure base for science that the inductivists claim.

When observation and theory come into conflict which is correct? In an inductivist environment observations would be regarded as correct while in a constructivist environment both may have some claim to correctness. According to Hodson (1986b:383) "Most school science courses fail to recognize and appreciate this dynamic relationship between observation and theory." The improvement of school science courses may depend on the emphasis of this relationship.

According to Hodson (1990:37) the mistaken assumption that a priority and security should be given to observation has long since been thrown out by philosophers. He asks if it is not high time that teachers abandoned this assumption as well.

Norris (1985:825) claims that observations are not infallible. Why, therefore, do teachers support the concept of unbiased observations? He proposes that if scientific observation could be placed on a spectrum, then one would find all the examples used in school science occur at the simple end. At this simple end of the spectrum unbiased observations are plausible, but scientific observation is in many instances a complex activity which requires analysis at the non-simple end of the observation spectrum.

The disadvantage, according to Norris (1985:831), of sticking with simple unbiassed observations are the unintended lessons that pupils learn: namely, scientific observations contain nothing substantial; observe as quickly as possible; observation requires no planning; and detailed interpretation is not required.

The teaching/classroom implications of different views on the nature of science.

The view of science held at a particular time influences how science is taught. During the last century a particular view of the nature of science provided a justification for the inclusion of science in the curriculum. In a report by the British Association for the Advancement of Science published in 1867 entitled "On the Best Means of Promoting Scientific Education in Schools", one of the reasons for including science in the curriculum was because it provided "...an excellent means of mental training by `providing the best discipline in observation and collection of facts, in the combination of inductive and deductive reasoning,'..." (Jenkins,1989:27). According to Jenkins (1989:27) the British Association's motivation for the inclusion of science in schools was because it was perceived as objective and value-free. It was felt that these characteristics "...constituted a powerful weapon with which to fight dogma, superstition, and authoritarianism."

If a goal of teaching is to get a pupil to produce a predetermined response, then a behaviourist model of teaching will suffice (Yager,1991:54). According to this model of teaching the teacher must provide a set of stimuli and reinforcements and the student is expected to provide the appropriate response. Yager (1991:54) states that there is no place in the behaviourist model for understanding. Posner et al (1982:212) support this view.

If the goal of teaching is to get pupils to understand, solve problems and adapt present information and knowledge for use in new situations, then an entirely different model of teaching is required. Questioning, according to McKnight (1989:7), helps pupils to define and ultimately to solve problems. Pupils must be taught to ask questions. This can be done by introducing experiences that make pupils become aware of discrepancies between what they observe, and what they expect to observe. She goes on to say that "Discrepancies - differences, inconsistencies, disagreements, disharmonies - can only be perceived by comparison with prior knowledge." If teachers don't take the time to find out what pupils' prior knowledge is, then they cannot set up situations that will enable pupils to become aware of these discrepancies. Expecting pupils to first note trivial, unbiased observations, does not promote learning.

According to Tomlinson (1977) the "heuristic model", developed by Armstrong in the UK at the turn of the century, influenced much of the practical work attempted in schools at that time. The Thomson Report in 1918 cast doubt on the value of practical work, especially the so-called "discovery method". After this report the "discovery method" started to take a back seat to the "transmission model". This heralded a relatively stable period in the development of science education. This stable period was characterised by a predominantly inductivist approach. The behaviourist view gave a stimulus and an appropriate response was expected. What and how pupils thought, was regarded as irrelevant. Practical investigations were expected to start, in typical inductivist fashion, with unbiased observations. This model, which Bodner (1989a & 1989b) argues is wrong, still prevails in many classrooms today. Bodner (1989b:D5), a strong supporter of the constructivist approach, maintains, "Knowledge is seldom transferred intact from the mind of the teacher to the mind of the student, (and consequently) useful knowledge is never transferred intact."

It was during the 1950's and 1960's period that new science curriculum initiatives were started. These initiatives did not seem to acknowledge the developing philosophy on the nature of science but reverted back to the philosophy of science as proposed by Armstrong in the early part of this century.

One of the initiatives, Nuffield, was based on a heuristic view of knowledge acquisition. Although Nuffield, and similar projects, moved from a "passive" to an "active" approach, the prior knowledge of the learner was still not emphasised. Knowledge was still seen as absolute and non-problematic.

Millar & Driver (1987:57) claim that if pupils failed to "discover", it is not a problem with the teacher or pupils but with the underlying principles that underpinned the heuristic method. According to Wellington (1981:167-173) this view encouraged pupils to ask what it is that they are expected to discover.

Wheatley (in Bodner,1989b:D5) says that problem solving is what you do, when you don't know what to do. A pupil cannot "discover" something when he is told what to discover. So when teachers give pupils guidance on what to expect, the activity ceases to be a problem solving activity and the aim of the activity can no longer be achieved.

A strong criticism of the heuristic view came from Hodson (1986b:390) who maintained that:

> Science is not learnt by the gradual revelation of a series of absolute truths derived from observational data, as discovery learning implies, but by the construction of increasingly sophisticated ways of explaining and understanding phenomena and dealing with problems.

If observation is given a priority in science, then the belief that there can be unbiased observations, sets up a chain of logic that is based on a false assumption. It is this type of false assumption about the nature of science that leads curriculum designers to propose "discovery learning". Hodson (1986b:384) feels that the promotion of discovery learning has come about as a result of the "...fusion of inductivist ideas about scientific method with progressive child-centred views emphasising direct experience and inquiry." The experiences of Nuffield led Hodson (1986b:381) to conclude that advances in the philosophy of science did not inform and guide developments in the science curriculum. Hodson (1986b:381) continues:

> Despite the ever-growing number of books and articles dealing with the curriculum implications of issues in the philosophy of science, science teachers and science curriculum developers remain surprisingly ill-formed about fundamental thinking concerning the nature of science and its methodology.

Support for Hodson's claim comes from Millar (1989:59) and Yager (1991:53). According to Yager "Despite recent research findings, the quest for never-changing objective truths continue as though it were completely possible to fulfil..." These perceptions support Elkana's, (in Hodson,1986b:381), claim that science teachers' understanding trails developments in the philosophy of science by some twenty to thirty years. Curriculum designers in South Africa seem to suffer a similar time lapse. Yager (1991:53) proposed that all educators should know of current developments in the natures of knowledge, learning and science, if developments and reforms based on them are to have any effect. Teachers require acceptable reasons before they will be convinced to accept and implement reforms. A clear understanding of the current theories can provide these reasons.

Present-day inductivists may have changed, but only in superficial ways. They may have incorporated some ideas from other views into their inductivist view of the nature of science, but the fundamental principles of inductivism remain.

The CED still emphasises the inductivist position in science syllabuses. The CED junior secondary course syllabus for general science, (implementation date:1991-1993), has the following as one of its general aims: "...the pupil should develop the ability to <u>observe objectively</u> and to solve problems by applying a <u>scientific method</u> of reasoning and scientific procedures." (aim 1.3, my emphasis). This inductivist sounding statement tends to set the tone of the content and the methods of teaching general science in the RSA's junior high schools.

According to Millar (1989:49) the inductivist approach has portrayed the processes of science as a hierarchical series of processes, begining with observation and leading via classification and inference to a hypothesis. Science does not develop using a series of discreet steps and Millar argues that it is misleading to see this as the method of science. In a 1990 CED document on practical work, the emphasis is still placed on the Scientific Method. In this document, the Scientific Method proposed by the authors starts with a hypothesis and not observation. This may seem to be a tentative move away from the predominantly inductivist approach of the past, but according to Storey & Carter (1992:18) this is still not the way that scientists work. They claim that science starts with a question and not a hypothesis.

Other statements in the junior secondary syllabus also tend to be inductivist in nature. "...the pupils should acquire a certain amount of knowledge..." (aim 1.1). "The pupil should become aware of the majesty of creation through his acquaintance with the wonder of and order in nature and in this way develop a sense of awe and reverence for the Creator." (Aim 1.5). This aim has embedded in it an implication that there are facts or truths in nature. All that the pupil needs to do is to carefully observe and these facts or truths will be uncovered. The Creator would not be so cruel as to make our sense organs lie to us about what we perceive!

A specific aim is the gaining of knowledge so that the pupil can develop "...the ability to arrange and analyse data and to make meaningful deductions from it." (aim 2.1.6). This aim seems to indicate a process of induction occuring before deductions can be made.

One of the attitudinal aims is to develop "Objectivity in observations and in the evaluation of deductions." (Aim 2.2.6). From a constructivist point of view there is nothing wrong with objectivity in observations, in fact, constructivists will attempt to make observations as unbiased as possible, by utilising various methods and by developing observational skills. The constructivist observer is aware that all observations are theory-based and do not provide a secure base for scientific knowledge. It would seem from the tone of the other aims that this "constructivist objectivity" is not what was meant by the authors of the syllabus. Many teachers who implement this syllabus could justifiably interpret this objectivity as meaning independence from observer bias - "inductivist objectivity".

An analysis of the draft core syllabus for physical science in the senior high school, (Provisional implementation date: 1992-1994), also tends to show a distinct inductivist view. "Pupils must be guided to make careful observations, to measure, to take down data, and make valid deductions." (Aim 2.2.3). In this document "objective observations" are replaced by "careful observations". A constructivist would support this view, but the document still tends to imply that these "careful observations" are the starting point of science, an inductivist view.

Aim 2.3.7 says that pupils must be guided to be aware of the abilities and limitations of people. The implied assumption, especially since no mention is made of the limitations of the Scientific Method, seems to be that any "fault" in observational bias, lies with humans and not with the method.

A CED document (1990a:7-9) discusses the form of practical work in schools. Here some comments tend to be constructivist in origin: "Pupils must have the relevant background and have mastered the terminology." There tends to be inductivist characteristics in the rest of the document: During field work "Relevant information can be collected by means of observation, experimentation, interviews etc. This information can <u>then</u> be analysed, processed and presented..." (1990:9, my emphasis).

The CED has published a document concerning the examining of physical science (CED Circular No 26/1993). The science study committee, in conjunction with present and past examiners and moderators, have drawn up this document to guide teachers. Assessment is an important aspect of any curriculum and in many ways also gives an indication of the particular view adopted by the examiners.

The following example illustrates the view adopted by the examiners:

> Consider the following system which is in equilibrium at 25°C:
>
> $$2NO_2\ (g) \rightleftharpoons N_2O_4\ (g)\ ;\ \Delta H < 0$$
>
> reddish brown — colourless
>
> The container and its contents are now heated with a bunsen burner. What do you observe?

The only acceptable answer, "becomes darker brown", is an inductivist one, especially when answers such as: "reaction to left more favourable, or rate of backward reaction increases, or equilibrium shifts to the left", are not acceptable answers. The argument is that, although factually correct, the question has not been answered. Three marks are allocated for; "becomes darker brown", but all the other options get zero. The inductivist view of objective observations dominates to the detriment of the candidate who is actually using a more sophisticated conceptual model.

Anyone can give trivial, purely observational answers, but the pupil who can actually predict and explain the observational answer, using theory, is discriminated against purely because the examiners are using a view of the nature of science that is not only outdated, but is being seriously questioned and discredited.

The researcher's personal experience of marking external physical science examinations for the CED has been that if the question asks: "What is observed?" only answers that reflect the actual, descriptive sensory input are accepted.

According to Ausubel et al (1968:41) one reason why pupils resort to rote learning is because they have learnt from experience that substantially correct answers, which do not correspond to the teacher's marking scheme, receive no credit whatsoever from some teachers.

Hodson (1986a:18) refers to characteristics of the inductivist view as the "myths about science". He says that these myths "...are internalized by teachers during their own science education and in turn, represented to children through the curriculum." Many teachers and examiners do not even entertain the idea that there may be a different and better view of the nature of science and learning than the inductivist view.

Teachers' views of the nature of science and pre- and in-service education.

According to Glasson & Lalik (1993:187) "Pedagogical decisions in science are rooted in an understanding of the nature of knowledge and how students learn." Support comes from Smith (in Abimbola,1983:189) "...what a given teacher believes, knows and does as well as what he/she doesn't believe, know, and do represents what science education will be given for a child." Unfortunately Cleminson (1990:429) claims "A review of the literature... shows that educational theory has had very little effect so far on classroom practice."

A problem, highlighted by McDivitt et al (1993:595), is that the relationship between teacher's beliefs and behaviour are highly complex, and according to Shaw (1992:14), poorly understood. Lederman & Zeidler's (1987:732) findings do not support the assumption that teacher's conceptions influence teaching behaviour. Despite this Abimbola (1983:189) claims that "Knowledge of the philosophy of science will enable science teachers to know what science they are teaching and this knowledge will affect their instructional practices." How do teachers obtain this knowledge and reflect on it? There are two areas, namely pre- and in-service training, but according to Clark & Peterson (in Shaw,1992:14) veteran teachers studied showed that their beliefs were well-grounded and extremely resistent to change while Kagan (in McDivitt et al,1993:608) claims that it is very difficult to influence the beliefs of pre-service teachers. This might not appear to be problematic but McDivitt et al (1993:595) points out that while teachers' beliefs appear to be stable and resistant to change, these beliefs are not necessarily consistent with literature about "good teaching". On the other hand Edmondson & Novak (1993:557) claim "The only thing science educators need to do is 'change their minds' about how teaching and learning can proceed using what is already known." The challenge is: "How to get teachers to change their minds, and alter their conceptual framework?"

The aim of teacher education should be to develop "...transformative intellectuals who combine scholarly reflection and practice in the service of educating students to be thoughtful, active citizens." According to Kyle et al (1991:415) "...teachers must assume responsibility for raising serious questions about what they teach, how they are to teach, and what the larger goals are for which we are striving." Lederman & Druger (1985:661) suggest that teachers must get training in enhancing their conceptions of the nature of science as well as in the methods of how to convey an adequate conception of the nature of science to their pupils. It is not sufficient for teachers to have an adequate and valid conception of the nature of science they must also have a repertoire of teaching behaviours that can effectively convey this conception of the nature of science to pupils.

According to Lederman (1986:3) "...much time and effort have been invested in programs designed to improve science teachers' conceptions of science with the anticipation that improved student conceptions would necessarily follow." His research did not reflect this.

Ray (1991:92) claims that how teachers teach will be informed by how they view the subject and he cannot see how they can develop a sensible view without a thorough knowledge of the watershed debates within the philosophy of science. There is a need for teachers to be made aware of these debates, to come to terms in their own minds about the key issues and to debate them and their implications with colleagues. Workshops dealing with these issues may be effective.

CHAPTER 3

RESEARCH DESIGN

Chapter outline.

The principal method used in this research was a descriptive survey via a questionnaire, to elicit information from a clearly defined sample. The instrument purports to assess a teacher's position with respect to various statements concerning the nature of science. The aim of methodology is to describe and analyse the method, to highlight its limitations, and clarify its presuppositions and consequences. (Kaplan in Cohen & Manion,1989:42). A detailed discussion of the methodology is embarked upon.

The results of any research depends heavily on the quality of what is measured. Two important criteria for measuring the quality of measurement are validity and reliability. (Schumacher & McMillan,1993:223). A number of factors impacted upon the validity of the instrument, not the least of which was the selection and characteristics of the sample. Details of preliminary pilot studies carried out during the development of the questionnaire, are highlighted. Version 1993 Part 5 and the corresponding parts of the 1994 questionnaires were the nub of the research and their detailed analysis is crucial to the success of this study. Three methods were used to classify respondents as having either predominantly inductivist or constructivist orientations towards the nature of science, while a fourth method placed respondents on an Inductivist/Constructivist continuum.

Research design.

The method used is described by Leedy (1985:132-171) as the DESCRIPTIVE SURVEY METHOD. Leedy (1985:132) describes this method as observation <u>with</u> insight. It entails much more than the act of mere observation and it considers more than merely collating data and presenting it in a graph or table form. Observations are made, in this study by means of questionnaires, the data is intensely considered, analysed, and interpreted.

Leedy (1985:143) highlights four characteristics of the Descriptive Survey:

* It involves a carefully chosen, well defined and specifically delimited population;

* observations, in the broadest sense, are used to collect data from the sample population - in this case the responses to a questionnaire;

* the data collecting device must be specifically designed to safeguard the data from the influence of bias; and

* the method requires the organisation and presentation of data in such a way that valid and accurate conclusions can be drawn.

Useful research must have credibility i.e. can it be judged to be trustworthy and reasonable? (Schumacher & McMillan,1993: 157). Credibility is enhanced when an account is given of possible threats to it, among these threats, the most important are considered to be the validity and reliability of results and the different forms of bias (Schumacher & McMillan,1993: 158).

<u>Validity.</u>

According to Schumacher & McMillan (1993:225):

> Validity is clearly the most important aspect of an instrument and...consumers and investigators of

> the research (must be able) to judge the degree of validity, based on available evidence.

It is important to note that it is inferences that are valid or invalid and not the instrument itself. The instrument can be used in different circumstances and produce valid inferences in one case and invalid ones in another. "Validity is a situation-specific concept: validity is assessed depending on the purpose, population, and environmental characteristics in which measurement takes place." (Schumacher & McMillan,1993:223). Schumacher & McMillan (1993:167) claim validity is "...the extent to which inferences made on the basis of scores from an instrument are appropriate, meaningful, and useful." Does the instrument measure what it is intended to measure?

The instrument was used to:

* assess both the teacher's and the sample's dominant philosophical view on the nature of science;
* assess how teachers view practical work and the assessment of practical work and in particular the assessment of observation with respect to the different views on the nature of science;
* make teachers aware that there are different views of the nature of science to the ones that they currently hold;
* give teachers the ability to identify and clarify their own views on the nature of science and,
* provide a framework around which they can debate the different views on the nature of science and its implications.

According to Schumacher & McMillan (1993:225) "Validity is a matter of degree and is not an all-or-nothing proposition." Obviously it is important to establish the highest possible degree of validity.

Schumacher & McMillan (1993:226) claim that it is not practical to establish validity for each research situation and possible use therefore, "In practice, it is necessary to generalize from other studies and research that interpretation and use are valid." It is useful to use, or incorporate, established instruments for which some evidence for validity has already accumulated. This has been done by incorporating questions from questionnaires developed by Pomeroy (1993) and Nott & Wellington (1993). Schumacher & McMillan (1993:226) caution that it cannot be assumed that because an instrument is established it is necessarily valid. In fact, Nott & Wellington (1993:112) emphasize that their questionnaire "...does not purport to be a 'valid measurement' of an individual's position or 'philosophy'." They do, however, claim, that during trial sessions of their workshops, indications were that their main aim, to introduce and encourage teachers to reflect on their own views of science, was achieved.

Munby (1983:141) also claims "There are grounds for viewing research on the affective outcomes of science education with misgiving, because there seems to be little said of the instruments to enlist our confidence in their use." This is supported by Schumacher & McMillan's (1993:226) cautionary note. According to Munby (1983:150), studies done in 1979 and 1980, claiming to measure attitude:

> ... might not be measuring attitudes to science, but rather assessing the respondents' philosophical view of the nature of science which, by definition, is not attitudinal but largely cognitive, since it is based upon knowledge and understanding of science.

If it is extremely difficult to establish validity for an attitudinal survey then, it should be easier to establish validity for the present survey, because it purports to measure views on the nature of science. The main aim of this survey is a developmental one, a tool to help teachers become aware of their own perspectives with respect to the nature of science.

Locally devised instruments, such as the present study, need to be evaluated with great care. Evidence for validity needs to be gathered. Three areas in which one can look for good evidence have been identified by Schumacher & McMillan (1993:224-5).

Content-related evidence is established by ensuring that the content represents what "experts" would deem appropriate. All the questions included in Version 1993 Part 5 were adapted from various sources in the literature dealing with the characteristics of inductivist and constructivist views of the nature of science. Before extensive use of the questionnaire it was workshopped by seven Rhodes MEd students and one senior lecturer. The aim of the workshop was to see if the questions measured what they claimed to measure i.e. What did agreement or disagreement with a question indicate? Any questions which did not show face validity i.e. they were irrelevant to helping teachers assess their orientation towards the nature of science, were rejected. In an attempt to establish content validity, which is more objective than face validity, a number of questions were removed or changed from the original draft. As an example, the draft question: "Scientific 'facts' are not 'given' or directly observable but are merely interpretations." was changed to read: "Scientific facts are merely interpretations."

According to Lythcott & Duschl (1990:447) "The reliability and validity of any research is determined by the coherence of the relationships between correctly applied methods, legitimate warrants employed in the interpretation of data,..." Toulmin (in Lythcott & Duschl,1990:451) describe warrants as "...those things which allow one to move from data to conclusions in a defensible fashion." It makes the step from data to conclusions "safe". Data is what we go on, warrants are how we get there. "Arguments of the form, data-to-conclusions, via warrants, are warrant-using arguments, and their purpose is to move from fresh data to new conclusions, using established warrants." One defensible warrant, i.e. one from which it is safe to draw conclusions, is one in which we don't put words into the respondent's mouth. In the workshop it was felt that by stressing the words "facts" and "given" there was a sense of implying that facts could not exist. This bias in the questionnaire was removed.

A second form of evidence, criterion-related evidence, is an indication of how the instrument scores compared to well specified predetermined criteria. This was one of the shortcomings of the 1993 questionnaire. In the 1994 questionnaires a number of questions from Pomeroy (1993) and Nott & Wellington (1993) were used in conjunction with the original questions. A problem that must be noted is, firstly that Nott & Wellington do not claim that their questionnaire is valid in determing the orientation of a teacher towards the nature of science and secondly, the comparison of Nott & Wellington's Positivist/Relativist continuum can only tentatively be compared to the Inductivist/Constructivist continuum of this survey.

The third form of evidence according to Schumacher & McMillan (1993:225) is construct-related evidence. It "...is of primary importance with instruments that assess a trait or theory that cannot be measured directly." One of the failings of the 1993 survey was that it attempted to categorise teachers into one of two camps. Teachers do not necessarily have one particular view of the nature of science for all circumstances, and Ray (1991:91) feels that this "context-related approach" may be preferable to that of choosing only one view of the nature of science for all occasions.

Two forms of validity can be identified: internal and external.

Internal validity.

According to Schumacher & McMillan (1993:391) internal validity is the extent to which extraneous or irrelevant variables have been controlled and accounted for, while Cohen & Manion (1989:200) see it as being concerned with the question, "Do the experimental treatments, in fact, make a difference in the specific experiments under scrutiny?"

The Grahamstown workshop and the pilot questionnaires were carried out to ensure that "the interpretations and concepts have mutual meanings between the participants and researcher." (Schumacher & McMillan,1993:391).

Preliminary pilot studies involved only Version 1993 Parts 3 & 5. Part 5 is the crux of this research and it was also the part most likely to elicit the most discussion. Attempts were made during these pilot studies to ensure that the language was unmistakably clear and that underlying assumptions supporting each question in Part 5, were highlighted.

A preliminary pilot study using four science trained colleagues at Theodor Herzl School was undertaken to test the readability and ease of understanding of the language in Part 5 (June 1991). The respondents made notes on the questionnaire. The researcher knew all the respondents and had sat in on some of their lessons in previous years. All these respondents were interviewed in an attempt to improve the questionnaire.

A second pilot study involving a multicultural and multilingual group of twenty four Primary Science Programme (PSP) implementers followed. They only answered Part 5 (August 1991).

It was at this stage that it became clear that the original design for the analysis of Part 5 was inadequate.

A colleague doing a BSc(hons) in science education gave some comments on Part 5 (October 1991). This respondent was doing work in the area of "constructivism" and added some valuable comments on the wording of some of the questions.

After each pilot study the questions were reconsidered, question by question, for precision of expression and suitability in determining the orientation of the respondent.

Cohen & Manion (1989:200-201) and Schumacher & McMillan (1993:391-394) highlight a number of threats to internal validity.

One of the threats is history. Would affects not attributable to the instrument, be detected between tests? In other words, could the instrument be affected by external factors? When a comparison was done between individual's responses to Version 1993 Part 5 and the identical parts in Version 1994c, using Pearson r correlations, the median correlation coefficient was +0,71 for 46 respondents. The average correlation coefficient was +0,62 (σ = 0,25). These correlations are considered significantly high to show that extraneous factors in the intervening year did not significantly affect the responses. What was more significant, was when respondents were asked if they could think of anything that may have influenced or changed their views on the nature of science in the intervening year, four respondents claimed that there had been intervening factors. If respondents who changed their views were excluded then the Pearson r coefficient increased to +0,72 (appendix 12).

Pearson r correlation coefficients are given in brackets. Respondent 021 (+0,19) claimed that a more mature approach to science had caused a change. Respondent 045 (+0,73) claimed more concern about the nature of science. Respondent 051 (-0,24) changed schools - significant in itself if one considers Ray's (1991:91) view that:

> ...when we focus upon the activities of particular schools..., there is often a single-minded approach to science inspired by some partial view

> of science which does little justice to the subject, frequently responsible for such inspirations: the philosophy of science.

Respondent 098 (+0,21) claimed that her views had changed dramatically as a result of starting an MEd at Leeds University in the area of constructivism. History can be designated a low priority as a threat to the internal validity of this study, because, according to Schumacher & McMillan (1993:393) "...studies of educational change processes consider history not as a threat to internal validity but a research focus to be investigated." This focus is a theme of this study.

A second possible threat to validity is maturation, which questions whether subjects change between different applications of the instrument. Only differences which occur independently of the experimental treatments are considered. This study is concerned ultimately with conceptual change in respondents, so maturation, using similar arguments used to discard history as a threat, need not be considered a threat to internal validity.

The unreliability of the measuring instrument can cause a third threat to internal validity, namely statistical regression. When a Pearson r correlations were performed between the 12 questions used to determine the respondent's views on the nature of science in the 1993 and 1994 versions, a significant correlation median was obtained (appendix 12).

In the original questionnaire certain questions could be used to check for internal reliability. Pearson r correlation coefficients were performed on these pairs of questions. The Pearson r correlations are given in brackets for the three pairs of questions: questions 3 & 10 (-0,015), questions 7 & 9 (+0,291) and questions 5 & 12 (+0,528). Apart from the question 5 & 12 pair, the other pairs are significant for their extremely low correlations. If, however, only those respondents who could be classified as having predominantly inductivist or constructivist orientations were considered, the Pearson r coefficients improved significantly. Questions 3 & 10 (+0,554), questions 7 & 9 (+0,593). This is significant in that it illustrates an abuse of the data. Questions 3 & 10 were crucial in the classification process and a respondent, except in exceptional circumstances, could not be classified if they had contradictory responses to these two questions. Only a mathematical error could have stopped these correlations from being significantly higher when "non-classified" respondents were removed!

Another threat to internal validity was the possibility of sensitising the subjects to the true purpose of the experiment and causing a distortion of results. This is not considered a threat because the more aware a respondent was of what was being asked, the more thoughtful an answer they might give. This may have been the first time that many respondents had reflected on their views of science. After all, one aim of the research was to sensitise teachers to reflect on their views concerning the nature of science.

An obvious threat to internal validity is the unreliability of the instrument. The reliability of the instrument was assessed by performing Pearson r correlations between the 1993 and 1994 surveys (appendix 12) and between questions within the instrument (table 3.2).

Table 3.2
Pearson r correlation coefficients between different pairs of questions in Version 1994c Part 2.

QUESTIONS	PEARSON r
3 & 28	+ 0,208
10 & 28	+ 0,212
4 & 14	+ 0,652
9 & 15	+ 0,098

If the primary aim of the research were to categorize teachers into two distinct camps, then these correlations are far to low to instil a great deal of confidence in the instrument's ability to do this grouping. The instrument could still be used to place teachers on a continuum, an improvement that was made on the 1993 questionnaire.

The selection techniques employed to obtain a sample are always a threat to internal, as well as external validity. Bearing the main aims of this research in mind, the selection techniques created serious bias in the sample, more threatening to external than internal validity.

In research that consists of two surveys carried out in successive years there is always a threat of experimental mortality or attrition. Do "drop-outs" confound results? As will be pointed out later the original selection is not unbiased, so even though only a small group stayed the course, it is not as if an unbiased original sample becomes biased on a second application of the questionnaire. Attrition could serve as a focus for the research, as only interested respondents would answer the questionnaire twice.

External validity.

According to Cohen & Manion (1989:203) an instrument can be internally valid to the extent that "within its own confines" its results are credible, but for results to be useful they must be generalisable beyond the confines of the experiment i.e. they must be externally valid as well. With no internal validity there is no external validity and internal validity does not imply external validity. According to Schumacher & McMillan (1993:394) most qualitative studies are not treated as probability studies of a larger universe.

> ...the researcher does not aim at generalization of results but the extension of understanding, detailed descriptions that enable others to

> understand similar situations and extend these understandings in subsequent research.

The purpose of this research is not to generalize the results to the whole science teacher population, it is to develop an instrument to enable teachers to experience conceptual change. While it may be interesting to speculate and compare the results with other researcher's results, these results are not generalizable - there is no external validity. Although no claim to external validity is made, the findings of this study may still be useful for extending understanding on the topic, but exceptional caution must be exhibited when using them.

According to Cohen & Manion (1989:202-203) four threats to external validity can be identified: the failure to describe independent variables explicitly, which implies that the study cannot be replicated; the Hawthorne effect where the subjects realise that they are "guinea pigs'; a sensitizing to experimental conditions i.e. the application of a pretest affects later tests and clouds the true picture; and a lack of representativeness of the available and target populations.

The last of these threats, representativeness of the sample, completely destroys any external validity for this survey. As has been pointed out, this is not sufficient to make the survey pointless, because the aim was not to generalize the results.

This survey does not presume to give an accurate picture of South African science teachers' views on the nature of science. It only indicates a trend in a sample that is biased towards predominantly more experienced and more qualified science teachers.

The sample size may at first appear to be a bit large for an evaluative pilot study, but the methods of data collection, mainly by postal survey, does not normally give a large percentage return. It was with this in mind that such a large number of potential respondents were approached.

The selection of the population for the survey is an essential factor that influences the descriptive survey method (Leedy, 1985:144). The results of the survey depend for their reliability on the quality and representativeness of the sample. It would be impossible to get the sample out of all science educators in South Africa. A decision was made to obtain a sample from the 1992/3 paid-up members of the South African Association of Teachers' of Physical Science (SAATPS) (appendix 1). The sample was convenient and addresses were easily obtainable and using this accurate address list reduced the cost of postage. A short introductory letter was enclosed with the questionnaire (appendix 2A). A longer letter was sent to teachers in the Port Elizabeth and Uitenhage area (appendix 2B). This was done in the event of follow-up interviews being required from locally based teachers. During the process of the study this was found to be unnecessary. Stamped self-addressed envelopes were included.

A total of 453 Version 1993 questionnaires were sent out and the 158 returned represented a 34,88% return (appendix 3). Not all members of SAATPS were canvassed because membership was in some instances in the name of the Head of Science and not a particular individual. Not all completed questionnaires could be used in their entirety because some respondents did not complete all the sections.

An inherent bias is built into the research as a result of the decision to use members of SAATPS. SAATPS membership represents only a small percentage of South African science teachers. Drost (1982:175) found that only a small percentage (9,30%) of natural science teachers belonged to national, natural science teacher associations. SAATPS is dominated by white teachers. A personal estimate, (based only on names and schools), is that the organisation consists of approximately 60% white teachers teaching in historically white schools. Appendix 4 gives an analysis of where the different versions of the questionnaire were used and the percentage return. (Includes respondents from 1993 and 1994).

For Version 1993 respondents, 76,58% (121) taught in predominantly white or private schools and only 11,39% (18) respondents taught in other schools. 10,13% (16) of the respondents were involved in science teacher education at tertiary institutions (appendix 5A). This was one area of bias that was addressed by the 1994 surveys.

A broader representation of teachers was obtained when the researcher attended a number of workshops, and at some point in the proceedings, got teachers to fill in the questionnaire. This method had two purposes, firstly, self-selection by respondents was sidestepped - respondents were still, however, given the opportunity not to complete the questionnaire, but few chose this option, and secondly the researcher was on hand to help clarify questions. In most instances this was merely to translate or simplify the wording, mainly instructions, to respondents whose first language was not English. Some HDE students who had completed a course in science method that stressed the constructivist approach to science teaching also completed the questionnaire. In order to get some response from non-SAATPS members who attended the 1993 Science Convention 20 questionnaires were posted to a random selection of convention delegates (appendix 5B).

Appendix 5C gives a break down of the total sample with respect to the departments in which they worked. Appendix 5D illustrates the result of attempts to broaden the representativeness of the sample.

A second area of bias created by the 1993 sample is the level of experience of the respondents (appendices 6A, 6B, 6C, 6D, and 6E). Most of the respondents had a great deal of experience of teaching science in all standards (table 3.3).

Table 3.3
A sumary of the original 1993 sample's teaching experience in the different standards.

STANDARD	TEACHING EXPERIENCE (YEARS)		
	MEAN	MEDIAN	MODE
SIX	7,15 YRS	4 YRS	3 YRS
SEVEN	7,15 YRS	4 YRS	3 YRS
EIGHT	10,46 YRS	7 YRS	5 YRS
NINE	10,66 YRS	8 YRS	7 YRS
TEN	10,76 YRS	8 YRS	2 YRS

The mean values, although interesting, are not as valuable as the median and the mode for each standard which indicates that the majority of the original 1993 sample were very experienced.

It is significant that 76,58% (121) of the 1993 sample had experience at teaching standards 6 while 87,97% (139) had experience of teaching at the standard 10 level. This original survey was biased towards teachers teaching at the senior level. Science is compulsory for all pupils at most schools in standards 6 and 7 and optional in standards 8, 9 and 10. The number of pupils taking science drops significantly in the higher standards. According to van Wyk (1993,3-5), using a 1991 RIEP survey, more than 85% of pupils in OFS state schools took science in standards 6 and 7 while the number taking science in standard 8 was 22,6% and dropping to 19,5 % in standard 10. The result of more pupils taking science in the junior standards means that there are more classes to be taught and consequently more science teachers are required at this level than in the senior standards. Many teachers who teach standard 6 and 7 science are not qualified to teach the senior standards. The sample used in this survey is therefore not representative of the majority of science teachers, many of whom teach science in the junior standards.

A third area of inherent bias may arise from teachers not wanting to admit in writing that they are not doing what the syllabus requires of them. Teachers know they are expected to do practical work and to assess this practical work in some or other prescribed form. The syllabuses used in South African schools specify a minimum number of practical demonstrations and pupil experiments that must be done in the different standards. Teachers are not easily going to tell others that they are not doing or assessing prescribed practical work. On the other hand, many teachers may be very proud of the fact that they not only do practical work, but that they go to the trouble of assessing this practical work. They may very well want others to know what they are doing. This could result in a much more positive picture of the state of practical work and its assessment than is the case in the broader community of science teachers. This is especially true considering that SAATPS is a voluntary association.

Any survey that includes a multicultural sample, as this one did, has a problem of communicating intentions to individuals of different cultures. This survey, (a paper and pencil survey), suffered the natural limitation of having possible ambiguities of meaning within a particular cultural and language group. A number of respondents circled certain words in Version 1993 Part 5. "Value-free" was an example that may indicate a problem with the use of terminology for some of the respondents. Limitations associated with cross-cultural and inter-language surveys also surfaced. A wide range of respondents were used in pilot studies in an attempt to minimize these problems and "workshop" respondents were assisted with explanations of the language.

The primary method of administering the questionnaire was by post. Cohen & Manion (1989:109) claim that frequently postal questionnaires are the best form of survey in education. They are able to get to respondents who would not otherwise be reached and respondents are able to complete them in their own time. According to Cohen & Manion (1989:111) some of the myths that have evolved around postal surveys can in certain circumstances be dismissed. They are not invariably less useful than interviews and they don't have to be short. Sophisticated respondents may feel that important issues are trivialised if the questionnaire is too short.

A postal survey does, however, have some major weaknesses. One of which is the poor postal service to rural areas. This may not have been a major problem for questionnaires posted to SAATPS members who lived mostly in urban areas. This did, however, contribute to the distorted sample. The weaknesses of the method were to some extent sidestepped in the 1994 follow-up surveys that were carried out at teachers' workshops.

According to Cohen & Manion (1989:116) the validity of postal questionnaires rests on two perspectives: firstly, did those who did complete it do so accurately, and secondly would those who did not return have given the same distribution. The significantly high Pearson r correlation (appendix 12) between parts of Version 1993 and the identical parts of Version 1994 serve to indicate that the questionnaires were filled in consistently, if not accurately, with respect to the respondent's views on the nature of science. Intensive follow-up interviews with those who did not respond were not carried out because of time and financial constraints.

The concept of "volunteer bias" that Benson (in Cohen & Manion,1989:116) refers to will always bedevil a postal survey. Only interested and motivated respondents return questionnaires. Attempts made to negate this bias were restricted to trying to make the questionnaire interesting and relevant to teachers. Some of the 1994 surveys were carried out at teacher workshops in an attempt to reduce this volunteer bias.

Reliability.

Reliability requires that similar results are obtained with different forms of the same instrument or on different occasions. Significantly high correlation coefficients contribute to the stability of the instrument (appendix 12). According to Schumacher & McMillan (1993:385) reliability is the extent to which independent researchers could discover the same phenomena. According to Schumacher & McMillan (1993:232) reliability is a necessary condition for validity but a relaible instrument is not necessarily valid.

Internal consistency can be assessed by reference to specific questions included at different stages in the questionnaire to assess the same thing. The specific questions used are discussed in chapter 4.

CHAPTER 4

THE QUESTIONNAIRES.

Chapter outline.

Version 1993 of the questionnaire consisting of six parts was developed to assess the predominant orientation towards the nature of science of a convenience sample of science teachers. The aim was to see if teachers could be categorised as being either predominantly inductivist or constructivist.

Parts 1 & 2 dealt with the respondent's biographical details, and it consisted of determining teaching experience in particular standards as well as the standards in which the teachers carried out practical assessments (if applicable). The form that this assessment took was reported in a free-response reply. It was felt that there are such a large number of possible forms that assessment, (as opposed to examination), could take, that free-response replies would be more suitable.

In Part 3 respondents were asked to allocate a percentage of the total marks to various aspects of a practical laboratory assessment. Six categories, taken from different literature sources, were stated and provision was made for additional categories. (Tomlinson,1977; Ganiel & Hofstein,1982; and Josephy,1986).

Parts 4A & 4B were designed to ascertain the respondent's reasons for doing practical work. The results obtained here were compared to other researchers' findings.

Part 5 ascertained respondents' predominant orientation towards the nature of science. The analysis was performed in two parts:

* an analysis of the whole samples' responses to the questions; and

* an analysis of the individual respondent's responses.

The intention of Part 6 was to confirm the individual respondent's classification in Part 5. The respondents were asked to rate the answers given in a theory paper to a "What do you observe...?" type question.

A number of weaknesses emerged from the 1993 questionnaire:

* The reliance on one method, a postal survey, was not adequate to instil confidence in the instrument's validity to classify teachers.
* Parts 4A & 4B were very difficult to analyse because of their open-ended nature.
* Although teachers were categorised into two distinct camps, it was felt that this "either/or" scenario was inadequate to do justice to the richness of teachers' views.
* The degree of internal validity could be questioned.
* The reliability of the questionnaire could not adequately be assessed by a once off postal survey.
* Because of sample bias, serious doubts could be cast on the external validity.

Revised versions of Version 1993 of the questionnaire, i.e. Versions 1994a, 1994b, and 1994c were developed to address these weaknesses. The development of these 1994 versions is discussed in the latter part of this chapter.

<u>VERSION 1993 OF THE QUESTIONNAIRE</u> (appendix 2C).

<u>Development of Part 5 of the questionnaire.</u>

The first draft of Part 5 consisted of 16 questions based on a review of the literature dealing with the nature of science, observation in science, and the assessment of practical work.

Two statements were regarded as neutral for both inductivist and constructivist respondents; seven were statements that an inductivist respondent could strongly agree with and seven were statements that a constructivist respondent could strongly agree with. It must be noted that paper and pencil measures, however well constructed, are limited in the amount of information they yield because they allow only a narrow range of responses and do not provide the opportunity for thoughtful exploration. A space was provided on the pilot questionnaires for respndent's comments. These comments were used in the development of the questionnaire. Space and financial constraints did not allow for this on the bulk of the questionnaires. This did not, however, prevent respondents with strong feelings on statements, from finding space to air their views. A five point Likert-type scale was used because it gave a little more flexibility. There was a strong possibility that respondents may not have had strong views either for or against a statement and the "neither agree nor disagree" column provided this flexibility.

Pilot study respondents answered Part 5 in their own time and the researcher discussed each question of Part 5 with them. In this way questions could be validated in a non-structured interview type situation.

An instrument, such as the one in this study, is constructed from the perspective of the researcher who is engaged in the research and therefore has access to and uses words unique to the area of study. Careful selection of words was carried out to ensure that this did not happen, but it became evident during the Theodor Herzl pilot study that many words were "loaded" and could be interpreted in many different ways. Examples being: "deduction", "true", "inductive" etc.

Part 5 was probably the most time-consuming part of the questionnaire to answer. Respondents probably had to re-read the questions before answering. Sixteen questions made answering the questionnaire inordinately long.

As a result of comments made by pilot study respondents the number of questions were reduced to twelve. All the questions would then fit onto one page. This considerably reduced the time taken to answer the questionnaire and improved the layout.

Some questions were rephrased so that if a respondent "strongly agreed", then they tended towards one particular orientation and if they "strongly disagreed" with that particular statement then it could be concluded that they tended towards the opposite orientation. This was, however, not possible with all questions. By using this technique the number of questions could be reduced without losing too much of the information that the original sixteen questions gave. The advantage of brevity was preferred over the advantage of more data.

Question 1:

A good scientist aims to make objective observations.

Inductively orientated respondents should strongly agree with this statement. These respondents would concentrate on the idea that observations have to be completely objective for them to be valid. They might accept that it is very difficult to make objective observations, but they would find it very difficult to accept that it is impossible to make completely objective observations.

To strongly disagree with this statement does not imply a tendency towards a constructivist approach. No constructivist would say the a <u>good</u> scientist <u>aims</u> to make subjective observations. Constructivists simply accommodate the idea that all observations <u>are</u> subjective. Chalmers (1990:41) explores the idea that, when human sense organs are supported by appropriate instruments, observations can be regarded as objective. Constructivist leaning respondents may, however, strongly agree with the statement. They could acknowledge that all observations are subjective and consequently one must accept that this is the case. This does not mean that a scientist may be sloppy and not be concerned about the objectivity of scientific observations. The "good", constructivist scientist would attempt to observe well, as opposed to unbiasedly

Norris (1984:129) believes that an observationally competent person is one who makes observations well, reports them well and can correctly assess the believability of the reports. This is not the same as an unbiased observation.

According to Martin (in Hodson, 1986b:387):

> The idea that the best scientific observation is naive like a child's, and that to become a good scientific observer one must unlearn all ideas one has previously learned and return to the pristine purity of infancy, has little merit. Becoming a good scientific observer involves great sophistication and skill. The cure for bad scientific observation is not naive observation, but more training and sophistication.

Question 2.

Doing regular practical work enables pupils to improve their observational skills.

This question was one of the neutral questions. The responses have no bearing on the predominant orientation of the teacher.

Question 3.

Scientific knowledge is objective and value-free.

Respondents who strongly agree or tend to agree that scientific knowledge is objective and value-free show inductivist tendencies.

Disagreeing with the statement implies that scientific knowledge is subjective and is not value-free. A clearly constructivist orientation.

Question 4:

> **There is a set pattern for scientific procedure: guesswork and intuition play no part.**

According to Millar (1989:51) "...scientific enquiry cannot be portrayed as rule following but involves the exercise of skill: in deciding what to observe, in selecting which observations to pay attention to, ..." (my emphasis). Often it is guesswork and intuition that provide guidance as to what to observe.

Inductivist respondents should strongly agree, or at least agree, with this statement. Constructivist respondents should believe that guesswork and intuition play a major role in scientific procedure.

Inductivist respondents may, however, disagree with the statement on the grounds that intuition and guesswork are the sparks that start the Scientific Method. Once the guesswork or intuition has provided the spark, then the rigid rule following exercise of the Scientific Method is implemented.

Respondents who agree with the statement tend to have an inductivist orientation but those who disagree are not necessarily constructivists. Constructivism does not reject a method of working, it simply does not claim that scientific knowledge can only be uncovered by the rigid application of a set procedure.

Staunch inductivist respondents may claim, on the grounds of Cross's (1990:18) statement that the "...perception exists that intuition must be proved or disproved through reasoning and experiment and that its academic credentials are dubious,..." that intuition has no part in the development of scientific

knowledge. **To be classified as** scientific implies a claim to some "truth". If the "truth" is based on the concept of intuition, that has itself not conformed to the rigourous application of the Scientific Method, then the final "truth" cannot be a "truth".

Question 5:

Inevitably all observation is influenced by what the observer already knows.

All constructivists would have to strongly agree with this statement. Inductively orientated respondents may agree that this is what really happens, but they could claim that it is not an ideal situation. They may regard the influence of prior knowledge on observation as being a shortcoming of the observer. Inductivists would believe that really "good" observers are able to exclude prior knowledge from their observations. They are therefore able to make unbiased observations. Observers who "allow" prior knowledge to influence their observations need experience and training to enable them to undertake the "respectable" art of making unbiased observations. If respondents disagree with the statement then they are tending towards an inductivist orientation. If they believe that observations are not influenced by prior knowledge at all then they are placing themselves firmly in the inductivist camp.

Question 6:

Valid scientific theories can only be formulated on the basis of sufficient observation.

Inductively orientated respondents would tend to agree with this statement. An important tenent of the inductivist method is that sufficient observations are made. Only once sufficient observations have been made is it possible, by the process of induction, to propose a theory or law.

A respondent who disagreed with this statement would not necessarily tend to have a constructivist orientation. Constructivists do not propose that a theory is valid after only one or two observations. They would make a number of observations, but they would have a fairly good idea of the worth of each observation before the observation is made. They would be basing all the observations or experiments on prior theory. A constructivist respondent could still feel that a large number of observations are needed before a theory is validated and agree with the statement.

Constructivists may be inclined to think that once a theory has been proposed there needs to be some form of verification of the theory. Teachers with a falsificationist orientation would agree with this statement. The "sufficient" observations would be attempts to falsify the theory.

Question 7.

The validity of observational statements are dependent on the opinions and expectations of the observer.

Respondents agreeing with this statement will tend to have a constructivist orientation. Respondents who disagree with this statement would tend towards the inductivist orientation.

Question 8.

Practical assessments should always include assessment of scientific observation.

This was the second neutral statement. It does, however, indicate the degree of importance attached to the skill of observation by the respondents. This in turn indicates the importance attached to the orientation towards the nature of science used by the respondent when assessing the practical skill of observation.

Question 9.

Inevitably observation produces subjective data.

Respondents with a constructivist orientation should strongly agree with this statement. Respondents with inductivist leanings may also agree with this statement. They would, however, use a similar argument to the one used by the inductively orientated observer who agreed with question 5's statement.

According to Chalmers (1990:41) it is very easy to attack the positivist approach that sees it as essential that science is based on secure, "factual" foundations. The attack has been based on the "...non-given, revisable, fallible, 'theory-dependent' character of observational statements."

Chalmers goes on to maintain that while there is much that is correct in this attack, the conclusion that is often drawn is not necessarily correct. Chalmers (1990:41) emphasises that it is <u>not</u> necessarily correct to conclude that all observations are necessarily so subjective and relative to the observer's psychology, history and culture that they cannot be of any use. He goes on, however, to maintain that "objectivity" in observation still does not allow the empiricist to claim that all scientific knowledge can only be based on objective, unbiased observations.

Question 10.

Scientific facts are merely interpretations.

This question was an attempt to clearly separate the sample into an inductivist and a constructivist orientation.

Constructivists would have to support the idea that scientific facts are merely interpretations.

The inductivist orientation supports the idea that scientific facts are out there and the careful observer would be able to collect all the data and then, by the process of induction, uncover the irrefutable, scientific facts of nature. The use of words "scientific facts" would make it very difficult for an inductivist respondent to support the statement.

Question 11.

> **The method of science consists of a sequence of processes: observation --> data collection --> classification --> inference --> hypothesis.**

The Scientific Method has been detailed in many textbooks and articles. Inductivism is based on a process of collecting data and then, by the process of induction, formulating a theory or law. Inductivist respondents would have to support this statement. They may, however, wish to place the hypothesis first, and then follow with the rest of the method. As long as the method followed, or supposedly followed, has the process of "inference" as a separate step that follows after data collection, the approach will still have an inductivist flavour.

A staunch constructivist would not be able to support that science develops along a rigid pattern. Some respondents with a predominantly constructivist orientation may still support this statement. Respondents may think and act constructively in many areas but because of their classical, scientific training they may find it very difficult to reject the Scientific Method. The Scientific Method has had such a "respectable" past: "Why reject it now?" they may ask.

Question 12.

> **Pupils observe things in terms of what they already know.**

This question was introduced as a consistency check on question 5. The statement has been supported by many learning theorists

(Novak, 1976, Driver, 1983 and Watts & Pope 1989). This essential, constructivist concept has crucial implications for classroom practice. Watts & Pope (1989:326), claim that childrens' learning is similar to that of scientists' advancement of ideas. "Their (childrens') prior knowledge and initial theorizing are therefore important as part of the process of reaching a scientific understanding of the world around them."

Respondents who agree with this statement are, however, not necessarily constructively orientated. They may say that this is what really happens but that it is not "good" science (see question 5).

Key indicators towards a particular classification.

A number of "key indicators" can be used to classify a respondent as having a predominantly inductivist or predominantly constructivist orientation. These "key indicators" were included in different forms in different questions. This enabled a check on the consistency of a respondent's responses.

The first "key indicator" is the status afforded the objectivity of scientific knowledge obtained via observation and the second indicator is a belief in the method by which scientific knowledge is advanced.

The objectivity of scientific knowledge.

Questions 3, 9, and 10 deal directly with this "key indicator". During the past three decades there has dominated a faith in the objectivity of scientific knowledge. According to Yager (1991:53) this traditional epistemological paradigm is now being turned upside down:

> Yet, in most schools of education, teacher preparation continues as though nothing has

> happened. Despite recent research findings, the quest for never-changing objective truths continue as though it were completely possible to fulfil. It is important that all educators know of these developments if changes and reforms based on them are to have any effect.

This view is supported by Hodson (1990:37) and Norris (1984:140). Scientific knowledge, which is supposedly based on objective truths, predisposes objective, unbiased observations. Such observations require that we first exhaustively note all visual stimuli that enters our eyes before any analysis or inferences may be made.

The method or procedure for advancing scientific knowledge.

Questions 4, 6 and 11 deal with the second "key indicator". Many researchers agree that real scientists do not work by following a set of rules, especially a set of rules that originate in the problematic area of "unbiased" observations that are theory-laden. Sticking rigidly to the "rule following" of the so-called Scientific Method does not promote the development of science. Science has not progressed using the Scientific Method. The Method has been offered as a neat summary of what does not really happen (Millar,1989:56).

<u>Classification of respondents using Version 1993 Part 5.</u>

When the questionnaire was first designed it was anticipated that one or both of two ways could be used to analyse the respondents' predominant orientation towards the nature of science. In the first method all the "positive", ("strongly agree" or "agree"), constructivist responses and all the "positive" ("strongly agree" or "agree") inductivist responses would have been totalled (table 4.4).

The second method consisted of allocating a series of numbers (1 - very inductive, through to 5, very constructive) to each response (table 4.4). The analysis of the respondents' predominant orientation towards the nature of science could then be determined by adding up the individual scores. A high score would indicate a constructivist orientation and a low score would indicate a predominantly inductivist orientation. Some appropriate high and low cut-off score would have been predetermined.

As soon as some of the pilot study returns were analysed using these methods it became clear that a meaningful analysis could not be made in such a simplistic way. Some of the questions were phrased in such a way that if one respondent strongly disagreed with the statement and another strongly agreed with the statement then it could not be assumed that they held opposing views on the nature of science. Some respondents did not answer every question and many chose the neutral responses of "neither agree nor disagree". This response was not catered for in the original method of analysis.

Some responses to questions in Part 5 carried more importance than others. What was clear, was that the importance of a question could depend on the way that other questions were answered by the respondent.

As a result of the above a number of other methods were designed to enable a more reliable classification of the respondents. Eventually three methods were tried and the results of all three methods were compared. Classification of the respondents was made using all three methods.

Method 1.

The ratings from table 4.4 were used.

Step 1:
Figure 4.2 is a flow diagram that summarises the process.

Table 4.4
An analysis of Version 1993 Part 5's questions and the ratings and interpretations assigned to the responses.

	I STRONGLY AGREE	I TEND TO AGREE	I NEITHER AGREE NOR DISAGREE	I TEND TO DISAGREE	I STRONGLY DISAGREE
1. A good scientist aims to make objective observations.	STRONGLY INDUCTIVE 1	INDUCTIVE 2	0	0	0
2. Doing regular practical work enables pupils to improve their observational skills.	NEUTRAL	NEUTRAL	0	NEUTRAL	NEUTRAL
3. Scientific knowledge is objective and value-free.	STRONGLY INDUCTIVE 1	INDUCTIVE 2	0	CONSTRUCTIVE 4	STRONGLY CONSTRUCTIVE 5
4. There is a set pattern for scientific procedure: guesswork and intuition play no part.	STRONGLY INDUCTIVE 1	INDUCTIVE 2	0	0	0
5. Inevitably all observation is influenced by what the observer already knows.	STRONGLY CONSTRUCTIVE 5	CONSTRUCTIVE 4	0	INDUCTIVE 2	STRONGLY INDUCTIVE 1
6. Valid scientific theories can only be formulated on basis of sufficient observation.	STRONGLY INDUCTIVE 1	INDUCTIVE 2	0	0	0
7. The validity of observational statements are dependent on the opinions and expectations of the observer.	STRONGLY CONSTRUCTIVE 5	CONSTRUCTIVE 4	0	INDUCTIVE 2	STRONGLY INDUCTIVE 1
8. Practical assessments should always include assessment of scientific observation.	NEUTRAL	NEUTRAL	0	NEUTRAL	NEUTRAL
9. Inevitably observation produces subjective data.	STRONGLY CONSTRUCTIVE 5	CONSTRUCTIVE 4	0	0	0
10. Scientific facts are merely interpretations.	STRONGLY CONSTRUCTIVE 5	CONSTRUCTIVE 4	0	INDUCTIVE 2	STRONGLY INDUCTIVE 1
11. The method of science consists of a sequence of processess: observation --> data collection --> classification --> inference ---> hypothesis.	STRONGLY INDUCTIVE 1	INDUCTIVE 2	0	CONSTRUCTIVE 4	STRONGLY CONSTRUCTIVE 5
12. Pupils observe things in terms of what they already know.	STRONGLY CONSTRUCTIVE 5	CONSTRUCTIVE 4	0	0	0

This was an attempt to identify predominantly constructivist orientated respondents. The respondent's responses to questions 3, 10, 5, 12, 7 and 9 were considered in order. The questions chosen for consideration were those that were considered to be basic tenets of the constructist view of the nature of science. If a respondent neither agreed nor disagreed with the statement, this was considered to be a neutral response and a "0" was allocated. If a respondent did not answer the question an "X" was allocated. Respondents who answered with a "0", "4" or "5" were considered to show possible constructivist tendencies. Up to question 7, as soon as a respondent responded with a "1" or a "2" (inductivist response), no further questions were considered. If the responses to question 7 and 9 were a "1" or a "2" and all the previous questions were answered with a "4" or a "5" then the analysis was continued.

Questions 1, 6 and 11 were not considered because respondents who tended towards a constructivist orientation could, with certain reservations, respond to these questions as if the were inductively orientated.

Once this classification was completed further consideration had to be given to those respondents who managed to fulfil the criteria by using more than four neutral responses ("0" or "X"). If there were too many neutral responses then the respondent was not considered for classification.

Step 2.
Appendix 7 is a flow diagram that illustrates the process.

This was an attempt to identify respondents who had predominantly inductivist tendencies. The questions chosen for consideration were those that were considered to be basic tenets of the inductivist view of the nature of science. The respondent's responses to questions 3, 10, 11, 6, 1 and 4 were considered in this order. If a respondent neither agreed nor

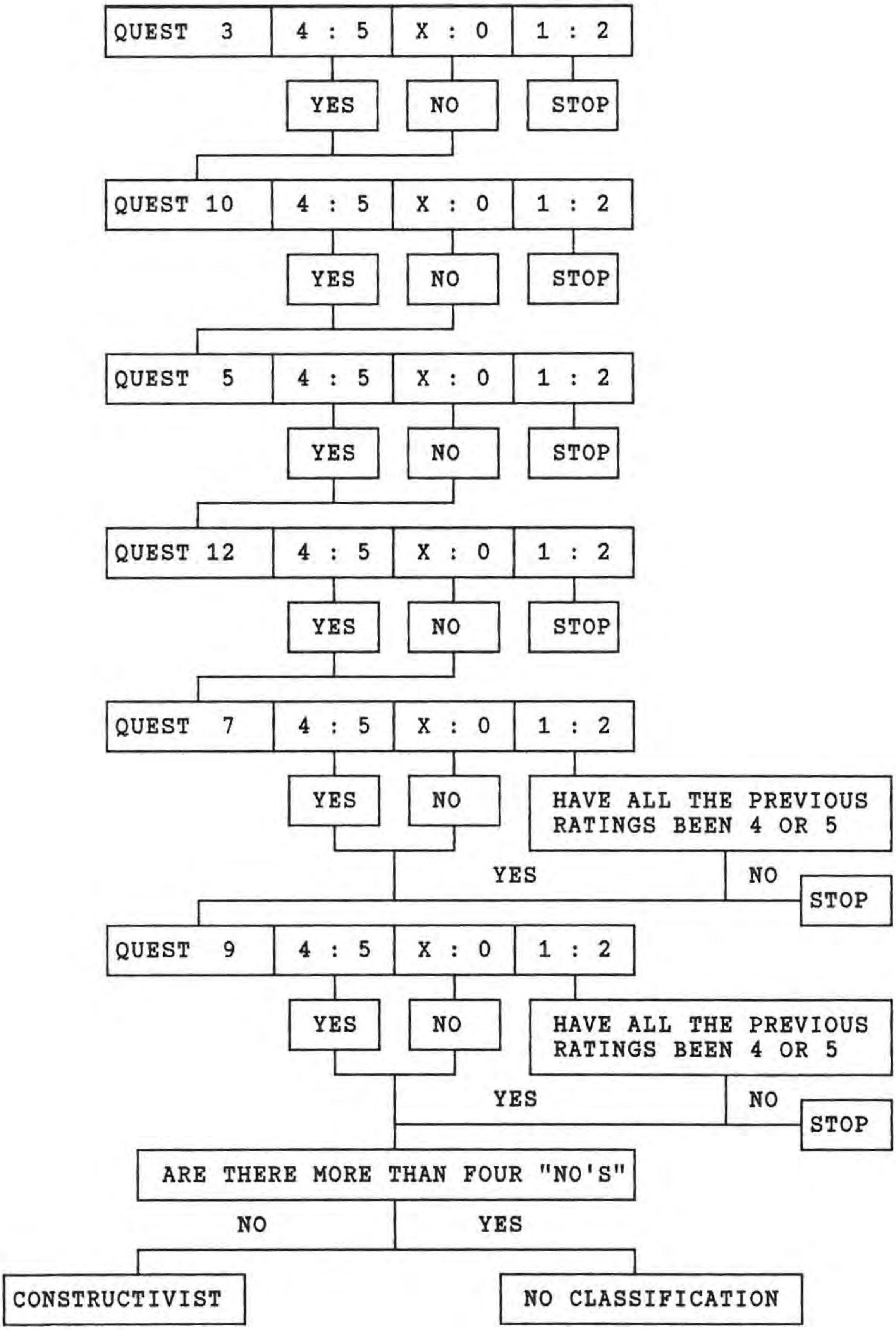


Figure 4.2
Flow diagram that summarises method 1 used to identify respondents who have a predominantly constructivist orientation towards the nature of science.

disagreed with the statement, this was considered to be a neutral answer and a "0" was allocated. If no attempt was made to answer the question an "X" was allocated. Respondents who answered with a "0", "1" or "2' were considered to show inductivist tendencies. As soon as a respondent failed to respond with a "0", "1" or "2", up to question 1, then no further questions were considered and no classification was made. If, for question 1 or 4, the respondent answered with a "4" or "5" and all previous responses were a "1" or "2" then further analysis was done.

Respondents with a predominantly inductivist orientation could, with certain reservations, have answered questions 5, 9 and 12 as if they held a constructivist view of the nature of science. These questions were not considered in the classification.

Once this classification was completed, further consideration had to be given to those respondents who managed to fulfil the criteria by using more than four neutral responses ("0" or "X"). If there were too many neutral responses then the respondent was not considered for classification.

Method 2.

This method involved using the same rating scale as used in method 1 (table 4.4). Only questions 3 and 10 were considered. If a respondent scored a "1" or a "2" in a question they were allocated an "I" (inductivist) and if they scored a "4" or"5" then they were allocated a "C" (constructivist).

If there were glaring contradictions between questions 10 and 3, (ratings of "1" and "5" or "5" and "1") then the respondent was not classified. If the respondent scored any other combination, then the general trend was considered for classification. If a person scored a rating of "1" in question 3 then they could not be classified as constructivist.

The sum of the ratings for questions 10 and 3 were considered. Respondents were classified as constructively orientated if they scored a total rating of 9, 10 or 8 (4 + 4 only) and respondents who scored totals of 2, 3 or 4 (2 + 2 only), were classified as inductively orientated.

Method 3.

This method involved combinations of two questions. The pairs of questions chosen were those that were included in Part 5 to check for consistency in responses (figure 4.3 is a flowchart of the process).

The final classification for method 3 was made on the basis of a majority classification. If the respondent had an equal number of constructivist and inductivist classifications then they were not classified.

(@) Questions 4 and 11.

QUESTION 4		QUESTION 11		CLASSIFICATION
1 OR 2	PLUS	1 OR 2	GIVES	INDUCTIVIST
0	PLUS	4 OR 5	GIVES	CONSTRUCTIVIST

($) Questions 7 and 9.

QUESTION 7		QUESTION 9		CLASSIFICATION
1 OR 2	PLUS	0	GIVES	INDUCTIVIST
4 OR 5	PLUS	4 OR 5	GIVES	CONSTRUCTIVIST

(§) Questions 1 and 9.

QUESTION 1		QUESTION 9		CLASSIFICATION
1 OR 2	PLUS	0	GIVES	INDUCTIVIST
0	PLUS	4 OR 5	GIVES	CONSTRUCTIVIST

(#) Questions 5 and 12.

QUESTION 5		QUESTION 12		CLASSIFICATION
1 OR 2	PLUS	0	GIVES	INDUCTIVIST (NAIVE)
4 OR 5	PLUS	4 OR 5	GIVES	CONSTRUCTIVIST *

* If all the previous classifications were "inductivist" then this respondent could be classified as a sophisticated inductivist.

Final classification for method 3.

NUMBER OF "I's" > NUMBER OF "C's"	INDUCTIVIST
NUMBER OF "I's" = NUMBER OF "C's"	NO CLASSIFICATION
NUMBER OF "I's" < NUMBER OF "C's"	CONSTRUCTIVIST

Figure 4.3
Diagram that summarises method 3 that was used to identify the predominant orientation to the nature of science held by a respondent.

(@) Questions 4 and 11.

To be classified as inductivist the respondent was required to score as follows:

Question 4: 1 or 2 and Question 11: 1 or 2

To be classified as constructivist the respondent was required to score:

Question 4: 0 and Question 11: 4 or 5

($) Questions 7 and 9.

To be classified as inductivist the respondent was required to score:

Question 7: 1 or 2 and Question 9: 0

To be classified as constructivist the respondent was required to score:

Question 7: 4 or 5 and Question 9: 4 or 5

(§) Questions 1 and 9.

To be classified as inductivist the respondent was required to score:

Question 1: 1 or 2 and Question 9: 0

To be classified as constructivist the respondent was required to score:

Question 1: 0 and Question 9: 4 or 5

(#) Questions 5 and 12.

To be classified as inductivist the respondent was required to score:

Question 1: 1 or 2 and Question 9: 0

This respondent would be further classified as a naive inductivist.

To be classified as constructivist the respondent was required to score:

Question 5: 4 or 5 and Question 12: 4 or 5

If, however, the person on the method 2 showed a clear inductivist orientation then the classification of sophisticated inductivist is added.

Final Classification.

Respondents were finally classified on obtaining two or more identical classifications.

Question 6 was not used in the latter two methods because it was considered to be too problematic. It could easily be misinterpreted by a respondent who held a predominantly constructivist orientation.

If a respondent made any additional comments on the questionnaire and they were considered relevant to their final classification, then these were considered in the notes on appendix 20A.

Version 1993 Part 6:

In the introduction to Part 6 it was stressed that the pupils had been given the theoretical background as well as practical experience of the experiment. This approach was found to be effective by Harris (1990).

The intention of this part was to confirm the individual respondent's classification in Part 5. The respondents were asked to rate the answers given in a theory paper for two "experiments".

In each of the two experiments four possible pupil answers were given as options. One option was clearly an answer that included only actual, visual stimuli that entered the eye (an inductivist answer) and another option was clearly an interpretation of what was observed (an answer that a constructivist could accept). The remaining two responses were combinations of the above two.

The experiment described in Part 6.1 was chosen because it is a typical standard 6 experiment. Most of the respondents should have set and assessed questions on this experiment during their teaching experience. Part 6.2 experiment was based on an experiment that most respondents would not have previously experienced.

In Part 6.2 the purely descriptive answer (inductivist) was the longest and contained the most "facts" while in Part 6.1 the longest option, (containing the most "facts"), was the interpretive option. One that a constructivist could support.

Predominantly constructivist respondents were expected to choose the interpretive option as the best one because it illustrated the thinking of the pupil and inductivist respondents were expected to choose the purely descriptive option.

Part 6.2 originated from an idea proposed by Norris (1984:131) which he referred to as "the candle activity". He quotes from a book on chemistry titled "Experimental Foundations", in which pupils were asked to report on everything they observe when they observed a burning candle. They are cautioned not to suggest the compositions of things in their results. They may report a colourless liquid appears at the top of the candle, but they may not say that they observe paraffin or candle wax. The authors of this chemistry textbook clearly claim that the former is an observation but the latter is to offer an interpretation. Norris (1984:133) claims that pupils who have no reason to doubt that the molten liquid is wax should not refrain from claiming that it is wax. Scientists always try to make the strongest claims that are not subject to doubt. To say that there is molten liquid, and then to claim that it is possible that it is not wax, when very little doubt exists, is irrational. Is science not concerned with the rational? Norris goes on to claim that the implication is that there is a language reserved for observational reports and another language that is used in making interpretations.

Some science programs quoted by Norris actually set questions that ask pupils and teachers to classify statements as either observations or inferences. Part 6 was formulated in an attempt to identify if these two "languages" existed within the sample of respondents.

Responses were analysed and compared to the individual respondent's predominant orientation towards the nature of science as determined in Part 5.

THE 1994 VERSIONS OF THE QUESTIONNAIRE. (appendices 2D, 2E and 2F).

From Version 1993 it became obvious that certain changes to the questionnaire could improve the quality of the data collected and cast more light on both the validity and reliability of Version 1993 Part 5. Three 1994 versions of the questionnaire were developed. Versions 1994a and 1994b were abridged versions of Version 1993 - time constraints and teaching level of the respondents necessitated these changes in content but not concept. All 1994 versions included Version 1993 Part 5.

The primary aims of Version 1994c were to assess the reliability over time of Version 1993 Part 5; to reassess the internal consistency of certain questions; to investigate the possibility of placing teachers' views on a continuum in contrast to two distinct categories; and to investigate the relationship between where teachers would place themselves on a continuum of views on the nature of science and the position accorded their views by an analysis of their answers to certain questions.

In an attempt to increase external validity and limit the reliance on a postal survey, different versions of the questionnaire were given to more representative groups at teacher workshops. The resulting improvement in representation was still not sufficient to claim any significant external validity.

<u>The improvements in Version 1994 resulting from Version 1993.</u>

The problem created by the open-ended nature of Version 1993 Parts 4A &4B was addressed in the 1994 versions.

96,52% of the free-responses to Version 1993 Part 4A &4B could confidently be assigned to one or other of the following statements:

* To support or to understand the theory i.e. application of the theory.
* For the development of practical skills.
* To motivate by promoting excitement, fun and curiosity.

In all three 1994 versions respondents were asked to indicate which <u>one</u> of the above they considered to be the most important reason for doing practical work in schools. These responses were compared to Version 1993.

<u>The development of Version 1994c</u> (appendix 2F).

One of the aims of Version 1994c was to investigate the possibility of placing respondents on a continuum with respect to their views on the nature of science. The negative end of the continuum was allocated to the inductivist viewpoint and the positive end to the constructivist viewpoint. A decision had to made as to how many different degrees the continuum should have. Version 1993 Part 5 and Version 1994c Part 2 questions 1 - 12 were considered. The two "neutral" questions (numbers 2 & 8) together with question 1, which realised contradictory results, were omitted. Agreement or disagreement with a statement in some of the other questions did not necessarily mean opposing viewpoints. (See development of Version 1993 Part 5). Respondents responses were assessed and allocated values according to appendix 8. Strong agreement with a constructivist viewpoint was allocated +2 while strong agreement with an inductivist viewpoint was allocated -2. In this manner a position on the continuum, indicating a viewpoint on the nature of science, could be allocated to a respondent.

Version 1994c Part 2 questions 13 - 26 are attributed to Pomeroy's (1993) instrument used to assess teachers' beliefs about the nature of science, and in particular, their views on a traditional versus a non-traditional view of science. In each of these two sections Pomeroy had eight statements. In order to keep a similar pattern, one question was randomly omitted from each section. In these questions, unlike the first 12 in Version 1994c Part 2, agreement and disagreement did indicate opposing viewpoints. A teacher's position on the continuum with respect to a traditional and a non-traditional viewpoints was allocated by dividing the score obtained by 2 (appendix 9).

Nott & Wellington (1993) provided Version 1994c Part 2's questions 27 - 39 (appendix 10). Their instrument was designed to be used in workshop situations where the questionnaire would be used to place teachers on each of five 81 division continuums: Relativist/Positivist; Inductivist/Deductivist; Contextualism/De-contextualism; Process/Content; and Instrumentalist/Realism. Only those questions referring to the Relativist/Positivist, Inductivist/Deductivist, and Instrumentalism/Realism continuums were used. A simple process of adding up scores could not be used because some questions were used more than once for different continuums. There were seven questions for the Relativist/Positivist continuum and four each for the other two continuums. In these questions, as with the traditional/non-traditional continuum, agreement and disagreement were linked.

Version 1994c Part 3 allowed respondents to place themselves on each of the three continuums used to interpret Nott & Wellington's questions. Statements, by Nott & Wellington (1993:11), defining each extreme of the continuums were given to respondents in this part.

Neither Pomeroy (1993:273) nor Nott & Wellington (1993:112) claim that their instruments have been conclusively validated to accurately measure an individual's position or beliefs about the nature of science. In acknowledging these admissions of limited validity, it is accepted that they may not be able to provide significant criterion-related evidence for the validity of Version 1993 Part 5. Earlier in the chapter justifications for the use of questions 1 - 12 were made, no similar attempt was made by the researcher to expand on questions 13 - 39 because it was not intended to use these questions in the final version of the research instrument.

Version 1994c Part 2 questions 1 - 12 is an attempt at ascertaining the reliability of the questionnaire to give similar results over time, this is complemented by Version 1994c Part 5 which gives the respondent the opportunity to put forward reasons why their responses may have differed over the year between responses.

This was done in a number of ways:

* Pearson r correlations were performed between the individual's responses to Version 1993 Part 5 and Version 1994c Part 2 questions 1 - 12 (appendix 12).
* Comparison of the inductivist/constructivist allocation according to the methods set out earlier in the chapter. (referred to as the 1993 method) (appendices 20A & 20B).
* Comparison of the position on the continuum for 1993 and 1994c respondents according to the continuum method (appendix 11).

In order to establish criterion-related validity, internal relaibility, and consistency, Pearson r correlations were administered to certain pairs of questions: 3/28; 10/28; 4/14; 9/15 (appendix 13).

Version 1994c Part 4 was a more refined version of Version 1993 Part 6. Only one experiment, the zinc/copper electrochemical reaction was used and respondents were asked to allocate the percentage mark that they would give to two respective answers. The one answer was one that an inductivist respondent would reward handsomely while the other answer would present some problems to an inductivist teacher.

Version 1994c Part 5 gave teachers the opportunity to comment on any changes in attitude towards the nature of science and to speculate on the origin of these changes.

The use of the instrument at workshops.

Access to larger groups of teachers motivated this method. It must, however, be stressed that the primary aim of these workshops was not to change or influence teachers' views. The topics discussed at the workshops did not specifically deal with the nature of science, but certain "nature of science" and "nature of learning" issues were raised, and evoked limited debate, at all three workshops. The workshops were selected because those attending would, in many cases, be teachers who would not have received the 1993 questionnaire.

All three 1994 versions of the questionnaire were used at workshops to improve external validity, although it must be stressed that although this may have happened, there is not sufficient evidence to claim any significant degree of external validity.

The first workshop was attended by DET teachers who had been exposed to at least six months of a SEP programme. They were given Version 1994a to complete. This version differed from the other versions in that these std 6 teachers would not have had regular exposure to the zinc/copper electrochemical reaction. The part requiring the respondents to indicate a mark allocation for a certain pupil was revised to deal with a density question. The researcher demonstrated, during the course of the workshop, how an egg could "hover" in water if the density of the water was changed using table salt. The question was a "What do you observe...?" type, with two possible answers supplied, one that would be an acceptable inductivist answer and one that an inductivist examiner would regard as inferential and not observational.

Table 4.5
A summary of the different workshops at which teachers were asked to complete the questionnaire.

	TOPIC	PRESENTERS	TARGET GROUP	VENUE	ATTENDANCE	RETURNS
1.	DENSITY	SEP PRESENTERS THE RESEARCHER	STD 6 SEP	ITRC	30	28
2.	ASSESSMENT OF PRACTICAL WORK	THE RESEARCHER	ALL CAPE	PETC	12	9
3.	ACIDS & BASES	THE RESEARCHER	STD 5 CAPE	PETC	7	7
4.	OBSERVATION	RESPONDENT 002	ALL ALL	PETC	15	3

ITRC - Independent Teachers' Resource Centre.
PETC - Port Elizabeth Teachers' Centre.

Respondents to the second workshop had to only complete Version 1993 Part 5 and a "What do you observe...?" type question based on the zinc/copper electrochemical reaction.

Respondents attending the final two workshops were give Version 1994c to complete. Obviously the std 5 teachers did not complete the final two parts dealing with the zinc/copper reaction.

Version 1994c was given to "Ripple" programme teachers, as well as teachers attending the observation workshop and to 1993 respondents whose addresses were current (updated SAATPS address list).

CHAPTER 5.

RESULTS AND DISCUSSION OF RESULTS.

Chapter outline.

Four different versions of the questionnaire were administered over a period of two years. After a series of pilot studies the first full-scale questionnaire was posted to respondents in February 1993. Two subsequent versions of the questionnaire, 1994a and 1994b, were administered to teachers attending workshops, the aim was to increase the representation of the sample. Version 1994c, was administered to a selection of 1993 respondents, in order to establish the degree of reliability and validity of the questionnaire to determine the view of science held by respondents. A small sample of non-SAATPS members who attended the 1993 Science Convention and two science teacher workshops were given Version 1994c in an attempt to further increase the representation of the sample.

It is only once the reliability and validity of Version 1993 have been addressed, that the survey can be discussed and some merit claimed for combining the 1993 and 1994 results. For purposes of discussion, the results from 1993 and 1994 are tabled separately and then combined. It is, however, in some instances impractical to combine results. The different numbers of useful responses reflect that not all versions contained exactly the same questions and not all respondents answered all the questions,

The results of each part of the questionnaires are discussed in detail and where possible comparisons are made with two previous studies on related areas of South African science education (Colussi,1976 and Drost,1982).

Where additional hand-written comments were sufficiently clear and precise it is possible to make a few limited assumptions concerning the respondent's views.

Validity

Of the 158 respondents to Version 1993, a convenience sample of 1994 paid-up members of SAATPS whose addresses were accurate, was selected to receive Version 1994c. The 40,38% (42/104:appendix 20B) return was an improvement on the 1993 response of 34,88% (158/453). This illustrates what Pomeroy (1993:263) refers to as self-selection bias. The 42 respondents represent an extremely biased sample: firstly they originate from the extremely small percentage of South African science teachers who choose to belong to SAATPS and secondly only one third of these teachers choose to return the first questionnaire. This extremely biased sample negates any claim to external validity, but Version 1994c was administered to ascertain the degree of internal validity and not external validity. 61,90% (26/42) of the respondents to the 1993 questionnaire who returned Version 1994c could be classified, using the 1993 method, as either inductivist or constructivist (appendix 11, part c) while 46,20% (73/158) of the 1993 respondents (appendix 20A) could be classified. Confidence in the classification accorded by the 1993 method was only claimed where respondents displayed reasonably strong preferences towards one or other orientation. This increase of 15% in the number of respondents classified supports Pomeroy's (1993:264) claim that teachers who responded to this type of questionnaire do so because they are more interested in philosophical issues, or in science education or are more confident about their views on science education. Claims of internal validity for the instrument to classify teachers can only be made for teachers who display strong views on the nature of science. This is sufficient if the instrument is to be used in workshop situations where appropriate and different activities are designed that enable teachers to reflect on their own views.

Nott and Wellington (1993:112) claim that in developing their questionnaire they "...borrowed heavily from other work done in this area, namely Ziman and Kouladis & Ogborn (in Nott & Wellington,1993:References), while Pomeroy (1993:263) developed her questions from the work of Popper, Polanyi, Keller, Gould, and Kuhn (in Pomeroy,1993:263). Version 1993 Part 5's questions originated from the writings of Hodson, Chalmers, Driver, and Gott & Wellford. A tentative claim to some content-related evidence is made, based on the wide range of appropriate authors' ideas used. An attempt can now be made to assess the degree of validity based on criterion-related evidence, i.e. how does Version 1993 Part 5 compare to the instruments developed by Nott & Wellington and Pomeroy.

A continuum method was used to allocate a teacher's predominant orientation towards the nature of science using Version 1994c Part 2 questions 1 - 12. This was compared to the positions on Nott & Wellington's Relativist/Positivist; Inductivist/Deductivist; and Instrumentalist/Realist continuums. Care must be taken when doing these comparisons because it is only in the first instance, the Relativist/Positivist continuum that a strong case can be made for comparing it to the Constructivist/Inductivist continuum. Comparisons are, however, made of the Inductivist/Deductivist and the Instrumentalist/Realist continuums to the Constructivist/Inductivist continuum. In the latter case, Hodson (1982a & 1982b) claims that the categorisation into Realist/Instrumentalist may be context related.

Two methods of comparison were performed: Pearson r correlations, and the percentage of respondents who were placed on the same side of the continuum for both classifications (i.e. similar signs on both continuums).

<u>Relativist/Positivist:Constructivist/Inductivist</u> (appendix 11).

A Pearson r correlation of +0,64 (64 respondents) was regarded as significant enough to claim a certain degree of criterion-related evidence for validity, especially when viewed in the light of the second method of comparison where 56,25% (36/64) of the respondents had similar signs and only 26,56% (17/64) had opposing signs on the two continuums. 21 of the respondents chose 0 for either one or both continuums.

The value of the following two comparisons must be viewed with circumspection, because the link between deductivism and constructivism is at best tentative and the Realism/Instrumentalism division is contextually based.

Inductivist/Deductivist:Inductivist/Constructivist.

The Pearson r coefficient was +0,46 and 45,31% (29/64) of respondents had similar signs while 23,44% (15/64) had contradictory signs. This lower correlation could arise from trying to equate deductivism with constructivism.

Instrumentalist/Realist:Constructivist/Inductivist.

A Pearson r correlation of +0,53 and 57,81% (37/64) of the respondents having similar signs could indicate a degree of criterion-related evidence, but as was illustrated earlier the Instrumentalist/Realist debate is not simple (Hodson,1982a & 1982b). One must also be very cautious here and consider Lythcott & Duschl's (1990:447) claim that all research yields knowledge claims and these claims or conclusions are often underdetermined by the data i.e. "...there will be more than one explanation that is compatible with the evidence."

It is interesting to compare where individual respondents placed themselves on the continuum with respect to their allocations according to the instrument (table 5.6 & appendix 11).

Table 5.6
The correlation between the positions on the continuum according to the respondent's opinion and according to the allocation by administration of the questionnaire (appendix 11).

CONTINUUM	a.	b.	c.
Relativist/Positivist	+0,41	57,63%	30,51%
Inductivist/Deductivist	+0,12	31,03%	25,86%
Instrumentalist/Realist	+0,43	55,17%	27,59%

Key: a. Pearson r correlation coefficient.
b. Similar signs - on same side of the continuum.
c. Contradictory signs - on different sides of the continuum.

The low Pearson r correlations are significant in that they indicate that teachers' perceptions of their basic philosophy may not coincide with their views as measured by the instrument.

The most useful continuum, the Relativist/Positivist one does, however, indicate that despite the significantly low correlation coefficient, more than 50% of the respondents agree with the "position" that the analysis of the instrument gave them (table 5.6 column b). The significance of the discrepancies can open up new debates in workshop situations.

There are grounds to claim a reasonable degree of validity to use the instrument to classify teachers according to their predominant orientation towards the nature of science provided that the teachers have significantly strong views on the nature of science.

Reliability.

Reliability over time (appendix 12).

Version 1993 Part 5 and Version 1994c Part 2 questions 1 - 12 were identical. Pearson r correlations were carried out for each respondent between their 1993 and 1994c responses. The average correlation coefficient was +0,62 (σ = 0,25: 46 respondents) and the median was +0,71. If the four respondents who claimed that their views had changed in the intervening year were omitted, then the mean correlation coefficient changed to +0,66 (σ = 0,21) and the median increased to +0,72. These correlations are sufficiently high to claim a reasonable degree of reliability over time in the absence of extraneous factors.

<u>Comparison between the 1993 classification method and the continuum method applied in Version 1994c</u> (See p 87-95 & appendix 8).

Of the 65 respondents who completed Version 1994c, 36 could be classified using the 1993 method. 88,89% (32/36) of these had a similar classification when placed on the continuum. This illustrates a high degree of correlation between the two methods.

<u>Internal reliability with respect to similar questions within Version 1994c.</u>

Table 5.7
Correlation coefficients and percentages of respondents with respect to the questions chosen to check for internal consistency.

QUESTIONS	PEARSON r	NO CONTRADICTIONS	CONTRADICTIONS
3/28	+0,21	49,18%	34,43%
10/28	+0,21	45,16%	30,65%
4/14	+0,65	85,90%	6,30%
9/15	+0,01	43,50%	30,60%

See appendix 13 for the rating scale given to each pair of questions.

In all cases, except questions 4/14, the Pearson r correlations are too low to claim any significant degree of internal consistency, but the contradictory results were in most cases less than a third, and as such a small degree of internal consistency can be claimed.

Version 1993 Part 1.

This part established the level of experience of the sample (table 3.3).

In subsequent versions of the questionnaire teachers were not asked to state years experience in each standard but merely their total number of years experience of teaching science.

Table 5.8a
The percentage of respondents in different groups, according to years experience, for Version 1993.

YEARS OF SCIENCE TEACHING EXPERIENCE				
0 - 5	6 - 10	11 - 15	15 - 20	> 20
28,76%	25,49%	21,57%	12,42%	11,76%
44/153	39/153	33/153	19/153	18/153

Table 5.8b
The percentage of respondents in different groups, according to years experience, for the 1994 versions.

YEARS OF SCIENCE TEACHING EXPERIENCE				
0 - 5	6 - 10	11 - 15	15 - 20	> 20
52,46%	29,50%	6,56%	6,56%	4,92%
32/61	18/61	4/61	4/61	3/61%

Table 5.8c
The percentage of all respondents in different groups, according to years experience.

YEARS OF SCIENCE TEACHING EXPERIENCE				
0 - 5	6 - 10	11 - 15	15 - 20	> 20
35,51%	26,64%	17,29%	10,75%	9,81%
76/214	57/214	37/214	23/214	21/214

Although the respondents to Version 1993 were not specifically asked to state their science qualifications, the majority had experience in teaching science to the senior standards. Teaching at this senior level requires certain qualifications, or requires that teachers are completing in-service training in order to obtain the necessary "formal" qualifications. It is therefore reasonable to assume a higher level of qualifications among the respondents than among the general science teacher population. With the incorporation of the 1994 versions this status changed because many of the additional teachers had fewer years experience.

Throughout the questionnaire respondents were only required to answer questions where they were relevant. Therefore the number of responses differs for different questions.

Version 1993 Part2.

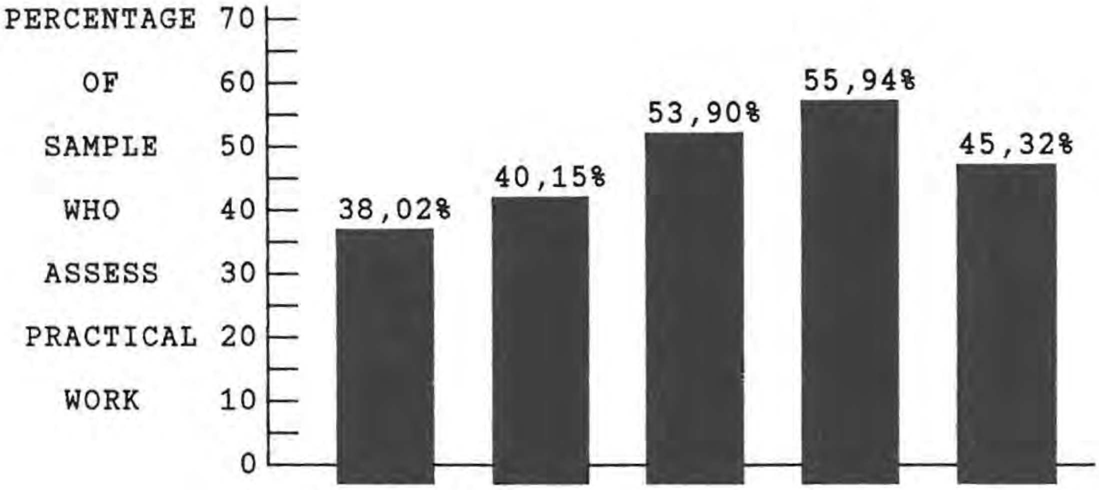
The following discussion involves only the respondents to Version 1993. The comparisons to Colussi and Drost are more appropriate to the 1993 group because this group, as well as Colussi and Drost's surveys was dominated by white teachers.

Table 5.9
A comparison between the results obtained in this survey and Drost's 1982 survey.

SURVEY	STD 6	STD 7	STD 8	STD 9	STD 10	%	TOTALS
MEIRING	38,02%	40,15%	53,90%	55,94%	45,32%	47,04%	318/676
DROST	45,99%	52,50%	48,81%	63,21%	40,36%	50,15%	2266/4518

Notes on table 5.9
* Drost's survey was for teachers who regularly evaluated actual practical work in a practical form of assessment and included these marks as part of the pupils' final examination result.
* Drost's survey included general science, senior biology and physical science teachers. This survey excluded senior biology teachers.
* A similar method of obtaining the percentage was used in both surveys.

Most assessment of practical work was undertaken by teachers who taught standard 9 science (55,94%). This confirms Colussi's (1976) and Drost's (1982) findings. Table 5.9 illustrates the comparison between this survey and Drost's (1982:109) findings.



0	STD 6	STD 7	STD 8	STD 9	STD 10	TOTAL
	46	53	76	80	63	318
	OUT OF	OUT OF	OUT OF	OUT OF	OUT OF	OUT OF
	121	132	141	143	139	676
	38,02%	40,15%	53,90%	55,94%	45,32%	47,04%

Figure 5.4
The percentage of respondents who actually assess practical work in a practical form (Version 1993).

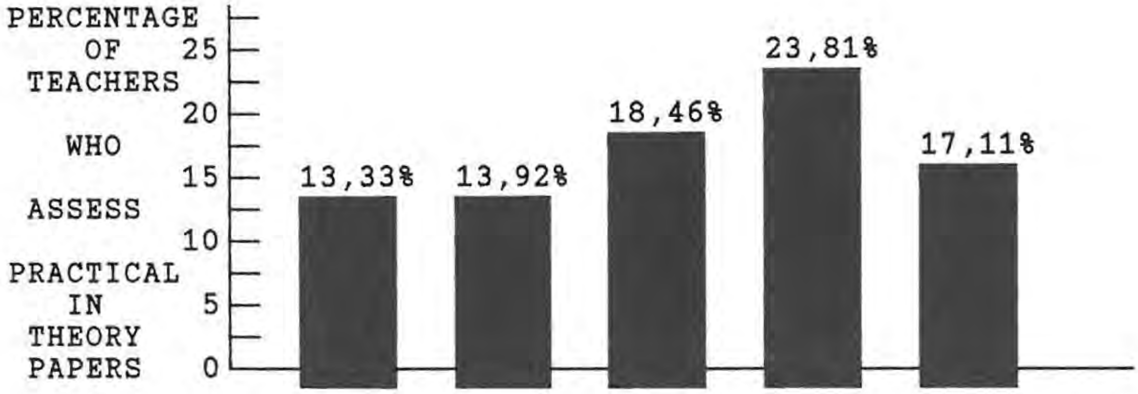
Colussi (1976:43-47) attempted to explain why more practical assessment was carried out in standard 9 than in any other standard. He claimed that the lack of teaching time in standards 6 and 7 and the shortage of equipment, caused by larger classes (van Wyk,1993:3-5), mitigates against pupils doing sufficient individual practical work to justify assessment. He also found that teachers felt that these junior pupils were too immature and dependent on others to handle apparatus with confidence. Teachers also felt that many pupils who did science in standard 6 and 7 did not continue with it into the senior standards, (van Wyk,1993:3-5), and therefore practical assessment was meaningless to them. On the other hand Colussi (1976:44) found that some teachers felt that assessment in standard 6 and 7 would make pupils view the subject more seriously and an assessment would act as a motivator.

Colussi (1976:44) claimed that teachers felt that practical assessments were more desirable in the higher standards because pupils treated the work more seriously. Practical assessment, it was felt, provided a more complete picture of pupils' level of achievement and it promoted insight and comprehension.

Smaller numbers in a class also make it much easier to carry out assessment in the higher standards and the fewer science classes per standard make it much easier to prepare for practical assessments.

More than 50% of the respondents in standard 6 and 7 did not assess practical work (figure 5.4). The most inexperienced teachers are usually allocated to teach science at this junior level and they may be afraid to attempt practical work. The actual year in which respondents taught the junior standards was not asked for in the survey so it is possible that, although as a whole the sample may have been very experienced, it is usually in the early days of their teaching experience that they taught in the junior standards. After a year or two the school would get another novice teacher and the original teacher, after gaining at most one or two years experience in the junior standards, would move up a few standards. Many teachers may only start with serious practical work and assessment after two or three years experience and by this time they have been "promoted" to teaching at a higher standard and the novice teacher teaches at the junior level. The consequence is that practical work and its assessment are sadly neglected at the junior secondary school level, but in the higher standards more attention is paid to the assessment of practical work either directly (laboratory) or indirectly (theory paper).

It is possible to assess certain aspects of practical work by means of a paper and pencil assessment, usually in the normal theory paper. It is significant that once again it is at the standard 9 level that the most assessment of practical work occurs in the theory paper (figure 5.5).



STD 6	STD 7	STD 8	STD 9	STD 10	TOTAL
10 OUT OF 75	11 OUT OF 79	12 OUT OF 65	15 OUT OF 63	13 OUT OF 76	61 OUT OF 358
13,33%	13,92%	18,46%	23,81%	17,11%	17,04%

Figure 5.5
Teachers who do not assess practical work as a <u>practical</u> assessment but do consciously assess practical work in theory papers (paper and pencil).

Much more attention seems to be given to practical work in standard 9 than in any other standard. Contributing reasons could be the lack of pressure caused by the external examination in standard 10, smaller classes, more highly motivated pupils and more experienced and better qualified and motivated teachers.

Only 47,04% of the respondents assess practical work where they can (table 5.9). In Drost's survey (1982:109) 50,15% of the respondents assessed practical work in a practical way. This does not mean that approximately 50% of the respondents did not do any practical work. According to Ganiel & Hofstein (1982:582) teachers may do practical work as part of their teaching, but shy away from practical assessments because its implementation is time consuming and difficult. In both surveys many of the respondents probably have laboratory assistants to help them administer practical assessments, and still the burden may be too heavy. Teachers often complain that the syllabuses are long and overloaded and there is no time to accommodate practical assessment.

Colussi (in Drost,1982:108) claims that the most compelling reason for not assessing or even doing adequate practical work is that teachers often obtained good examination results in external examinations without paying sufficient attention to practical work. According to van Wyk (1993:19) 25,9% of his respondents regarded themselves as excellent teachers because of the results "they" achieved in the external examinations.

Teachers are aware of the inadequacy of paper and pencil tests in the assessment of practical work. According to Lynch (1985:4) practical work really counts only a small amount, if any, towards the final mark and consequently pupils and teachers put minimum effort into it. This mitigates against improving the quality and quantity of practical work in schools.

Some of the aims of science can only be achieved, according to Colussi (in Drost,1982:108), by means of practical work. These specific aims of science are: self-discovery, planning of an investigation, skills in handling chemicals and equipment.

> Probably teachers who do pay the necessary attention to practical work, and for that reason have less time for theoretical work and "examination training" at their disposal, obtain poorer results with their pupils and in that way spoil their own chances of promotion. As long as evaluation of practical work is not a syllabus requirement, it can be expected that teachers will lay more emphasis on those aspects of the syllabus which can be tested in the standard 10 examination.

The practice by external examiners of asking questions relating to practical work in theory papers is an attempt to encourage teachers to undertake practical work. This will not work! It is possible, and probably more efficient, for pupils to learn by rote the answers to "practical" questions in theory papers. This is supported by respondent 049 who claimed that practical work is important "...but not for gaining good results in the NSC exams." Respondent 151 claimed, in Version 1993 Part 6.1 of the questionnaire, that answers 2 and 4 were explanations of what was observed and that pupils could have answered this from a theoretical base that they obtained directly out of a textbook - they could have rote learnt the answers. The claim implies that both sensory input and theoretical answers can be rote learnt.

In the light of the above a crucial question that needs to be asked and answered is: Can we assess practical work by means of paper and pencil tests?

According to Lock (1988:118) "Even in the 1980's science syllabuses are still available which have no means of assessing practical skills other than through written examinations." (my emphasis). Lock's comment could refer to the syllabuses used in the 1990's in South Africa. According to Drost (1982:120) 51,88% (594/1145) of his respondents did not support the inclusion of an external practical examination in standard 10. Only 30,83% of Drost's respondents would support such an activity. It would seem that if teachers had their way, external examinations would in the future have to continue to assess practical work by means of paper and pencil tests.

A number of researchers (Bryce & Robertson,1985:1; Doran et al,1992:22) highlight the paradox of science teaching: Practical work is regarded as very important by a most science teachers, we spend a great deal of time on it, and yet, we assess it with paper and pencil tests in a non-laboratory settings.

A number of respondents (17,04%) stated that they assessed practical work in paper and pencil form (figure 5.5). In standard 9 23,81% consciously assessed practical work in paper and pencil tests. It is assumed that some of the respondents who claimed that they did not assess practical work (56,07%) would also have asked practically orientated questions in their theory papers. This is especially probable in the light of the large number of respondents (43,94%) who claim that the single most important aim of practical work at school is to support the theory (appendix 14).

Teachers who do practical work, but make no attempt to assess it, may simply be going through the motions. They may support the idea that practical work is essential for effective science learning, but according to Bryce & Robertson (1985:21) "...real progress (in practical science) will only be made when assessment is <u>practical</u> and <u>integral</u> to practical science."

The methods used to evaluate (assess) practical work recommended by the CED (1990a:13) include the following:

* Formative:- Evaluation of 10 to 15 of the experiments done during the year plus the evaluation of pupil records of observations, conclusions and answers to questions.

* Summative:- A practical examination/test on practical work done by the pupils.

* Evaluation of practical work in a written test. (The assessment of practical in a theory assessment).

39,93% of the respondents who practically assessed laboratory work used only formative assessments and 35,22% used a summative form of assessment only. 20,44% claimed to use both formative and summative forms of assessment (appendix 15).

Appendices 16A and 16B compare the results of Drost's (1982:109 and 115) survey with this survey. Formative assessment was used by 54,73% of this survey's respondents who assessed practical work and by 50,15% of Drost's respondents. A similar pattern is obtained from those respondents who use summative forms of assessment (Meiring 26,18% and Drost 19,53%). The slightly higher percentages obtained in this survey can be attributed to the sample being more experienced than Drost's sample which included a wider range of teachers.

The marking of worksheets was the most widely used form of formative assessment, but according to Bryce & Robertson (1985:8) the marking of these worksheets may be "...characterised as quasi-continuous if they are merely intrusive, have no formative characteristics and lead to simple arithmetical aggregation equivalent to terminal procedures." A better means of formative assessment should be continuous assessment that promotes improvement, pupils must not be penalised for early practice of skills.

Summative assessments take on a number of forms. The practical examination is the most common. According to Tomlinson (1977:10) the practical examination was the only means of assessing practical work in the past. Mainly manipulative skills were assessed in a limited period of time and this put pupils under needless pressure and resulted in below expected performances. The skills tested were very limited and the final mark did not take into account the many hours spent doing laboratory work prior to the assessment. He claims that this method can hardly be thought of as fair or just.

The two most widely used forms of practical examination used by respondents in the study are the so-called "stations" and "paper-chase" assessments.

Bryce & Robertson (1985:20) claim that many teachers start practical assessments using the "stations" method of practical assessment where pupils move from one experiment or station to the next according to a fixed schedule. The main attraction of this method is its manageability. Stations are a useful first strategy for teachers to gain familiarity with test items and it can reveal certain pupil weaknesses and strengths. Teachers who begin practical assessment using "stations" assessments, gain in confidence and usually move on to more integrated forms of assessment.

The counter claim is that stations are a constraint from which teachers must be liberated if they are to conduct practical assessments in ways which will most influence the pupil's learning. According to Josephy (1986:215) the "stations" or "set-piece" practical assessments are an unsatisfactory means of assessing the main aims of practical work. He claims that they take the practical out of context and separate it from the concept of context.

According to Tamir (in Bryce & Robertson,1985:7) the "paper-chase" type of assessment of practical work does measure some unique qualities. This method, where pupils receive information on separate pieces of paper at different times during the assessment was used by a few respondents.

The responses to Version 1993 Part 2.3 clearly indicated that there are many different interpretations and reasons for assessing practical work. The free responses to Version 1993 Part 2.3 were broadly classified into formative and summative forms of assessment (appendix 15). There is place for both forms of assessment and yet only 20,44% of the respondents who claim to actually assess practical work used both methods.

According to Bryce and Robertson (1985:1) assessing practical work is not easy. The distinction between practical and non-practical science blurs when one considers the respective aims of each. Lynch (1987:34) claims that the "...assessment of practical work is not a straight forward enterprise and requires more than the usual paper and pencil tests to cover the outcomes." The reasons why we do practical work must be clearly stated and understood by all science teachers before the most suitable method of assessment can be attempted.

According to Kempa (1986:69) there are aspects of practical work that can be assessed by means of written tests and examinations. The formulation of the problem to be solved by practical means and the design and planning of an experiment can be assessed using a paper and pencil test. The interpretation and evaluation of experimental observations and data all have a "theoretical" orientation and despite forming an integral part of the experimental process, they can be assessed in a paper and pencil test because they do not depend on the actual practical skills of manipulation and observation. There are, however, practical skills that cannot be assessed by paper and pencil. This is supported by Lynch (1987:34), Ganiel & Hofstein (1982:581 and 588) and Bryce & Robertson (1985:1).

The CED guidelines for practical work (1977:9) suggest that experiments which are technically difficult, involve complex equipment, or may require a number of days to complete may be assessed using a written test. Teachers could easily interpret this as giving them the green light to assess all practical work in theory papers. The CED examiners ask these types of questions in the theory papers but they also ask questions involving direct observation. The most common "practical" aspects assessed in theory examinations are the "What do you observe..?" type question. The CED, and consequently the teachers who prepare pupils to write the CED examinations, tend to ignore the assessment of other aims of practical work. They could claim that they are not in a position to be able to assess practical work in a practical form so the paper and pencil assessments seem to be the next best option. This is contrary to the spirit of assessing practical work as laid down by the 1977 CED document on practical work.

> Both in compiling experiments and questions for evaluation purposes and in setting practical examinations care should be taken to test practical work and procedures and NOT the facts or theory to be memorised.

The opposite should also apply; when testing theory, the assessment of practical work, procedures and skills should not be attempted. The present "second best" solution is just not good enough.

Answers to questions that involve purely sensory inputs, can be rote learnt and according to Igelsrud (1987:56) questions requiring only rote learnt answers do not qualify to be called an assessment of practical work. "If exams measure only the ability to remember information that can be learnt from text, they really are not lab exams."

It is acceptable to have a low correlation between methods that assess different things, but researchers have found low correlation between written questions on practical work and the direct assessment of practical laboratory work. Practical work and theory work may not be as similar as has been claimed by many teachers. Bryce & Robertson (1985:2) claim that a great deal of practical work is assessed by non-practical means but a question mark must hang over the effectiveness of such assessment:

> ... does the tradition of non-practical assessment have a particular advantage or validity? Or is it simply by default, because practical assessment seems difficult and unreliable? Is the imbalance justified? ...Or, is the imbalance embarrassing, representing an awkward mis-match between what we actually teach and what we test?

Lynch (1987:34) claims that there is a growing body of opinion amongst educators, who want to improve the status and contribution of practical work, that it does not lend itself to assessment by the usual paper and pencil testing method.

<u>Version 1993 Part 3.</u>

Table 5.10
A comparison of the different percentages allocated by different researchers and examining boards to different aspects of practical work that are assessed by them. Some of the studies combined some aspects.

	A.	B.	C.	D.
Ability to plan and carry out the experiment. This includes ordering and organising work and setting up the apparatus.	14	10		10
	28	40	25	40
Appropriate manipulative skills (titrations etc).	14	30		30
Skills in observation, measurement (quantitative and qualitative) and the accurate recording of results.	23	25	25	30
Organising and processing data including the drawing of graphs.	20		25	
	44	15	50	20
Interpreting the data, critically discussing the results and drawing conclusions.	24		25	
Attitude to practical work.	5	20	0	10

Key:
A. This survey (1993).
B. Nuffield Chemistry (Tomlinson, 1977).
C. Ganiel & Hofstein (1982).
D. London Examining Board A level Chemistry (Lynch,1985).

Table 5.10 compares the percentages allocated to the various practical skills that are assessed by four different studies and examining boards. It was a synopsis of these studies that was used to construct Version 1993 Part 3 of the questionnaire.

Table 5.10 illustrates that observational skills are highly rated in all these studies. These observational skills were allocated approximately 25% of the total mark by all the studies. The percentage allocated to manipulation skills differs in the different studies, but this is due to the different skills required by chemistry and physics.

Most respondents allocated the 100% among the first five categories in Version 1993 Part 3 (table 5.10). Consequently, if a skill were allocated more than 20% of the total, then it can be regarded as being more important to the respondent than skills that were allocated less than 20%.

Table 5.11 illustrates the percentage of the marks allocated to different skills in a "hands-on" practical assessment by the respondents. Space was allocated for respondents to add any other skills that they felt should be assessed (appendix 17). The majority of respondents who added additional skills did, however, allocate less than 15% of their total mark to any one of these additional categories.

14,39 (appendix 18A) of the respondents felt that the <u>one</u> most important aim of practical work was to motivate pupils by promoting fun, excitement and curiosity and yet the mean percentage allocated to this aspect, (attitude towards practical work), was only 4,61% (table 5.11). Nearly half the respondents (48,57%, table 5.11) would not allocate any marks to this aspect of practical work. One reason noted by some respondents was the difficulty of assessing the attitude of pupils towards practical work. Attitude can only really be assessed by the teacher on the spot and over a long period of time. South African science education, with its obsession with external examinations, mitigates against the assessment of attitude towards practical work. "Many teachers remain

Table 5.11

The percentage of the marks allocated by the sample to different skills in a "hand-on" practical assessment.

		0%	1 - 5%	6 -10%	11-15%	16-20%	21-25%	26-30%	31-35%	36-40%	41-45%	46-50%	51-55%	56-60%	MEAN %
1.	Ability to plan and carry out the experiment. This includes ordering and organising work and setting up the apparatus.	11,43% (16)	10,00% (14)	31,43% (44)	12,86% (18)	21,43% (30)	5,71% (8)	2,14% (3)		5,00% (7)					13,93%
2.	Appropriate manipulative skills (eg using a pipette etc).	3,57% (5)	10,71% (15)	45,00% (63)	14,29% (20)	19,29% (27)	3,57% (5)	2,14% (3)		0,71% (1)				0,71% (1)	13,29%
3.	Skills in observation, measurement (both quantitative and qualitative) and the accurate recording of results.		2,14% (3)	8,57% (12)	15,00% (21)	38,57% (54)	10,71% (15)	16,43% (23)	0,71% (1)	5,71% (8)		0,71% (1)		1,43% (2)	22,29%
4.	Organising and processing data (including the drawing of graphs).	1,43% (2)	2,14% (3)	12,86% (18)	12,86% (18)	42,14% (59)	12,86% (18)	12,86% (18)		1,43% (2)	0,71% (1)			0,71% (1)	20,14%
5.	Interpreting the data, critically discussing the results and drawing conclusions.	1,43% (2)	1,43% (2)	7,14% (10)	10,00% (14)	36,43% (51)	14,29% (20)	16,43% (23)	2,14% (3)	5,00% (7)	1,43% (2)	4,29% (6)			23,61%
	Attitude to practical work.	48,57% (68)	23,57% (33)	22,14% (31)	2,86% (4)	2,14% (3)						0,71% (1)			4,61%

Notes:

140 replies could be used.

15 replies could not be used because the question was not answered or the total percentage was not 100%. 3 respondents felt that the questionnaire could not apply to them.

sceptical and prefer to leave the assessment to those less involved with pupils." (Tomlinson,1977:10). But it is worth noting that despite this preference, teachers are still willing to assess pupils via references and testimonials.

An important aspect of the assessment of practical work is the number of marks allocated to interpreting data, critically discussing the results and drawing conclusions (23,61%, table 5.11). 43,57% of the respondents would allocate more than 20,00% to this aspect of assessment. This aspect of practical assessment can, according to Kempa (1986:69) be assessed by means of paper and pencil. The extensive use of paper and pencil testing of practical work in South Africa could explain this high percentage.

The skill of observation and measurement had a mean of 22,29% and 35,71% of the respondents would allocate more than 20,00% in a practical assessment to these concepts (table 5.11). This shows the importance attached to the skill of observation by the respondents. It is the assessment of this skill that is inappropriately assessed by means of paper and pencil tests by the CED.

The verification of sample consistency using Version 1993 Part 3 of the questionnaire.

As soon as the returned questionnaires arrived by post the respondents were allocated identification numbers. The first return was allocated 001 and 158 was allocated to the last Version 1993 questionnaire to arrive. The average percentage of marks allocated to three of the options were averaged after 25 useful responses, 50 useful responses, 75 responses etc. were received. Table 5.12 shows the consistency of the results. The percentages varied only by small amounts as the results were analysed after 50, 100 etc. returns were received. This procedure was followed with all parts of the questionnaire and a similar pattern emerged.

Table 5.12
Verification of sample consistency using Version Part 3 of the questionnaire.

NUMBER OF RESPONSES	a.	b.	c.
25	25,20%	23,60%	22,20%
50	24,30%	21,90%	20,60%
75	23,86%	22,33%	21,27%
100	24,25%	21,95%	21,50%
125	24,60%	22,16%	21,40%
140	23,61%	22,29%	20,14%

Key:
a. Interpreting data, critically discussing results and drawing conclusions.
b. Skills in observation and measurement and in accurate recording of results.
c. Organising and processing data.

<u>Versions 1993 Part 4, 1994a Part 2, 1994b Part 1, and 1994c Part 1.</u>

According to Lynch (1987:31) "... the importance of practical work is largely undisputed ...", but it is the aims and objectives of practical work that are disputed!

O'Neill (1992:35) in his Lab Development Project found little consensus among science educators on the exact value of practical work, but 96% of his respondents agreed that pupil practicals were necessary for good science teaching. Van Wyk (1993:16) confirmed this when 95,56% (86/90) of his respondents strongly supported the statement: "Physical Science cannot be taught without practical work." In Version 1993 92,96% of the respondents felt that practical work is essential for effective science learning (appendix 14).

A number of other researchers (Woolnough,1983:60; Engels, 1991:D7; Hodson,1990:33) have found that most science teachers believe that practical work is a "good thing". Almost as if science could not be effectively learnt without it. Woolnough (1983:60) claims that there is, however, "...ample evidence that practical work done at schools often lacks direction and educational effectiveness."

O'Neill (1992:35) found that there was such a vast spread of opinions supporting practical work that the aims were obviously not commonly agreed upon. He concluded that "If we don't even come close to agreeing why we are doing it, could practicals have any meaning or value?"

56,07% of the respondents actually assessed practical work, (either in the laboratory or in the theory paper), this was much lower than the 92,96% (appendix 14) who felt that practical work is essential for effective science learning. So, while practical work is regarded by respondents as important, the assessment of it is another matter. The 1977 CED document says that in some instances "...the allocation of marks may destroy the very purpose of the practical exercise." This approach clearly does not encourage the assessment of practical work.

The respondents to Version 1993 supported three main aims for doing practical work (appendix 18A).

1. To support the theory (58,27%).
2. To develop practical skills (27,34%).
3. To motivate (14,39%).

These three options were given in Versions 1994a Part 2, 1994b Part 1, and 1994c Part 1. The discussion of these results include all respondents.

The CED's rationale for doing practical work revolves around the concept that practical work is an integral part of science (CED Circular 21, March 1977). The CED claims that practical work, should, together with other things:

* create learning opportunities for pupils to explore concepts - **support the theory**;
* enable pupils to master practical skills and techniques - **develop practical skills**; and
* make natural science interesting and exciting - **motivate**.

The 1977 and 1990a CED documents on practical work listed the aims of practical work. The 1977 document was superceded by the 1990a document and in the process the following five aims were omitted:

1. to meet the prescriptions of syllabuses and examinations;
2. to verify principles and facts already taught;
3. to elucidate the theoretical work so as to aid comprehension;
4. to give training in the technique of problem solving; and
5. to be an integral part of a scientific process of finding facts by investigation and arriving at principles.

It is clear that by omitting aims numbered 2, 3 and 5 above, there has been some movement towards a more modern emphasis in approach to the aims and purpose of practical work by the CED, but have the teachers in the classrooms changed their approach?

1. **To support the theory.**

It was not surprising that 57,29% (appendix 18C) of the respondents claimed that for them the main aim for doing practical work was to support the theory. This result confirmed van Wyk's (1993:16) survey. When he asked his respondents whether they felt that practical work contributed towards a better insight into and comprehension of the theory or subject matter, in short, does practical work support the theory, 73,86% (65/88) of his respondents felt that the statement applied to a very large extent and 23,86% (21/88) felt that it applied to a large extent. These results can be contrasted with those of Tomlinson's 1977 research in Britain which showed that, when given twenty possible aims for practical work, the verification of facts and principles was ranked very low and the ranking for the elucidation of theoretical work did not rank within the first five (appendix 19).

O'Neill (1992:35) and Woolnough (1983:61) claim that there is no proof to support the idea that practical work reinforces theory in any more significant a manner than lecture, demonstration or discussion methods might. This is confirmed by Lynch (in Bryce and Robertson,1985:1) and Kempa (in Engels,1991:D7) who claim that teaching theory through practical work is not an efficient way of transmitting an understanding of scientific concepts. This view is also supported by Tomlinson (1977:9), Osborne (1990:193), Harris (1990) and respondents 049, 073, 105, 113, and 128.

Osborne (1990:193) goes so far as to claim that while practical work is valuable, it is not fundamental to the understanding of physical principles. He says that practical work is often called upon to play a leading role in helping with the understanding of the theory and this is not a purpose for which it is well suited.

Woolnough (1983:61) claims "...without an appropriate conceptual framework, no meaningful observation can take place." Insight and understanding are probably more of a prerequisite to successful practical work, than a result of successful practical work.

Comments from some of the respondents illustrate their perceptions on the aims of practical work. Respondent 070, highlighted the following in Version 1993 Part 6: "Each time you took a great deal of time to explain the theoretical basis of the experiment before you demonstrated it." The respondent then added:

> Educationally unsound. You spoil the whole "Scientific Approach!" Is this perhaps the reason why S.A. produces so few graduates in Chemistry, Physics and Engineering?

The implication here is that the "Scientific Approach" requires no prior knowledge of the event to make it successful. Needless to say this respondent was classified as having a predominantly inductivist orientation towards the nature of science.

Respondent 104 claimed that explaining the theory before a demonstration was "Bad technique for an experiment." This respondent showed many inductivist characteristics in methods 1 and 3 of the inductivist/constructivist classification BUT in method 2 scored a rating of 5,5 and therefore had both strong constructivist and inductivist characteristics.

If teachers view practical work merely as a means of supporting the theory then, according to many researchers, we may end up short-changing practical work. An overall aim of assessment in practical work could crudely be stated as assessing the ability of pupils to "do" science, rather than just to learn about it. "The distinction is an important one, because it is based on the belief that practical work can be justified in its own terms and not only as an aid to theoretical understanding." (Josephy,1986:214).

Woolnough (1983:61) suggests that we don't use practical work solely to support theory but that we do practical work for its own sake. Shulman & Tamir (in Ganiel & Hofstein,1982:518) support Woolnough's belief that the laboratory is not just a place of demonstration and confirmation but "...the core of the science learning process."

Woolnough's "new" aims for such a model of practical work would be to: firstly develop specific skills including observation; secondly to develop a scientific way of working - not necessarily through the much maligned "Scientific Method"; and thirdly to enable pupils to obtain a "feel for various phenomena."

Woolnough's approach can be seen as a response to the Nuffield project of the 1960's and 1970's. Osborne (1990:193) expresses his concern about that which has been inherited from the Nuffield project, namely: "...the more practical, the better the quality of the learning experience." Osborne also claims that Nuffield supported the idea that by "doing" science a true understanding of the physical principle can be obtained. This approach, according to Osborne (1990:193), "...presents physics as a process of inductive realism which has been shown to be philosophically untenable by Popper."

The Nuffield project had a major influence on science education in Britain and South Africa. The concept of practical work being done to support theory, originating in the Nuffield project, gave its South African supporters a boost.

Lock & Ferriman (1989:110) found in a study on the Graded Assessment of Science Scheme that teachers very seldom created situations where pupils could and did make generalized statements from the information in the data. They suspected that this arose from the way that practical work was presented. They claim:

> Practical work is principally used to establish or confirm important concepts in the syllabus, consequently, it is directed towards a single outcome and teachers, with some justification, are concerned that inferences and explanations are the correct ones.

2. **To develop practical skills.**

21,61% of the respondents claimed that this was the most important reason for doing practical work (appendix 18C). Many South African syllabuses, under the development of skills section, require that pupils be guided to make objective, careful observations (a skill), and then to make relevant deductions.

It has been argued that individual practical work is more useful than the demonstration. It is claimed that it is only by doing the work themselves that pupils can learn skills. The demonstration of a particular skill certainly is not able to develop certain practical skills in pupils.

Four respondents (033, 100, 104 and 112) answered "No" to Version 1993 question 4A and claimed that a good demonstration is better or as good as, individual practical work. Two respondents (062 and 117) supported the use of the demonstration. These respondents are supported by Tomlinson (1977:9) who feels strongly that a well prepared and executed demonstration is worth many practical sessions. According to Miller (in Smit,1993:2) the demonstration is not as useful as has been made out "A demonstration, however well done, however dramatic, however convincing, has its virtues well-nigh completely lost if the physics of it is not seriously and penetratingly explored."

If one considers the method of the demonstration as prescribed by the CED (1990a:7-9), it can be seen to accommodate both inductivist and constructivist orientated teachers. The idea of presenting the theory before the practical, supports the constructivist viewpoint and the conveying of facts and knowledge supports the inductivist approach.

Finally according to Blosser (1988:57):

> Most of the research done on the role of the laboratory finds no statistically significant difference in achievement or attitude or lab skills between students given experiment-based lessons and students given lecture-based lessons.

3. **To motivate.**

According to Hodson (1990:33) nearly "...all the science curriculum developments of the 1960's and early 1970's promoted hands-on practical work as an enjoyable and effective form of learning." 21,10% of the sample respondents felt that practical work's most important aim was to motivate pupils (appendix 18C). This aim must obviously be important because 93,18% (82/88) of the respondents in van Wyk's survey had very often heard their pupils comment that practical work made science interesting and 84,1% (74/88) of his respondents had never heard pupils claim that practical work is dull and devoid of value.

In summary none of the respondents supported Woolnough's (1983:63) assertion that:

> Practical work can be justified for its own sake, its opportunities and resources are too valuable to be wasted in playing games with pupils leading them by the nose to "discover" theories which could be more appropriately taught by and used in other ways.

Versions 1993 Part 5, 1994a Part 4, 1994b Part 3, and 1994c Part 2.

All the respondents were grouped together for these results and discussion. An analysis of the responses to this section are the most useful to the research (appendix 20A and table 5.13).

Question 1.

A good scientist aims to make objective observations.

A strong inductivist orientation ("strongly agree" or "agree") was expected. However the results (93,15%:204/219) exceeded expectations (table 5.13).

From the point of view of what Chalmer's (1990:2) refers to as the "naive inductivist" a good scientist would be one who makes objective observations. The "theory-dependence" of observation was the basis of the first attempts to undermine the naive inductivist assumptions of the role of observation in science by concentrating on the subjectivity of observation. The small percentage of respondents who disagreed with the statement illustrates that the extreme relativist position is not a favoured position adopted by constructivist leaning respondents. The position supported by the majority of respondents supports Chalmers' argument that the extreme relativist position is not a valid position from which to attack the inductivist approach. According to Chalmers (1990:46-48), observational statements are always subjective and dependent upon the opinions and knowledge of the observer, but as he (1990:50) suggests "Objectivity is a practical achievement, an achievement that is frequently, though not without difficulty, accomplished in physical science." Science has tried to obtain this objectivity in observation by replacing sensory observation by measurements involving routine procedures and instruments under standardized conditions. This redefines the phrase "unbiased observations" and consequently

Table 5.13
An analysis of the responses to Versions 1993 Part 5, 1994a Part 4, 1994b Part 3, and 1994c Part 2.

	I STRONGLY AGREE	I TEND TO AGREE	I NEITHER AGREE NOR DISAGREE	I TEND TO DISAGREE	I STRONGLY DISAGREE	DID NOT ANSWER THE QUESTION
1. A good scientist aims to make objective observations.	68,95% (151)	24,20% (53)	2,28% (5)	1,83% (4)	0,91% (2)	1,83% (4)
2. Doing regular practical work enables pupils to improve their observational skills.	64,84% (142)	28,31% (62)	1,83% (4)	2,28% (5)	(0)	2,74% (6)
3. Scientific knowledge is objective and value-free.	11,87% (26)	30,14% (66)	15,06% (33)	24,66% (54)	11,42% (25)	6,85% (15)
4. There is a set pattern for scientific procedure: guesswork and intuition no part.	9,13% (20)	16,90% (37)	11,42% (25)	37,90% (83)	22,37% (49)	2,28% (5)
5. Inevitably all observation is influenced by what the observer already knows.	26,94% (59)	41,10% (90)	6,39% (14)	18,72% (41)	5,94% (13)	0,91% (2)
6. Valid scientific theories can only be formulated on basis of sufficient observation.	35,16% (77)	39,73% (87)	10,05% (22)	10,50% (23)	3,65% (8)	0,91% (2)
7. The validity of observational statements are dependent on the opinions and expectations of the observer.	9,59% (21)	44,75% (98)	11,87% (26)	22,37% (49)	9,59% (21)	1,83% (4)
8. Practical assessments should always include assessment of scientific observation.	31,51% (69)	47,95% (105)	10,50% (23)	6,39% (14)	(0)	3,65% (8)
9. Inevitably observation produces subjective data.	13,24% (29)	28,31% (62)	19,63% (43)	27,40% (60)	6,85% (15)	4,57% (10)
10. Scientific facts are merely interpretations.	12,33% (27)	27,40% (60)	14,61% (32)	33,33% (73)	10,50% (23)	1,83% (4)
11. The method of science consists of a sequence of processess: observation --> data collection --> classification --> inference --> hypothesis.	36,07% (79)	44,29% (97)	5,02% (11)	9,59% (21)	3,20% (7)	1,83% (4)
12. Pupils observe things in terms of what they already know.	31,96% (70)	46,58% (102)	7,76% (17)	7,76% (17)	3,20% (7)	2,74% (6)

There were 219 useful responses.

many constructivist respondents could support the statement.

According to Chalmers (1990:59) the theory-dependence of observation does not mean that science lacks objectivity, but that the accuracy and relevance of observations can and should be revised. "Observation in science may be objectified, but we do not thereby have access to secure foundations for science."

A result of the discussions during the Grahamstown pilot study was to replace the word "makes" with "aims to make". It is possible that this change made constructivist orientated teachers agree with the statement. The word "good" was also problematic for some respondents, they circled or underlined it. Any respondent who showed inductivist tendencies in other questions should have agreed with this statement. A respondent who tended to be a constructivist, as indicated by the rest of the questions, could also have agreed with this statement if they redefined the meaning of "objective observation". This redefinition would follow a similar argument to that used by Chalmers (1990:59). According to Norris (1984:141) as long as observation is not considered as being infallible, science can still rely on <u>sound</u> observation for its foundation. One must be able to separate scientific observation from emotional reactions.

Question 2.

> **Doing regular practical work enables pupils to improve their observational skills.**

According to Millar & Driver (1987:48):

> As far as teaching people to observe is concerned it is not surprising to find evidence that observation improves with practice in particular domains and contexts, particularly when guidance is given to which distinguishing features to pay attention to.

Again an emphasis on what to look for. The theory before the practical.

The high percentage of respondents 93,15% (204/219) who felt that doing regular practical work improved pupils' observational skills was to be expected. The crucial question to ask is what do teachers consider to be important observational skills. Sound or unbiased observations. Observation will improve with practice, but there may be little point in doing what is wrong, more efficiently. The philosophically "correct" form of observation must be the starting point and only then should more practice be given to improve the skill.

Question 3.

Scientific knowledge is objective and value-free.

Nearly half the respondents (11,87% "strongly agree" and 30,14% "agree") identify themselves as having inductivist tendencies. Significantly just over a fifth of the respondents 21,92% (48) neither agreed nor disagreed with the statement or chose not to volunteer an answer. This lack of response may reflect the sense of confusion that permeates science when there is no clear philosophical foundation on which teachers can base their practice. The teacher ends up being torn between the respectable, traditional philosophy and a philosophy that works in the classroom.

Question 4.

There is a set pattern for scientific procedure: guesswork and intuition play no part.

The high percentage, 60,27% (132) of respondents who disagreed or strongly disagreed with the statement, was higher than expected. On reflection, Fleming's discovery of penicillin and similar stories tend to highlight the concept that intuition and guesswork do play a role in scientific procedure. These classic stories recall incidents where the prepared mind used intuition and guesswork to propose an idea. The high percentage is therefore not surprising. According to Cross (1990:18) scientists agree on a number of definite aspects about intuition: it is not equally present in all researchers; the accumulated store of experience on which intuition is based is preceded by hard work and intense study; intuition is often wrong, it must be proved or disproved through reasoning and experiment; and lastly, intuition comes at odd moments and in odd circumstances. All this mitigates against proposing a rigid rule-based method on which to base the development of science.

A respondent who has an inductivist orientation may be able to claim that an "intuitive guess" could be the inspiration that initiates an investigation. The inductivist would claim that once the "intuitive guess" has been made and acted upon then intuition ceases and the rigid rule following of the Scientific Method follows. This investigation, using the rigid Scientific Method, would be used to either support or disprove the "guess". Theory would in reality precede the practical, but the clearly constructivist approach, which is how science really develops, continually uses inspired guesses to direct and redirect progress throughout the experiment. The statement could only identify 26,64% (57) of the respondents as agreeing with it. Respondents who disagreed with the statement are not necessarily constructivist.

Question 5.

Inevitably all observation is influenced by what the observer already knows.

All constructivists would have to agreed with this statement. The written comments of some respondents indicated that, although they had to agree, they felt that this was unfortunately not an ideal situation. More than one third of the useful replies (68,04%:149/219) felt that prior knowledge did influence observations but this does not imply that they all have a constructivist orientation.

By disagreeing a significant portion of the sample (24,66%:54/219) indicated a definite tendency towards the inductivist orientation.

Question 6.

Valid scientific theories can only be formulated on the basis of sufficient observation.

The strongly inductivist orientation ("strongly agree" or "agree") response of 74,89% (164/219) was not surprising. All inductivist orientated respondents must be found in this group, but the whole group are not necessarily inductively orientated. Respondents who tend to subscribe to an approach associated with Popper, namely a falsificationist orientation would also fall into this grouping. Many attempts need to be made to prove a theory false. This approach, according to Harré (1983:11), suffers from the same problem as the inductivist approach: "...how can he (the scientist) know that a theory that is false here today will be false in other places at other times?" This approach is a variation on the pure process of induction and suffers from what Chalmers (1990) cites as the "problem of induction".

Constructivists need not necessarily disagree with the statement because the constructivist orientation supports the idea that many observations are still required in an experiment.

Question 7.

The validity of observational statements are dependent on the opinions and expectations of the observer.

The 9,95% (21/219) of the respondents who strongly agreed and the 44,75% (98/219) who agreed show strong constructivist tendencies. The 31,96% (70/219) of the respondents who disagreed with the statement may be concentrating on the word "validity". If these respondents were to be classified as inductivist, then they could argue that an observational statement that depends on the opinions and expectations of the observer cannot be classified as "valid".

Question 8.

Practical assessments should always include assessment of scientific observation.

The 79,45% (174/219) respondents who agreed or strongly agreed with the statement indicate the necessity for a well formulated policy with respect to the role of observation in practical work.

Question 9.

Inevitably observation produces subjective data.

The total number of respondents (41,55%:91/219) who supported this statement may not all have possessed constructivist tendencies. Many inductivist respondents could once again, as in question 5, have accepted the inevitable, that prior knowledge does influence observation, but they could still claim that even though this is the case, it is not an ideal situation.

A large number of the respondents, 34,25% (75/219), believe that it is not inevitable that observation produces subjective data. The number of respondents who strongly disagree with the statement can be regarded as being firmly in the inductivist camp.

Question 10.

Scientific facts are merely interpretations.

This clearly constructivist statement was supported by, ("strongly agree"), 12,33% (27/219) of the respondents. The 39,73% (87/219) of the respondents who supported this concept is significantly similar to the percentage respondents who were finally classified as having a predominantly constructivist orientation.

Entertaining the idea the "facts" are interpretations would be rejected out of hand by inductivist orientated teachers. Any respondent who disagreed would have to have strong leanings towards an inductivist approach. 43,84% (96/219) of the respondents shared this idea.

Question 11.

> **The method of science consists of a sequence of processes: observation --> data collection --> classification --> inference --> hypothesis.**

A small percentage, 3,20% (7/219), of the respondents strongly disagreed that the method of science follows a rigid pattern. The 9,59% (21/219) of respondents who disagreed with the statement are clearly also not happy with this predominantly inductivist approach.

Storey & Carter (1992:18) ask "Why are teachers the only members of the scientific community who remain closely tied to THE Scientific Method?" The more than 80% (176/219) of the respondents who strongly agreed or agreed with the statement is an indication that Storey & Carter's question is just as relevant for this sample of teachers as it is for USA teachers.

Storey & Carter answer their question by concluding that few teachers have had the opportunity to be involved in research programs and that old textbook dogma dies very slowly. This shows more support for workshops on the nature of science.

A pitfall of teaching the Scientific Method as a rigid protocol, is that it fosters an inclination in students to see the results of research as "facts" and thus supporting an inductivist orientation (Storey & Carter,1992:20). Not all the respondents who support the method can be classified as inductivist, but a respondent showing inductivist characteristics in other questions should support the method.

Some respondents placed the hypothesis first, indicating this by drawing arrows on the questionnaire. This hypothetical-inductivist method (Storey & Carter,1992:18) is still, however, essentially inductivist in orientation.

Question 12.

Pupils observe things in terms of what they already know.

A majority of respondents (78,54%:72/219) supported this constructivist claim. Very few respondents disagreed with the statement. These results confirm Keogh's findings. In Keogh's (1992:2) survey not a single respondent agreed with the statement: "Children are ignorant of most things." The inductivist orientated teachers could easily have supported question 12's statement on the basis that pupils are "bad" scientists and that they have to be taught to observe objectively. Respondent 001 was classified as having a predominantly inductivist orientation. On her questionnaire she noted: "Pupils do sometimes observe subjectively. They need to be taught the skills of scientific observation." This respondent also agreed that regular practical work does improve observational skills.

Respondent 155 disagreed that pupils observed in terms of what they already know and added: "The younger the better". This respondent could mean that as pupils gain more experience they become more subjective. The respondent "strongly agreed" with question 1 and "agreed" with question 5 and could be classified as having an inductivist orientation (appendix 20A). The implication being that observation should be naive like a child's (Hodson,1986b:387).

Versions 1993 Part 5, 1994a Part 4, 1994b Part 3, 1994c Part 2: Individual Classification.

This was the nub of the research. The individual respondent's responses were classified according to the methods outlined in chapter 3 (appendix 20A).

Not all respondents could be classified with a great degree of certainty. Where there were ambiguities or inconsistencies in responses, respondents were not classified. To be classified there had to be a definite tendency towards one or other of the orientations.

In cases where contradictory responses were given to questions 3 and 10 no further classification was attempted except where in method 3, respondents had three or more identical classifications. In these cases the respondents' overall classifications was reassessed. This was required in 5 cases.

By making use of the 1993 method of classification nearly half the total sample (49,29%) could reliably be classified as having either a constructivist or inductivist orientation towards the nature of science. The results (table 5.14a) indicated that, of those who could be classified, approximately 60% tended towards an inductivist orientation while nearly 40% could be classified as showing predominantly constructivist characteristics. The domination of the inductivist approach of syllabuses and examiners and the results of previous studies, seemed to indicate that a much higher percentage of inductivist respondents could have been expected.

Table 5.14a.
Individual classification of all the respondents with respect to their predominant orientations towards the nature of science using the 1993 methods.

	METHOD 1		METHOD 2		METHOD 3		FINAL	
	I	C	I	C	I	C	I	C
	84	45	40	32	78	64	64	40
	65,12%	34,88%	55,56%	44,44%	54,93%	45,07%	61,54%	38,46%
TOTAL	129 61,14%		72 34,12%		142 67,30%		104 49,29%	

There were 211 useful responses.
Key:
"I" Inductivist.
"C" Constructivist.

If the continuum method is used then the following results were obtained.

Table 5.14b.
Individual classification of all the respondents with respect to their predominant orientations towards the nature of science using the continuum method (appendix 8 & 11).

INDUCTIVIST <————————————————————> CONSTRUCTIVIST

a.	<-3	-3	-2	-1	0	+1	+2	+3	>+3
b.	10,76%	4,62%	7,70%	7,70%	13,85%	10,76%	9,23%	10,76%	24,62%
c.	7	3	5	5	9	7	6	7	16
	15,38%		Useful responses = 65					35,38%	
	10		<——— Totals ———>					23	

Key: a. The numbers on the continuum.
b. Percentage of the respondents in a certain area of the continuum.
c. Number of respondents.

The 1993 method only classified respondents who exhibited definite constructivist or inductivist characteristics. Therefore a confident classification can only be made for respondents who fall in the region greater than + 2 and - 2 on the continuum. In this way 50,77% (33/65) of the respondents could be confidently classified. This is significantly similar to the 49,29% classified using the 1993 methods. The tilt towards constructivist respondents is not significant because the 1994 sample is biased towards more self-selection than the original 1993 sample. It would seem that either method could confidently classify about 50% of the sample.

Approximately 7,55% (17/225) of the respondents worked in tertiary education and were involved in teacher training. They should all be at the cutting edge of the developments in the natures of science and learning. Approximately 75% of the tertiary respondents could be classified as predominantly constructively orientated (table 5.15).

Table 5.15
Individual classification of all tertiary respondents with respect to their predominant orientations towards the nature of science.

	METHOD 1		METHOD 2		METHOD 3		FINAL	
	I	C	I	C	I	C	I	C
	2	7	2	6	4	8	2	7
	22,22%	77,78%	25,00%	75,00%	33,33%	67,67%	22,22%	77,78%
TOTAL	9 52,94%		8 47,06%		12 70,59%		9 52,94%	

There were 17 useful responses.

Table 5.16
Individual classification of all non-tertiary (classroom teacher) respondents with respect to their predominant orientations towards the nature of science.

	METHOD 1		METHOD 2		METHOD 3		FINAL	
	I	C	I	C	I	C	I	C
	81	38	38	26	74	56	61	33
	68,07%	31,93%	59,38%	40,62%	56,92%	43,08%	64,89%	35,11%
TOTAL (194)	119		64		130		94 48,45%	

There were 194 useful responses.

The results were approximately 65% inductively and 35% constructively orientated respondents when the tertiary respondents were removed from the analysis.

All the respondents who could be classified, were now grouped according to their years of experience of teaching science. The number of years experience in science teaching was assumed to be the maximum years of experience that the respondents indicated in Version 1993 Part 1 or where otherwise stated (table 5.18).

The number of respondents in the categories 16 - 20 years, and greater than 20 years experience, were regarded as being too few to make a meaningful comment. In the other three categories inductivist views dominated. It is, however, interesting to note from table 5.17 nearly half the the non-tertiary respondents with five or less years of experience showed strong constructivist orientations. Modern theories of learning and science are being used in the education of novice teachers today and the result is that novice teachers enter the profession with many of the constructivist ideas on the nature of science and the nature of learning.

More experienced, and consequently older respondents, who did their teacher education many years ago tend to have a more inductivist orientation

When non-tertiary respondents, with 6 - 10 years and 11 - 15 years experience were considered, the constructivist/inductivist split became approximately 25/75. It is in this grouping that that the Heads of Department and examiners are to be found. This is the group that is most likely to dictate policy within a school, and this policy is very likely to be underpinned by an inductivist view of the nature of science.

Table 5.17
Classification according to years' experience of non-tertiary respondents.

YEARS	0 - 5		6 - 10		11 - 15		16 - 20		21 --->	
TOTALS										
CLASSIFICATION	I	C	I	C	I	C	I	C	I	C
NUMBERS	19	17	17	5	12	4	4	5	9	2
PERCENTAGE	52,78%	47,23%	77,27%	27,73%	75,00%	25,00%	44,44%	55,56%	81,82%	18,18%

Table 5.18
Classification according to years' experience of the whole sample.

YEARS	0 - 5		6 - 10		11 - 15		16 - 20		21 --->	
TOTALS										
CLASSIFICATION	I	C	I	C	I	C	I	C	I	C
NUMBERS	20	18	18	8	12	6	4	6	9	2
PERCENTAGE	52,63%	47,37%	69,23%	30,77%	66,67%	33,33%	40,00%	60,00%	81,18%	18,18%

There were 176 useful responses.

Respondent 131 was a qualified teacher who had never taught.

The mismatch between how pupils learn (constructively) and how they are assessed (inductively), is now exacerbated by the mismatch between the approach to the nature of science adopted by junior teachers and senior teachers. The Heads of Department (HODs) of science have to evaluate all examination papers and moderate the scripts. The junior teachers could be teaching as they were educated to teach - in a constructivist manner, but their tests and examinations, even if they are set in a constructivist way, may be changed by the HOD to give them a predominantly inductivist flavour.

Of the respondents with more than 20 years experience more than 80% were inductively orientated. Two of these respondents were external examiners with the CED and Joint Matriculation Board (JMB) examining bodies. Both could be classified as having a predominantly inductivist orientation towards the nature of science. This supports the claim that there are examiners who have a predominantly inductivist orientation towards the nature of science.

Version 1994c Part 2 questions 13 - 39.

The purpose of including this section was to provide criterion-related evidence. It was not intended to discuss this section in any great detail with regard to the results for each question or the implications thereof. For interest the results are included in appendix 21A & 21B. What did, however, emerge was that many respondents exhibited both traditional i.e. positivist ideas as well as non-traditional i.e. post-positivist views on science education, despite being shown to hold predominantly constructivist or inductivist views (appendix 11). This is more grounds for supporting a continuum approach rather than an "either/or" view of classifying teachers.

Versions 1993 Part 6, 1994a Part 3, 1994b Part 2 and 1994c Part 4.

The original intention of these parts was to confirm the individual classifications done in Version 1993 Part 5. The results for Version 1993 Part 6 (table 5.19) indicated that the majority of the respondents claimed that they would assess a practical question in a theory paper/examination in a predominantly inductivist manner.

Table 5.19
The results of Part 6.

Part 6.1	1	2	3	4
1: Bubbles were seen rising in the test tube.	9,42% (13)	57,97% (80)	15,22% (21)	17,39% (24)
2: Hydrogen was released and it rose up the test tube and displaced the water.	5,07% (8)	23,91% (33)	63,77% (88)	6,52% (9)
3: Bubbles rise in the test tube and this gas displaces the water out of the test tube.	69,56% (96)	15,94% (22)	13,04% (18)	1,45% (2)
4: A reaction occurs between the water and the sodium. During this reaction hydrogen is released and sodium hydroxide is produced.	16,67% (23)	0,72% (1)	7,97% (11)	74,64% (103)

Part 6.2	1	2	3	4
1: The candle started to burn. It gave off black smoke and a clear liquid was formed at the top of the candle. This liquid then ran down the side of the candle. As it slipped down the side of the candle it solidified.	8,69% (12)	83,33% (115)	5,79% (8)	1,45% (3)
2: The candle wax got hot and melted. The molten candle wax solified on the sides of the candle.	7,25% (10)	6,52% (9)	73,19% (101)	13,04% (18)
3: The wax melted and solidified and carbon was given off.	5,79% (8)	2,89% (4)	15,94% (22)	75,36% (104)
4: Once the candle was lit it flickered a great deal. The colours of the flame seemed to vary from a purple to an orange colour. Black smoke was released into the air. A clear liquid was formed that ran down the sides of the candle. About half way down the candle the clear liquid got stiffer and became opaque.	81,16% (112)	6,52% (9)	3,62% (5)	8,69% (12)

There were 138 useful responses.

All 30 respondents, who were classified as having predominant constructivist orientations (appendix 20A), and who did not give mixed responses to Versions 1993 Parts 6.1 and 6.2, chose inductivist answers as the best answers (table 5.20). This could indicate the influence that the predominantly inductivist approach to the assessment of observation in theoretical papers has had on the respondents.

Table 5.20
A comparison between the classifications obtained in Part 5 and the responses to Version 1993 Part 6.

PART 5 CLASSIFICATION	CONFIRMED	REJECTED
INDUCTIVE	33,80% (24)	5,63% (4)
CONSTRUCTIVE	NIL	42,25% (30)
CONFUSED RESPONSE TO PART 6 18,31% (14)		

The marking criteria used by respondents tended to concentrate on the obvious features of sensory input. In Version 1993 Part 6.2 student 4 made more "observations" than student 1, but both students gave answers that reflected purely sensory observations. 81,16% of the respondents chose option 4 as the best and 83,33% of the respondents chose option 1 as the second best. Respondents tended to award more marks for more observations.

In Version 1993 Part 6.1 student 4's answer reflects working with a much more sophisticated conceptual framework. This option was rated as the worst of the four by 74,64% of the respondents. 63,77% of the respondents regarded the half/half option of student 2 as better than student 4's answer. The amount of "information" offered by student 4 is more than by student 2, but this still did not enable student 4 to get a better rating. Do we mark on the number of "sensory facts" and not on the quality and sophistication of the response?

Gott & Welford (1987:224) question whether the most appropriate mark scheme is one in which we merely count the number of correct observations and discount any answers that can be construed as having been inferred - a typical inductivist scheme. Gott and Welford argue that this view is both philosophically wrong, as well as inappropriate.

Norris (1984), and Millar (1989) argue that scientists will always try, in practice, to make:

> ...the strongest claim which is not subject to reason to doubt, and the mere fact that it is possible to doubt that the liquid is paraffin is not sufficient reason to have such doubt. It is possible to doubt anything. Norris,1984:133.

All assessment schemes are underpinned by a particular view on the nature of science, observation and learning. The inductivist orientation proposes a view of observation as being merely an activity concerned with the neutral collection of data while in the constructivist or theory-driven approach not all observations are given the same credit. Observation is regarded as a difficult and complex task which should reflect the pupils conceptual framework (Gott & Welford,1987:226).

A slightly different approach to Version 1993 Part 6 was attempted in the 1994 versions of the questionnaires. Versions 1994a and 1994c contained a question related to: "What do you observe when some zinc powder is placed in a concentrated copper sulphate solution?"

The following options given were:

PUPIL A: (An answer that an inductivist orientated respondent could not support.)

> Zinc is more reactive than copper and therefore the copper ion was displaced from the copper sulphate (the copper ion was reduced to copper atoms). Copper was formed. The zinc atoms were oxidised to zinc ions and zinc sulphate was formed. The reaction was an exothermic one.

PUPIL B: (An answer that an inductivist orientated respondent would encourage.)

> A brown precipitate was formed. The blue colour of the solution went clear. The temperature of the solution increased.

In Version 1994a respondents were asked to choose the best answer and motivate their response, while in Version 1994c respondents were asked to allocate a mark according to the following mark scheme for each answer: Fail, less than 40%; 40 - 60%; 60 - 80%; and distinction, greater than 80%.

In Version 1994a 62,50% (5/8) felt that Pupil B's answer was the best. Their reasoning followed the traditional pattern. An interesting conflict of views were expressed by two respondents. Respondents 165 (classified as inductivist) felt that Pupil A's answer was "...more detailed,...sounds like rote memory." while respondent 167 (unclassified) claimed that Pupil B's inductivist answer "Shows a very good memory of observations of experiments." Both answers were rote learnt!

The interesting pattern that emerged from Version 1994c Part 5's responses confirmed the results of Version 1993 Part 6.

Of the respondents who could be classified as constructivist nearly 60% would fail Pupil A for a substantially correct answer but that did not describe purely sensory input. This supports the results of Version 1993 Part 6.

Table 5.21a.
The assessment that the different classifications of respondents would give to Pupil A's answers.

PUPIL A: An answer that an inductivist would not support claiming that it was inferential and not observational.				
58 RESPONDENTS	FAIL< 40%	40 - 60 %	60 - 80%	DISTINCTION
CONSTRUCTIVIST	57,89% (11)	21,05% (4)	15,79% (3)	5,27% (1)
INDUCTIVIST	73,33% (11)	26,67% (4)	- (0)	- (0)
TOTAL	56,90% (33)	27,58% (16)	10,34% (6)	5,17% (3)

58 Useful responses (19 Constructivist and 15 Inductivist).

Table 5.21b.
The assessment that the different classifications of respondents would give to Pupil B's answers.

PUPIL B: An answer that an inductivist would support on the grounds that it reflected sensory input.				
58 RESPONDENTS	FAIL< 40%	40 - 60 %	60 - 80%	DISTINCTION
CONSTRUCTIVIST	- (0)	10,53% (2)	36,84% (7)	52,63% (10)
INDUCTIVIST	- (0)	- (0)	6,67% (1)	93,33% (14)
TOTAL	- (0)	8,62% (5)	25,86% (15)	65,52% (38)

58 Useful responses (19 Constructivist and 15 Inductivist).

93,33% of the inductively orientated respondents would give pupil B a distinction while more than half the constructively orientated respondents would support this.

In Version 1994b a different question was asked because it was done at a workshop for junior high school teachers and they would not have been able to answer the question involving zinc and copper sulphate that occurs in the std 8 syllabus.

PUPIL A's answer: (The inductivist answer).

> The egg floats inside the water. It does not rise to the top and it does not sink to the bottom.

PUPIL B' answer: (The inferential answer).

> The density of the egg is the same as that of the salt water.

27 of the respondents at the density workshop answered this part. 40,74% (11/27) of these respondents could be classified as having a predominantly inductivist orientation while only one could be classified as having a predominantly constructivist orientation. 55,55% (15/27) of the respondents choose the "inductivist" answer. In many cases their comments revolved around the ideas: "Were not asked why? They were not asked to interpret. Could not conclude from the observations.

Should not use theory first. Must say what they observe, see. Must answer what is asked." The one constructivist candidate choose both answers as being acceptable, stating; "Shows understanding of the concept."

Discussion.

When many teachers seriously reflect on their teaching practice they may end up echoing Minstrell's words (1989:129):

> My students tested well, and my administrators gave me glowing evaluations, but I was amazed at the relatively little effect I had on my students' understanding of the ideas of physics.

According to Dykstra (1985:504) "Are we helping our students by giving credit for papers with correct answers but incorrect or incomplete explanations and/or diagrams?" It is sobering to realise that pupils are aware of the situation: "I did okay in physics, but I'll never understand it." (pupil quoted in Dykstra,1985:504). There has to be something wrong!

Very early in their science careers pupils become aware that the answers to observational questions can be learnt off by heart and this provides little incentive to understand science and consequently they do not bother to try to change their own ideas or to understand science. They simply keep two explanations in their heads, one they believe and one they need to use to pass examinations. Some pupils get the right answers for the wrong reasons. Teachers need to be aware of these reasons if teaching is to be effective. The inductivist approach does not encourage pupils to give teachers these reasons, it merely encourages "correct" answers.

The inductivist method of teaching science may, on the surface, produce good results, but it is the constructivist approach, that probes and continually assesses pupils' understanding, that may be the more effective method of teaching science.

According to Rowe & Holland (1990:91). "The importance of making fundamental changes in conceptions cannot be underestimated in its impact on how we interpret the world and even on what observations we make." Copernicus, reinterpreting the universe to be heliocentric, changed the meaning of observation of the universe and impacted on philosophy and religion of the time.

As Minstrell (1992:1) claims:

> The phenomena of student conception is becoming familiar to all of us, but the inferences about the structure of students' knowledge and implication for instruction vary depending on our theoretical perspectives.

What is important for the future of science and science education in South Africa is the evidence from this study that suggests that many teachers have an approach to science education that is not conducive to identifying and correcting misconceptions, will not facilitate conceptual change and will not teach problem solving techniques. Teachers should be made aware of the different and more effective views on the nature of science and be encouraged to embrace them.

If the constructivist view of the nature of science is more useful and more effective in teaching science, then it is important that teachers, teacher educators and examiners reflect on their currently held views and make the necessary paradigm shifts that may be required. Much of the research done on pupil understanding of science has cogently illustrated that the constructivist approach is the more effective teaching approach. Two encouraging and significant results emerge from the survey: the majority of teacher educators, who are more exposed to current trends in the philosophical and pedagogical aspects of science education, could be classified as having a predominantly constructivist orientation and, perhaps even more significant, is the large percentage of respondents with five and less years of experience who could be classified as holding a predominantly constructivist orientation towards the nature of science and learning.

Many veteran teachers will have watched the coming and going of many "new" innovations in science teaching. They may be very sceptical of "new" ideas. These more "experienced" teachers, (more than ten years of experience), may not consider embracing the constructivist view of the nature of science and learning for themselves because of their past experience with "new" ideas. This is of concern, but the main concern is the influence these "experienced" teachers have outside their own classrooms. This is how the inappropriate philosophical and pedagogical view of the nature of science is perpetuated.

As long as the inductivist method continues to produce good external examination results and the constructivist method flounders in the inductivist environment of the external examination, the inductivist approach will triumph. No teacher can afford to use a method, no matter how philosophically justifiable, when it does not and probably cannot produce tangible results in an external examination. This is supported by van Wyk (1993:1) who claims that "...however well the child should be educated by way of the teaching process, if he does not pass his examinations he does not achieve success in the school."

The attitude ascribed to examinations also promotes the determinist attitude in schools. Marks are awarded for "blind-copying" and substantially correct answers are rejected because they do not conform to the accepted inductivist view of observation.

According to Josephy (1986:220) "If students can be helped to see the importance of, and become involved in the process of learning the pressure to `get the right answer' will be reduced." Josephy claims that it is not easy to change long-held views on assessment. As long as the deterministic approach to assessment persists, getting the "right answer" at all costs will be the aim of most pupils and teachers.

According to Norris (1984:133) a problem arises with the assessment of observational statements. "Such statements would be considered differently by those holding one or the other theory making the import of the theory different for both." The results could provide little conformity in assessment and cause confusion among those being assessed.

The question needs to be asked: If there are benefits to using the constructivist model instead of the inductivist (behaviourist) model, how can teachers move towards a more constructivist approach? Yager (1991:55) argues that there may not need to be a significant shift from what is happening at present. He claims that what is probably required is a reorganization with a new emphasis. He feels that many really good teachers instinctively teach in a constructivist mode. They may, however, be forced to adopt an inductivist approach to examinations. This is borne out by the responses of many of the inductively classified respondents who supported questions 5 and 12 in Version 1993 Part 5 of the questionnaire.

If the consequences of a CNE education system that supports an inductivist teaching and examining approach is compounded with the findings of a number of empirical studies that have indicated that science teachers all over the world hold a predominantly inductivist view of the nature of science (Carey & Strauss,1970; Billeh & Malik,1977; Hodson,1986b:381) then the results of this survey, showing that the majority of teachers have a predominantly inductivist orientation towards the nature of science, are not at all surprising.

There has been, and still is, a perceived conflict between religion and science. According to Woolnough, (1990:69) "It is only as students appreciate the natures of both science and religion that they will find that they are complementary, not in conflict." The conflict may be the misconception that Woolnough claims it to be, but it is a very real concept to the holders of conflicting viewpoints. Woolnough believes that this preconception needs to be challenged and an equitable resolution of the conflict developed. Can CNE, that predisposes strongly inductivist views on the nature of science be seen as being complementary to the constructivist view of the nature of science? Probably not. CNE with its roots firmly based in God, the Creator of Reality, creates the impression that there are "facts" out there that have been created by God and the goal of science education is to enable (lead), pupils to discover what God has created. Man must be taught to "uncover" the facts and attempt to understand this externally created reality. True answers are proposed instead of useful models. This positivist approach to the nature of science must have influenced the thinking and practice of teachers.

If a constructivist approach towards science education is seen to be more effective than the inductivist approach, and there is ample evidence to suggest that this is the case, then has the Church, and especially the reform movement, which influenced CNE, acted as an obstacle to the development of science? It would seem that this is the case when considering the influence that CNE has had on the view of the nature of science held by South African science teachers.

Woolnough (1990:69) in supporting his claim that religion and science are complementary claims that "Far from being a hindrance to the development of science, a religious faith has been the intellectual spring motivating and structuring the thinking of many scientists."

According to Woolnough a result of our materialistic times is that we tend to equate truth with literal truth, which in turn is equated with the equally inappropriate view of scientific truth. Woolnough claims that it is appropriate for students to see the spiritual truths of religious writings as being truths in their own right, and not to attempt to compare them to scientific writings. Woolnough claims that there are different types of explanations. e.g. "Scientists can give us an important insight into how the world developed, but not why or who, if anyone, is behind it.

Woolnough concludes that it is important to appreciate the natures of both science and religion in order to appreciate that they can be complementary to each other and not in conflict. The problem of CNE is that the natures of religion and science are inexorably intertwined. There is no appreciation that the nature of religion and the nature of science are different and separate.

The theoretical perspective of the teacher has a decisive impact on classroom atmosphere. A classroom based on CNE principles supports the concept of the teacher as the authority and more importantly, in authority. This classroom atmosphere does not encourage genuine pupil-teacher dialogue.

It is easier to assess sensory input than to assess pupils' interpretation of what they are observing. The authority figure, created by religion, does not invite questions. It is easier and "safer" to teach in such an environment.

An atmosphere that allows for genuine pupil-pupil and teacher-pupil dialogue and discussion supports a more effective learning environment. This environment enables pupils to become aware of their own conceptions and of the limitations of these conceptions. This is supported by Andersson (1986:560):

> If the atmosphere in the classroom is of a kind in which the pupils can express themselves without worrying too much about making mistakes, their hypothesis can be expected to illustrate their conceptions.

It is only once teachers become aware of pupils' concepts that they can try to point out and convince the pupils of the limitations of their misconceptions. Only when a pupil's conception is so limited that it no longer works for the pupil, will the pupil consider exchanging this concept for the teacher's alternative one.

A constructivist approach to learning requires a special classroom atmosphere, the atmosphere must be invitational, tolerant of "mistakes" and encourage collaborative working.

Pupils' concepts must be treated with respect. If pupils feel secure they may feel inclined to join in fresh discussions and consequently be able to change or adapt their conceptions (Andersson,1986:560).

<u>The teacher, research and science education.</u>

A far reaching implication of the inductivist approach is highlighted by Cross (1990:16) "We are trying to teach science using a flawed concept of how scientists work. This mistaken perception has frustrated our teaching, hobbled science education, and turned youngsters away from science."

The constructivist approach to the nature of science is not a "new" theory but it is only in recent years that it has started to impact on the South African science classroom and while it is acknowledged that resistance to change in education has been common throughout the world, (Ost, in Loubser,1993:42), it is crucial to the development of science education that this newer method be embraced by all stakeholders.

A view proposed by Popejoy & Burney (1990:99) is that:

> Science and mathematics educators increasingly use research on how students learn and reason as they plan efforts to improve student performance. This knowledge of cognitive development allows educators to help children develop their minds in a way that prepares them for later educational experiences, helps educators assess how well an activity or curriculum will be received by students, and guides educators' choices of teaching methods.

If we are to improve classroom practice then we must involve teachers as researchers. Practising teachers in South Africa tend to perceive themselves as users and not producers of knowledge. This perception needs to be changed.

CHAPTER 6.

CONCLUSIONS AND RECOMMENDATIONS.

According to Baird (in Ntombela, 1994:56) "The future of science education does not lie primarily in curricula or in technology. It lies in the teacher of science." If this assumption is valid, and there are reasonable grounds to claim a degree of validity, then it is clear that research on teachers' views of the natures of learning and science can assist in the development of science education.

This study illustrates how science education has been hobbled by what science educators have perceived as the "respectable" inductivist view of the nature of science. Effective science education requires a different way of thinking about teaching and learning than that which is proposed by the inductivist theory, and many teachers are not even aware of these different views. The future of science teaching lies in the hands of all science educators. We need to develop reflective teachers who will become receptive to conceptual change within themselves. A means of promoting the required paradigm shifts is for teachers to be exposed these "new" ideas, to debate them, and be enabled to assess their own position vis-à-vis these "new" perspectives. Herein lies the value of the instrument developed in this study.

Yager (1991:57) stresses that in the constructivist learning model:

> In-service education that really matters involves conceptual change on the part of the teachers. The thrust of the in-service program should be towards a constructive perspective on teaching and student learning and involves change in teachers' conceptions of learning and teaching.

Conceptual change in teachers is most helpful when considered in terms of whether or not new ideas are intelligible, plausible, fruitful and feasible to the teacher. This is the bottom line when it comes to teachers undergoing a paradigm shift towards the constructivist learning model.

According to Yager (1991:57):

> The conceptions held by teachers on entering an in-service program will sometimes include ideas and beliefs about the focus of the program that are in conflict with the ideas and beliefs of those running the program;...

This is vital and refers back to Yager's emphasis that to really matter, in-service training must involve conceptual change to a better system for the teacher. It is important at the outset that both those attending and those presenting workshops on conceptual change should be aware of the original beliefs and ideas of all involved and that change in these beliefs are measureable. It is naive to claim that twelve questions are sufficient to completely circumscribe a teacher's views - no relatively simple instrument is able to do justice to the extremely complex area of teachers' views (McDivitt et al,1993:595) - but the instrument used in this study does give an indication, a position, from which reflection can begin.

A word of caution is sounded by Ray (1991:88):

> Perhaps some of the most notorious of all professional pundits are those educationalists who seize on the latest philosophical trend and try to turn it into a universal panacea.

Ray (1991:87) suggests that we should consider doing school science without commiting ourselves to one particular philosophical line. He claims that this does, however, require a much more sophisticated view of the philosophy of science. The views exposed by this instrument do allow access to more sophisticated views than those which teachers may already hold.

Not only can the questionnaire claim sufficient internal validity to establish broad profiles of teachers' views on the nature of science and learning, but more importantly, it is able to register changes in these views over time. The continuum approach adopted in Version 1994c would seem to be able to measure changes in views. Where teachers claimed no external factors, the questionnaire was significantly reliable at revealing similar responses, but in cases where teachers were aware of changes in their views, due to external factors, that the questionnaire reflected these changes. Respondent 098 moved "up" (more constructivist) by three points over the year. She attributes this to starting an MEd at Leeds on the nature of science. Although respondent 221 only completed version 1994c, he claimed after conducting research in the area of teachers' views on the nature of science, also at Leeds, that he had changed his perspectives on the nature of learning and science. He was placed at +12 (very constructivist) on the continuum, one of the highest positions recorded. This research did not expand into the area of establishing the instruments validity at measuring change in teachers' views, but a degree of understanding that this might be the case, can be established. This is a possible area of further research.

The bias in the sample selection is so significant that no external validity can be claimed. These results cannot be extrapolated to the general South African science teacher population, The questionnaire was sent to a small, non-random sample of science educators and it is worth noting, once again, that "...those who elected to respond may be those who are most willing to engage in this philosophical dialogue about science and who also felt best about science." (Pomeroy:1993:271). The instrument was never intended to measure the views of the South African science teacher population, but as a tool to help teachers reflect on their own practice, and then hopefully, to shift these views towards ones that will be more beneficial to their students learning by creating a deeper understanding of the processes and products of science.

To summarise, Clough (1992:37) claims that there is no way for science education to develop other than to respect the growing body of pedagogical research. He claims that the best way for science educators to achieve their most desired goal - excellence in science teaching - is to use this body of knowledge that is growing daily.

Clough (1992:38) comments on a typical teacher response that research on effective science education is merely common sense. He claims that if this is the case, then "...why do so many teachers persist with ineffective archaic practices?" Teachers can respond to Clough by saying that these methods may be ineffective in teaching for understanding, but these archaic practices still get the results in examinations! (CED,1994).

If the approach towards the nature of science used by different stakeholders in the same scientific enterprise (school) differs, then we are sowing confusion. In such a confused situation there will be very little development. Curriculum designers and examiners need to be aware of the current developments in the nature of science and learning theories so that the form of assessment that they implement reflects the real nature of science and not the deficient Baconian view of the nature of science that has been accepted as the only "respectable" one for so long.

Curriculum developers should consider pupils' preconceptions and misunderstandings and design a curriculum that will address these. According to Watts & Pope (1989:326) constructivism "...suggests some basis for thinking about the thinking that young people do, and for learning about their learning." The embracing of constructivism generates a different view of all facets of teaching.

There is a widely held assumption that teachers' understanding of the nature of science has a profound influence on how they teach. Further research needs to be undertaken to investigate this claim, but in the meantime this instrument can open the way to meaningful debate amongst stakeholders, especially in science teacher training programmes, and hopefully lead to meaningful conceptual change among science educators.

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Appendix 1.
SAATPS membership.

YEAR	PAID-UP MEMBERS
1990/91	535
1991/92	487
1992/93	474
1993/94	579

Source: SAATPS membership secretary.

Appendix 2A.
The introductory letter that accompanied the questionnaire, Version 1993.

18 Lionel Road
Walmer Downs
Port Elizabeth
6070
5 February 1993.

Dear Colleague

MED IN SCIENCE EDUCATION

I am at present doing an MEd in Science Education at Rhodes University on the role of observation in practical work. I would like your help in determining the different approaches used by science teachers in their assessment observation.

Please take a few minutes to complete the enclosed questionnaire and return it to me in the enclosed pre-addressed envelope as soon as possible. I need some personal details for statistical purposes. All respondents will remain anonymous to all but me.

Thank you very much.

Best wishes.

LES MEIRING.

Appendix 2B.
The introductory letter that accompanied the questionnaire, Version 1993, to Port Elizabeth and Uitenhage teachers.

18 Lionel Road
Walmer Downs
Port Elizabeth
6070
1 February 1993.

Dear

MED IN SCIENCE EDUCATION

I am at present doing an MEd in Science Education at Rhodes University on the role of observation in practical work. I would like your help in determining the different approaches used by science teachers in their assessment observation.

Please take a few minutes to complete the enclosed questionnaire and return it to me in the enclosed pre-addressed envelope. I need some personal details for statistical purposes. All respondents will remain anonymous to all but me.

I will analyse the results and then conduct a structured interview with 10 identified teachers. The structured interview will be based on the role of observation in four experiments: Hoffmann's Voltameter, Zn/Cu electrochemical cell, the reducing action of H_2S and the dehydrating action of H_2SO_4. The interview will give you an opportunity to expand on some of your comments in the questionnaire.

I would like to follow up the interview with demonstrations to three of your std 9 pupils. The demonstrations to your pupils are not to teach them. I will explain the purpose of the experiment and then demonstrate it to the pupils. The pupils may ask me questions about the experiment. They will be asked to say what they observe. I would like to record their comments on audio tape for later analysis. The pupils should at some stage in their science careers have seen two of the experiments demonstrated by you. The other two experiments must be new to the pupils.

The structured interview should take about 15 minutes and the demonstrations about 45 minutes.

Thank you very much.
Best wishes.

LES MEIRING.

Appendix 2C.
Questionnaire Version 1993 on observation.

Please return to: LES MEIRING, 18 Lionel Rd, Walmer Downs, 6070.
NAME:.......................
INSTITUTION:......................

Would you agree to an interview on your approach to the role of observation in the four experiments mentioned in the covering letter?

YES	
NO	

Would you be prepared to let me demonstrate the four experiments to three of your std 9 pupils and to audio record their comments?

YES	
NO	

Please fill in the telephone numbers at which you may be contacted.

Home: School:
Any preferred time at which I can phone:

1. (Biographical Details)

Which standards you have taught science to and how many years experience do you have at each level. eg If you have taught std 6 for 3 years and std 8 for 2 years then you would fill in as follows:
EXAMPLE

STD 6	STD 7	STD 8	STD 9	STD 10
3	--	2	--	---

Now please complete these blocks.

STD 6	STD 7	STD 8	STD 9	STD 10

2.

2.1. Do you carry out any form of assessment of science practical work?

YES	
NO	

2.2. If YES then in which standards?

STD 6	STD 7	STD 8	STD 9	STD 10

2.3. Briefly describe this assessment. If you require more space please use an additional sheet of paper.

3. Please allocate the percentage of the total marks that you would give to each category if you were to assess "hands-on" practical work.

   If you feel that an aspect does not warrant assessment, then allocate 0% to it.

* Ability to plan and carry out the experiment. This includes ordering and organising work and setting up the apparatus.	%
* Appropriate manipulative skills (eg using a pipette etc).	%
* Skills in observation, measurement (both quantitative and qualitative) and the accurate recording of results.	%
* Organising and processing data (including the drawing of graphs).	%
* Interpreting the data, critically discussing the results and drawing conclusions.	%
* Attitude to practical work.	%
* Other:	%
*	%
*	%
TOTAL:	100%

4A. Is practical laboratory science work essential for effective science learning? Comment.

....

4B. What do you feel is the <u>one</u> most important reason for doing practical laboratory work in science at school?

....

....

Part 5.
Please answer the following statements by marking with an "X" the block that best describes how YOU feel about the statement.

	I STRONGLY AGREE	I TEND TO AGREE	I NEITHER AGREE NOR DISAGREE	I TEND TO DISAGREE	I STRONGLY DISAGREE	YOUR COMMENTS
1. A good scientist aims to make objective observations.						
2. Doing regular practical work enables pupils to improve their observational skills.						
3. Scientific knowledge is objective and value-free.						
4. There is a set pattern for scientific procedure: guesswork and intuition play no part.						
5. Inevitably all observation is influenced by what the observer already knows.						
6. Valid scientific theories can only be formulated on the basis of sufficient observation.						
7. The validity of observational statements are dependent on the opinions and expectations of the observer.						
8. Practical assessments should always include assessment of scientific observation.						
9. Inevitably observation produces subjective data.						
10. Scientific facts are merely interpretations.						
11. The method of science consists of a sequence of processes: observation --> data collection --> classification --> inference --> hypothesis.						
12. Pupils observe things in terms of what they already know.						

6. Some written examination papers include questions that attempt to assess practical work.

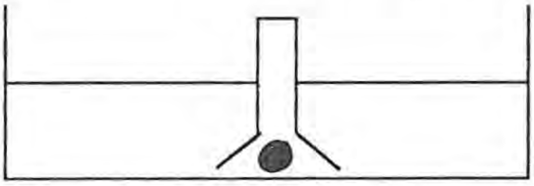
Assume that you have demonstrated the following demonstrations to a group of std 8 pupils. You have taught these pupils since std 6 and you have let them do all the practical work that is required and you have done all the demonstrations. Each time you took a great deal of time to explain the theoretical basis of the experiment before you demonstrated it.

You gave them the following two questions in a **WRITTEN** test paper. Rank the pupils' responses. "1" would be allocated to the BEST answer and "4" to the WORST answer. Do not give two or more answers the same rating.

Please respond to the following situations.

You set the following as an exam question:

6.1 A small piece of sodium metal was placed in a copper gauze cage and placed under an upside down test tube that is filled with water, in a large glass trough of water.



What did you observe?

Student 1 :	Bubbles were seen rising in the test tube.	☐
Student 2 :	Hydrogen was released and it rose up the test tube and displaced the water.	☐
Student 3 :	Bubbles rise in the test tube and this gas displaces the water out of the test tube.	☐
Student 4 :	A reaction occurs between the water and the sodium. During this reaction hydrogen is released and sodium hydroxide is produced.	☐

6.2. A candle was lit and allowed to burn. What did you observe?

Student 1: The candle started to burn. It gave off black smoke and a clear liquid was formed at the top of the candle. This liquid then ran down the side of the candle. As it slipped down the side of the candle it solidified. ☐

Student 2: The candle wax got hot and melted. The molten candle wax solified on the sides of the candle. ☐

Student 3: The wax melted and solidified and carbon was given off. ☐

Student 4: Once the candle was lit it flickered a great deal. The colours of the flame seemed to vary from a purple to an orange colour. Black smoke was released into the air. A clear liquid was formed that ran down the sides of the candle. About half way down the candle the clear liquid got stiffer and became opaque. ☐

THANK YOU FOR YOUR TIME

Appendix 2D.
Version 1994a of the questionnaire.

18 Lionel Road
Walmer Downs
Port Elizabeth
6070
20 May 1994.

Dear Colleague

MED IN SCIENCE EDUCATION

I am at present doing an MEd in Science Education at Rhodes University. I would like your help in finding out about science teachers' attitudes towards science education in general, and practical work in particular. Even if you are not able to do much practical work at your school, would you please still complete the questionnaire. Your opinion is valuable.

Please take a few minutes to complete the enclosed questionnaire and return it to me as soon as possible. (If possible with your students attending the Ripple Programme next week). I need some personal details for statistical purposes. All respondents will remain anonymous to all but me.

Please phone me if there are any queries at 514244 (s) or 382070 (h).

Would you try to get all the science teachers at your school to complete the questionnaire because the more returns that I get the more representative the results will be.

Thank you very much for your time.

Best wishes.

LES MEIRING.

****

Please respond to all the questions because this makes the analysis more accurate.

PART 1

NAME..

SCHOOL..

CONTACT TELEPHONE NUMBER..........................

NUMBER OF YEARS SCIENCE TEACHING EXPERIENCE........
HAVE YOU COMPLETED A SIMILAR QUESTIONNAIRE FOR ME IN THE

PAST?...

PART 2.

Three statements have been proposed as the main reasons for doing practical work in schools. Put a cross "X" in the box next to the statement that you regard as being the most important reason for doing science practical work at schools.

1.	To support or to understand the theory. Application of the theory.	
2.	For the development of practical skills.	
3.	To motivate by promoting excitement, fun and curiosity.	

PART 3.

This section deals with a section of std 8 practical work that is often asked in a theory paper.
The pupils are asked what they observe when some zinc powder is added to a concentrated solution of copper sulphate.
The following two boxes include the answers from two pupils.

PUPIL A's answer.
Zinc is MORE reactive than copper and therefore the copper ion was displaced from the copper sulphate (the copper ion was reduced to copper atoms). Copper was formed. The zinc atoms were oxidised to zinc ions and zinc sulphate was formed. The reaction was an exothermic one.

PUPIL B's answer.
A brown precipitate was formed. The blue colour of the solution went clear. The temperature of the solution increased.

3.1. Which pupil's answer was the best? | A | B |

3.2. Why do you think that this pupil had the best answer?

....

....

3.3. Why was the other pupil's answer not the best?...........

....

....

PART 4.

Please answer the following statements by marking with an "X" the block that best describes how **YOU** feel about the statement.

	I STRONGLY AGREE	I TEND TO AGREE	I NEITHER AGREE NOR DISAGREE	I TEND TO DISAGREE	I STRONGLY DISAGREE	YOUR COMMENTS
1. A good scientist aims to make objective observations.						
2. Doing regular practical work enables pupils to improve their observational skills.						
3. Scientific knowledge is objective and value-free.						
4. There is a set pattern for scientific procedure: guesswork and intuition play no part.						
5. Inevitably all observation is influenced by what the observer already knows.						
6. Valid scientific theories can only be formulated on the basis of sufficient observation.						
7. The validity of observational statements are dependent on the opinions and expectations of the observer.						
8. Practical assessments should always include assessment of scientific observation.						
9. Inevitably observation produces subjective data.						
10. Scientific facts are merely interpretations.						
11. The method of science consists of a sequence of processes: observation --> data collection --> classification --> inference --> hypothesis.						
12. Pupils observe things in terms of what they already know.						

Appendix 2E.
Version 1994b of the questionnaire.

I am at present doing an MEd degree at Rhodes University on teachers' opinions of practical work. Would you please complete the following questionnaire for me? Your details are for statistical analysis only and you remain anonymous to all but me.

NAME: ______________________________

SCHOOL: ______________________________

CONTACT TELEPHONE NUMBER: ______________________________

NUMBER OF YEARS EXPERIENCE OF TEACHING SCIENCE: ______________________________

PART 1:

Three statements have been proposed as the main reasons for doing practical work at schools. Put a cross "X" in the box next to the statement that you regard as being the most important reason for doing science practical work at schools.

1.	To support or to understand the theory. Application of the theory.	
2.	For the development of practical skills.	
3.	To motivate by promoting excitement, fun and curiosity.	

PART 2:

The following question deals with how you would mark a question on observation.

An egg is placed in a solution of salt water. The pupils are asked to describe what they observe.

The following boxes contain the answers given by two pupils.

PUPIL A's answer: The egg floats inside the water. It does not rise to the top and it does not sink to the bottom.

PUPIL B' answer: The density of the egg is the same as that of the salt water.

Which student, in your opinion, has given the best answer to the question: "What do you observe?"

A	B	BOTH ANSWERS JUST AS GOOD

Explain why you made the choice that you did. ....
....
....
....

PART 3:
Please answer the following statements by marking with an "X" the block that best describes how **YOU** feel about the statement.

	I STRONGLY AGREE	I TEND TO AGREE	I NEITHER AGREE NOR DISAGREE	I TEND TO DISAGREE	I STRONGLY DISAGREE	YOUR COMMENTS
1. A good scientist aims to make objective observations.						
2. Doing regular practical work enables pupils to improve their observational skills.						
3. Scientific knowledge is objective and value-free.						
4. There is a set pattern for scientific procedure: guesswork and intuition play no part.						
5. Inevitably all observation is influenced by what the observer already knows.						
6. Valid scientific theories can only be formulated on the basis of sufficient observation.						
7. The validity of observational statements are dependent on the opinions and expectations of the observer.						
8. Practical assessments should always include assessment of scientific observation.						
9. Inevitably observation produces subjective data.						
10. Scientific facts are merely interpretations.						
11. The method of science consists of a sequence of processes: observation --> data collection --> classification --> inference --> hypothesis.						
12. Pupils observe things in terms of what they already know.						

Appendix 2F.
Questionnaire Version 1994c.

Tel: 041-382070(h)
041-514244(s)
Fax: 041-382070(h)
041-512067(s)

18 Lionel Rd
Walmer Downs
Port Elizabeth
6070
25 August 1994

Dear

MED IN SCIENCE EDUCATION.

Last year you filled in a questionnaire for me on your approach to the assessment of practical work and your views on the nature of science.

I am at present doing a follow-up to test the questionnaire's reliability and validity. Please take a few minutes to complete the enclosed questionnaire and return it to me in the stamped pre-addressed envelope as soon as possible. If you prefer you can fax the questionnaire back to me. All respondents will remain anonymous to all but me.

Thank you for your time.
Best wishes

Les Meiring.

Part 1:

Please put an "X" in the box next to the statement that you feel is the one most important reason for doing practical laboratory work in science at school? Place an "X" in one block only.

1.	To support or to understand the theory. Application of the theory.	
2.	For the development of practical skills.	
3.	To motivate by promoting excitement, fun and curiosity.	

PART 2:
Please answer the following statements by marking with an "X" the block that best describes how YOU feel about the statement.

	I STRONGLY AGREE	I TEND TO AGREE	I NEITHER AGREE NOR DISAGREE	I TEND TO DISAGREE	I STRONGLY DISAGREE
1. A good scientist aims to make objective observations.					
2. Doing regular practical work enables pupils to improve their observational skills.					
3. Scientific knowledge is objective and value free.					
4. There is a set pattern for scientific procedure: guesswork and intuition play no part.					

5. Inevitably all observation is influenced by what the observer already knows.					
6. Valid scientific theories can only be formulated on the basis of sufficient observation.					
7. The validity of an observational statement is dependent on the opinions and expectations of the observer.					
8. Practical assessments should always include assessment of scientific observation.					
9. Inevitably observation produces subjective data.					
10. Scientific facts are merely interpretations.					
11. The method of science consists of a sequence of processes: observation --> data collection --> classification --> inference --> hypothesis.					
12. Pupils observe things in terms of what they already know.					
13. The process of scientific discovery often involves an ability to look at things in ways which are not commonly accepted.					
14. Intuition plays an important role in scientific discovery.					
15. Science is the ideal of knowledge in that it is a set of statements which are objective; i.e. their substance is determined entirely from observation.					
16. Scientists rigorously attempt to eliminate human perspective from our picture of the world.					
17. Insofar as a theory cannot be tested by experience it ought to be revised so that its predictions are restricted to observable phenomena.					
18. Legitimate scientific ideas sometimes come from dreams and hunches.					
19. Because of the validity of the scientific method, knowledge obtained by its application is determined more by nature itself than by the choices the scientists make.					
20. The process of scientific discovery often involves the purposeful discarding of accepted theory.					

	I STRONGLY AGREE	I TEND TO AGREE	I NEITHER AGREE NOR DISAGREE	I TEND TO DISAGREE	I STRONGLY DISAGREE
21. The purpose of science is to establish intellectual control over experience in terms of precise laws which can be formally set out and empirically tested.					
22. It is not unusual for scientists to get ideas from seemingly unrelated scientific and non-scientific sources.					
23. The best way to prepare to become a scientist is to master the scientific body of knowledge available in the finest texts.					
24. Non-sequential thinking, i.e. taking conceptual leaps, is characteristic of many scientists.					
25. Scientists integrate many processes concurrently.					
26. Most scientists believe nature strictly obeys laws					
27. The results that pupils get from their experiments are as valid as anybody else's.					
28. Science facts are what scientists agree that they are.					
29. The object of scientific activity is to reveal reality.					
30. Scientists have no idea of the outcome of an experiment before they do it.					
31. Scientific theories are valid if they work.					
32. Science proceeds by drawing generalisable conclusions (which later become theories) from available data.					
33. There is such a thing as a true scientific theory.					
34. Scientific theories describe a real external world which is independent of human perception.					

	I STRONGLY AGREE	I TEND TO AGREE	I NEITHER AGREE NOR DISAGREE	I TEND TO DISAGREE	I STRONGLY DISAGREE
35. Scientific theories have changed over time simply because experimental techniques have improved.					
36. In practice, choices between competing theories are made purely on the basis of experimental results.					
37. Scientific theories are as much a result of imagination and intuition as inference from experimental results.					
38. Scientific knowledge is different from other kinds of knowledge in that it has a higher status.					
39. All scientific experiments and observations are determined by existing theories.					

References:

Questions 13 - 26 adapted from: Implications of Teachers' Beliefs about the Nature of Science: Comparison of the Beliefs of Scientists, Secondary Science Teachers, and Elementary Teachers by D Pomeroy in Science Education, (1993) 77(3) p 261-278).

Questions 27 - 39 adapted from: Your nature of science profile: an activity for science teachers by M Nott and J Wellington in School Science Review September 1993, 75 (270) p 109 -112.)

PART 3:

A number of terms are used to describe the Nature of Science. The pairs given below can be represented on a continuum. (In this case from -14 through to +14. Read the definitions given to each term by Nott and Wellington and then place a "X" on the continuum where you believe your position on the continuum should be with respect to the two terms.
EXAMPLE: If on the RELATIVIST/POSITIVIST continuum you believe that your ideas are closely aligned to the positivist perspective then you would respond by placing a "X" on the +9 or +10 or +11 etc. on the continuum.

3.1. RELATIVIST/POSITIVIST

RELATIVIST: You deny that things are true or false solely based on an independent reality. The 'truth' of a theory will depend on the norms and rationality of the social group considering it as well as the experimental techniques used to test it. Judgements as to the truth of scientific theories will vary from individual to individual and from one culture to another.

POSITIVIST: You believe strongly that scientific knowledge is more valid than other forms of knowledge The laws and theories generated by experiments are our descriptions of patterns we see in a real, external world.
To the positivist, science is the primary source of truth. Positivism recognises empirical facts of science. The scientist's job is to establish the objective relationships between the laws governing the facts and observables. Positivism rejects inquiry into underlying causes and ultimate origins.

Relativism <--- ---> Positivism

-14	-13	-12	-11	-10	-9	-8	-7	-6	-5	-4	-3	-2	-1	0	+1	+2	+3	+4	+5	+6	+7	+8	+9	+10	+11	+12	+13	+14

3.2. INDUCTIVISM/DEDUCTIVISM

INDUCTIVISM: You believe that the scientist's job is the interrogation of Nature. By observing many particular instances, one is able to infer from the particular to the general and then determine the underlying laws and theories.
According to inductivism, scientists generalize from a set of observations to a universal law 'inductively' Scientific knowledge is built by induction from a secure set of observations.

DEDUCTIVISM: You believe that scientists proceed by testing ideas produced by the logical consequence of current theories or of their bold imaginative ideas. According to deductivism (or hypothetico-deductivism) scientific reasoning consists of the forming of hypotheses which are not established by the empirical data but may suggest them. Science then proceeds by testing the observable consequences of these hypotheses, i.e. observations are directed or led by hypotheses - they are theory laden.

Inductivsm. <-- --> Deductivism

-14	-13	-12	-11	-10	-9	-8	-7	-6	-5	-4	-3	-2	-1	0	+1	+2	+3	+4	+5	+6	+7	+8	+9	+10	+11	+12	+13	+14

3.3. INSTRUMENTALISM/REALISM

INSTRUMENTALISM: You believe that scientific theories and ideas are fine if they work, that is they allow correct predictions to be made. They are instruments which we can use but they say nothing about an independent reality or their own truth.	REALISM: You believe that scientific theories are statements about a world that exists in space and time independent of the scientists' perceptions. Correct theories describe things which are really there, independent of the scientist, eg atoms.

Instrumentalism <------------------------------------ --> Realism

-14	-13	-12	-11	-10	-9	-8	-7	-6	-5	-4	-3	-2	-1	0	+1	+2	+3	+4	+5	+6	+7	+8	+9	+10	+11	+12	+13	+14

PART 4:

The following question deals with practical work and is usually asked in a standard eight THEORY EXAMINATION.

> QUESTION: Some zinc powder is added to a concentrated solution of copper sulphate. DESCRIBE IN DETAIL WHAT YOU OBSERVE.

Read both "typical" pupil answers, (in the boxes below), before responding.

> PUPIL A:
> Zinc is more reactive than copper and therefore the copper ion was displaced from the copper sulphate (the copper ion was reduced to copper atoms). Copper was formed. The zinc atoms were oxidised to zinc ions and zinc sulphate was formed. The reaction was an exothermic one.

Place a "X" in the appropriate box:
Would you give this pupil:

MORE THAN 80% DISTINCTION	BETWEEN 60% AND 80%	BETWEEN 40% AND 60%	LESS THAN 40% FAIL

Explain why you gave the pupil this assessment.

....

....

PUPIL B
A brown precipitate was formed. The blue colour of the solution went clead. The temperature of the solution increased.

Place a "X" in the appropriate box:
Would you give this pupil:

MORE THAN 80% DISTINCTION	BETWEEN 60% AND 80%	BETWEEN 40% AND 60%	LESS THAN 40% FAIL

Explain why you gave the pupil this assessment.

....

....

....

PART 5:

If you think that your views on the Nature of Science have changed during the past year then please comment on how and why you think they have changed.

....

....

....

THANK YOU FOR YOUR TIME.

Appendix 3.
Number of respondents to Version 1993.

		Number posted	Number returned	Percentage returned
A. 1992/3 paid-up members of the South African Teachers of Physical Science (SAATPS).		425	145	34,12%
B. Non-members of SAATPS living in the Port Elizabeth area.		28	13	46,43%
	TOTALS	453	158	34,88%

Appendix 4.
Number of respondents to all Versions.

	Q'naire version	Number handed out	Number posted	Number returned	Percentage returned
A.1992/3 paid-up members of the South African Association of Teachers of Physical Science. (SAATPS).	1993		425	145	34,12%
B.Non-members of SAATPS living in the Port Elizabeth area.	1993		28	13	46,43%
C.Ripple Programme Teachers.	1994a	15		12	80,00%
D.SEP Density Workshop.	1994b	30		28	93,33%
E.Teachers' Centre Acid/Base workshop.	1994c	7		7	100,00%
F.1993 Science Convention delegates (non-members).	1994c		20	7	35,00%
G.Teachers' Centre Observation workshop.	1994c	12		9	75,00%
H. UPE HDE students.	1994c	6		4	66,66%
TOTAL (posted)			473	165	34,88%
TOTAL (handed out).		70		60	85,71%
TOTALS		543		225	41,44%

One response Number 163 was duplicated.

Appendix 5A.
Questionnaire Version 1993: Number of respondents per department per region.

	NATAL	TVL	OFS	CAPE	NAMIBIA	UNKNOWN	TOTAL
CAPE EDUCATION DEPT.	-	-	-	42	-	-	42
NATAL EDUCATION DEPT.	11	-	-	-	-	-	11
TRANSVAAL EDUCATION DEPT.	-	33	-	-	-	-	33
O. F. S. EDUCATION DEPT.	-	-	10	-	-	-	10
PRIVATE SCHOOLS	5	13	-	6	1	-	25
DEPT. OF EDUCATION & TRAINING.	1	1	-	3	-	-	5
HOUSE OF REPRESENTATIVES	-	-	-	4	-	-	4
HOUSE OF DELEGATES	7	1	-	1	-	-	9
UNIVERSITY AND COLLEGES OF ED.	4	4	-	8	-	-	16
INDUSTRY	-	1	-	-	-	-	1
UNKNOWN	-	1	-	-	-	1	2
STUDENTS (PRESERVICE)	-	-	-	-	-	-	0
TOTALS	28	54	10	64	1	1	158

Appendix 5B.
Questionnaire versions 1994a,b & c: Number of respondents per department per region.

	NATAL	TVL	OFS	CAPE	NAMIBIA	UNKNOWN	TOTAL
CAPE EDUCATION DEPT.	-	-	-	14	-	-	14
NATAL EDUCATION DEPT.	-	-	-	-	-	-	0
TRANSVAAL EDUCATION DEPT.	-	1	-	-	-	-	1
O. F. S. EDUCATION DEPT.	-	-	-	-	-	-	0
PRIVATE SCHOOLS	-	-	-	2	-	-	2
DEPT. OF EDUCATION & TRAINING.	-	5	-	36	-	-	41
HOUSE OF REPRESENTATIVES	-	-	-	-	-	-	0
HOUSE OF DELEGATES	-	-	-	4	-	-	4
UNIVERSITY AND COLLEGES OF ED.	1	-	-	-	-	-	1
INDUSTRY	-	-	-	-	-	-	0
UNKNOWN	-	-	-	-	-	-	0
STUDENTS (PRESERVICE)	-	-	-	4	-	-	4
TOTALS	1	6	0	60	0	0	67

Appendix 5C.
Total number of respondents per department per region who completed a questionnaire. (1993, 1994a, 1994b, and 1994c).

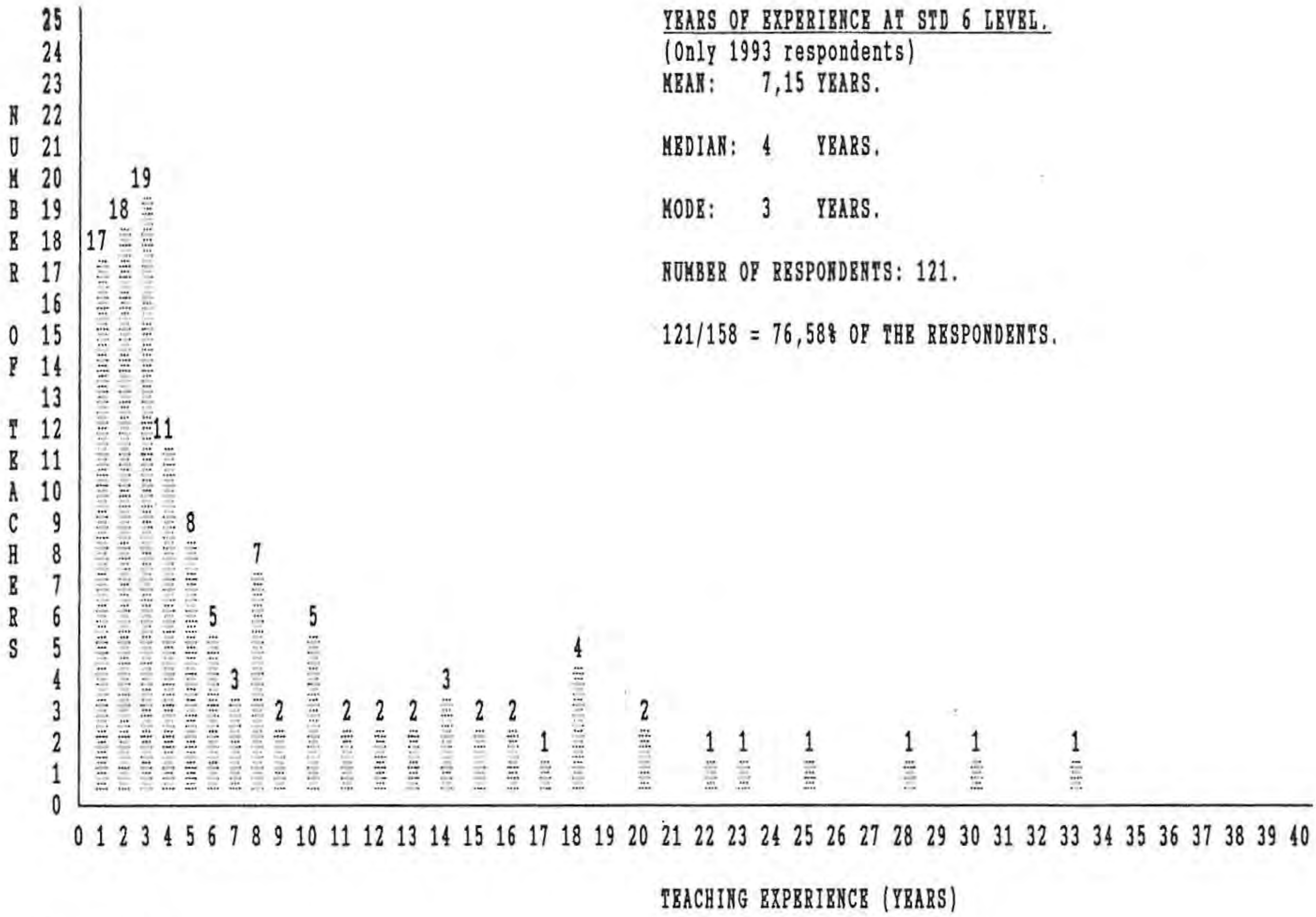
	NATAL	TVL	OFS	CAPE	NAMIBIA	UNKNOWN	TOTAL
CAPE EDUCATION DEPT.	–	–	–	56	–	–	56
NATAL EDUCATION DEPT.	11	–	–	–	–	–	11
TRANSVAAL EDUCATION DEPT.	–	34	–	–	–	–	34
O. F. S. EDUCATION DEPT.	–	–	10	–	–	–	10
PRIVATE SCHOOLS	5	13	–	8	1	–	27
DEPT. OF EDUCATION & TRAINING.	1	6	–	39	–	–	46
HOUSE OF REPRESENTATIVES	–	–	–	4	–	–	4
HOUSE OF DELEGATES	7	1	–	5	–	–	13
UNIVERSITY AND COLLEGES OF ED.	5	4	–	8	–	–	17
INDUSTRY	–	1	–	–	–	–	1
UNKNOWN	–	1	–	–	–	1	2
STUDENTS (PRESERVICE)	–	–	–	4	–	–	4
TOTALS	29	60	10	124	1	1	225

One Cape HOD respondent was duplicated.

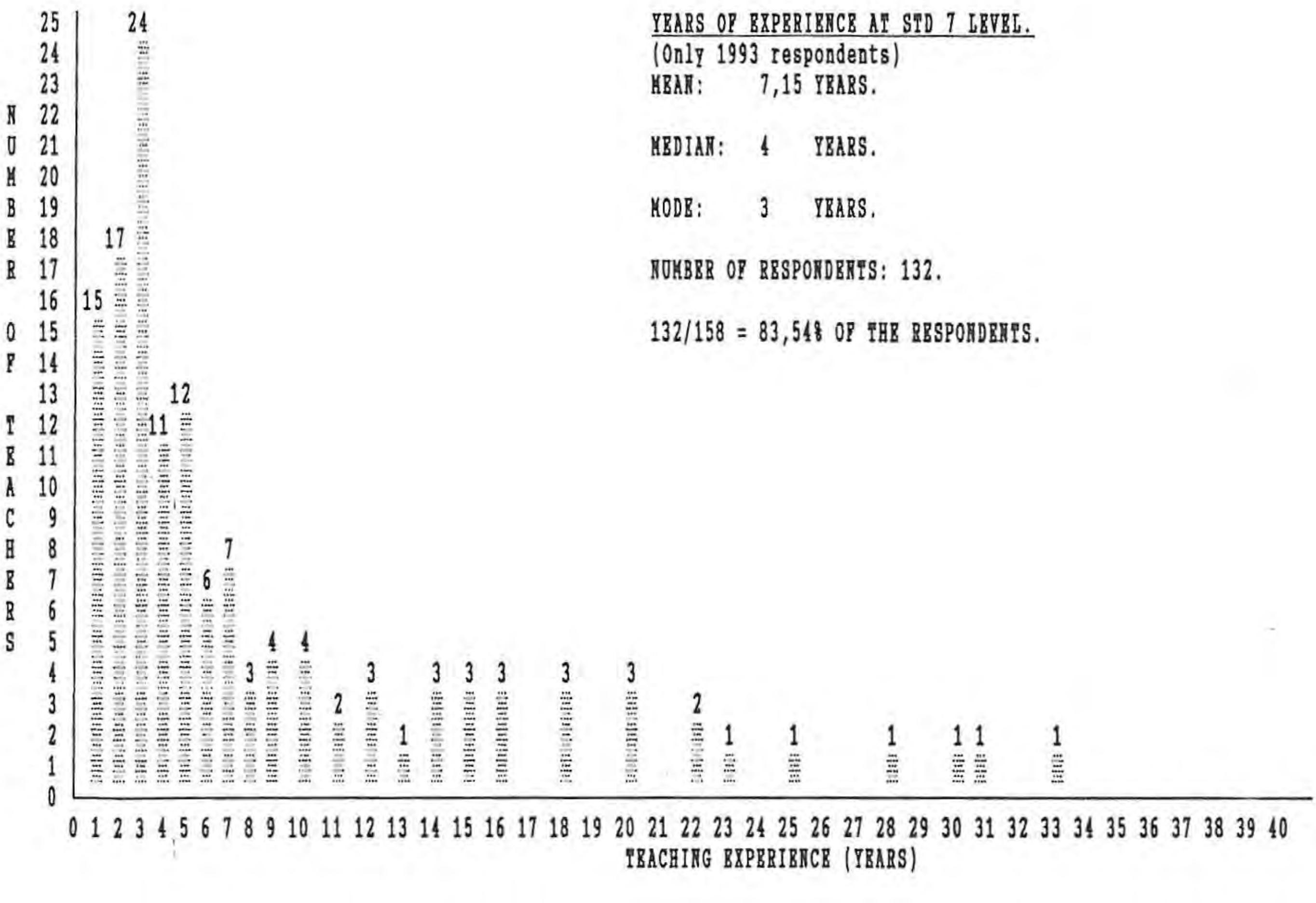
Appendix 5D.
Percentage change in representation from 1993 to 1994.

	Percentage of 1993 version 158 respondents	Percentage of all versions 225 respondents	Percentage change.
CAPE EDUCATION DEPT.	26,58% (42)	24,89% (56)	-1,69%
NATAL EDUCATION DEPT.	6,96% (11)	4,89% (11)	-2,07%
TRANSVAAL EDUCATION DEPT.	20,89% (33)	15,11% (34)	-5,78%
O. F. S. EDUCATION DEPT.	6,33% (10)	4,44% (10)	-1,89%
PRIVATE SCHOOLS	15,82% (25)	12,00% (27)	-3,82%
DEPT. OF EDUCATION & TRAINING.	3,16% (5)	20,44% (46)	+17,28%
HOUSE OF REPRESENTATIVES	2,53% (4)	1,78% (4)	-0,75%
HOUSE OF DELEGATES	5,70% (9)	5,78% (13)	+0,08%
UNIVERSITY AND COLLEGES OF ED.	10,12% (16)	7,56% (17)	-2,56%
INDUSTRY	0.63% (1)	0,44% (1)	-0,19%
UNKNOWN	1,27% (2)	0,89% (2)	-0,38%
STUDENTS (PRESERVICE)	0,00% (0)	1,78% (4)	+1,78%

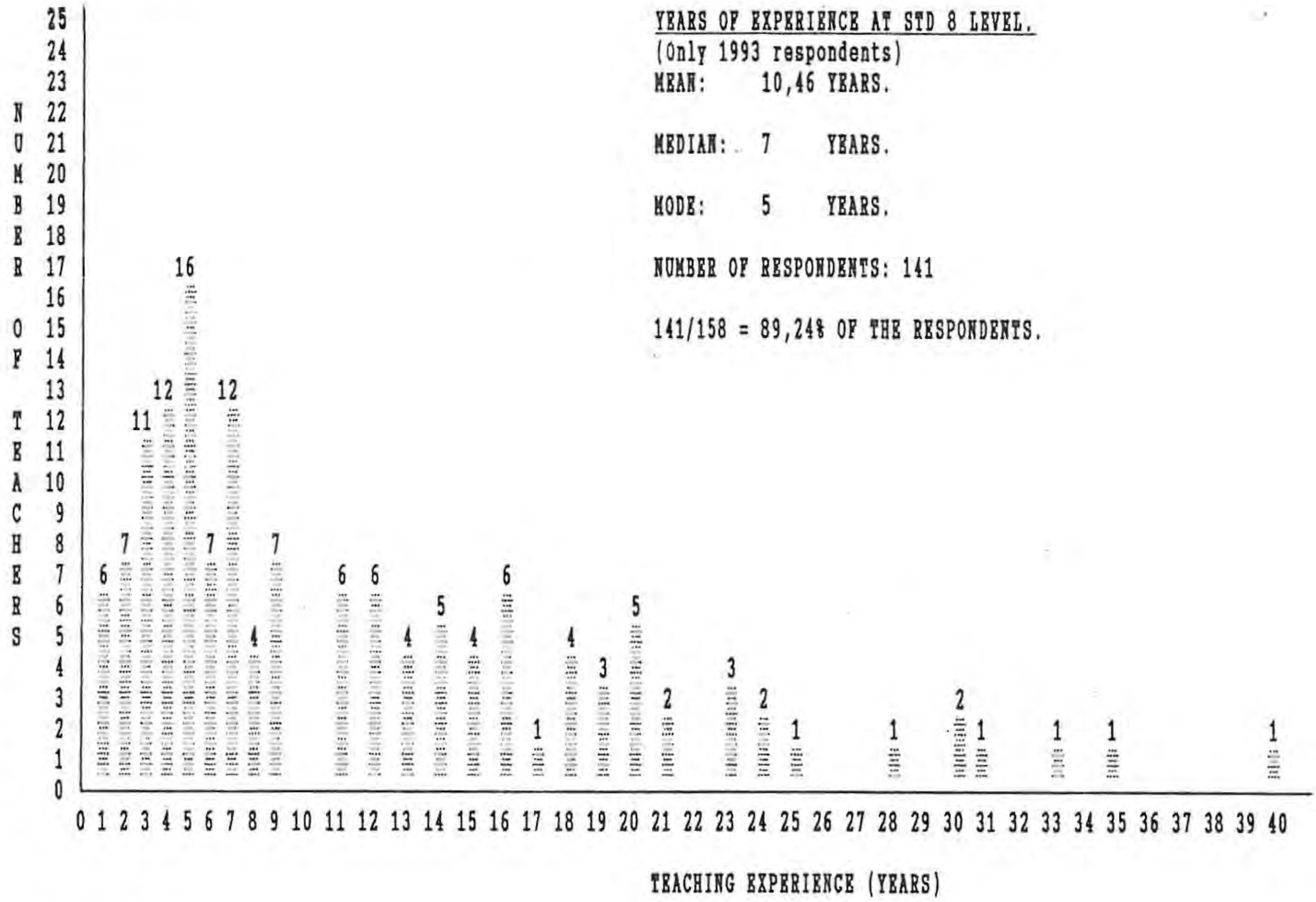
Appendix 6A.



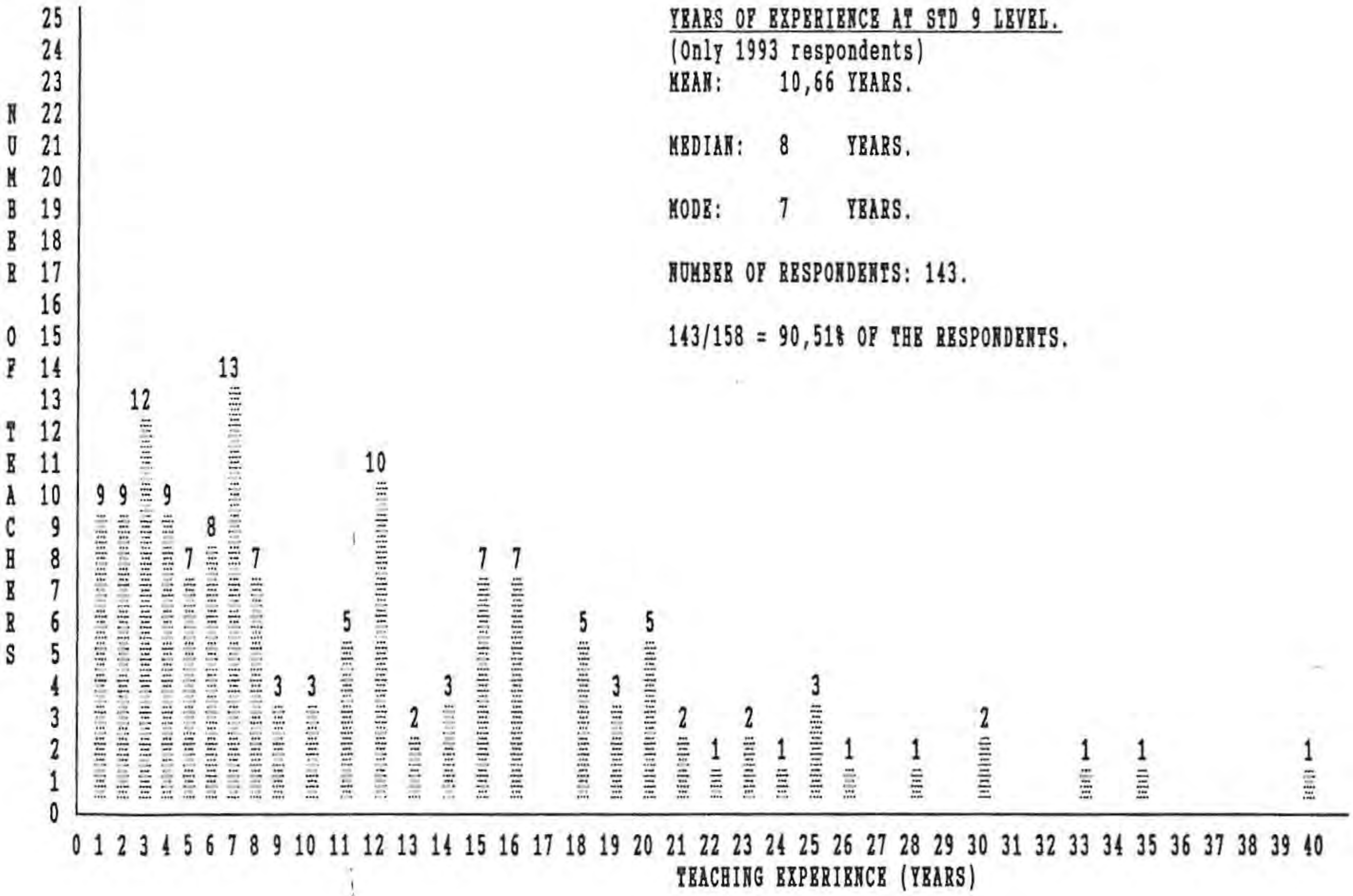
Appendix 6B.



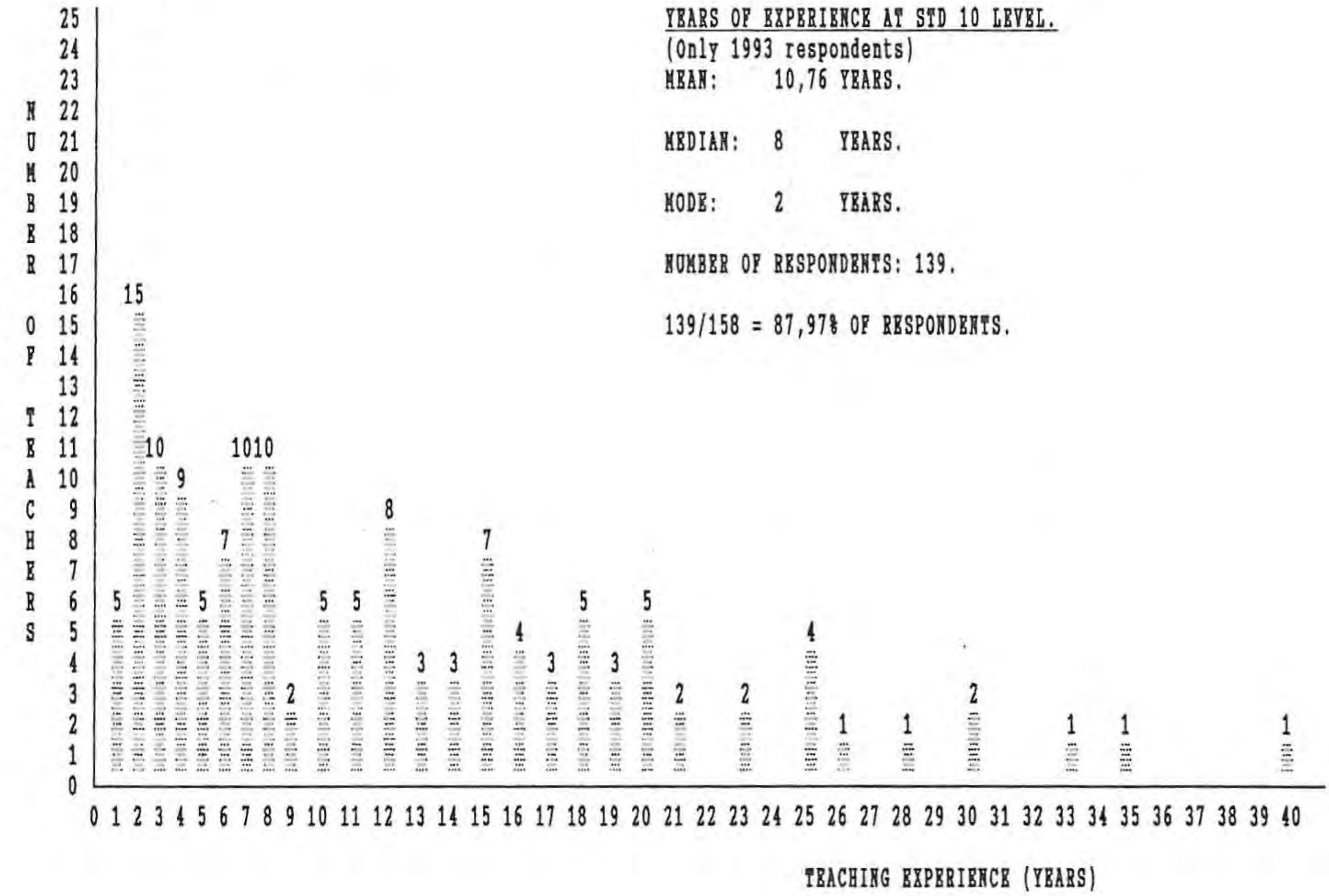
Appendix 6C.



Appendix 6D.

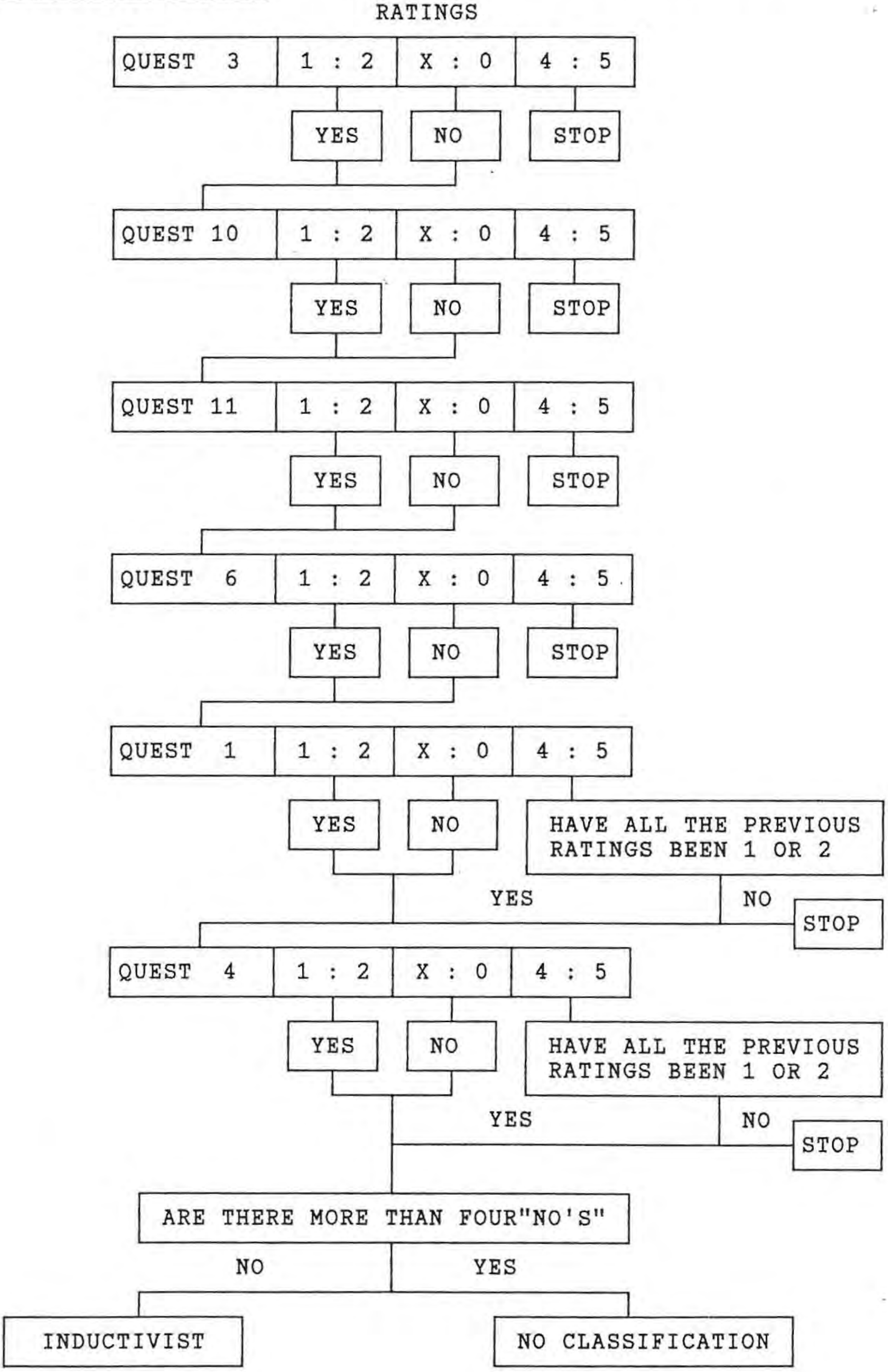


Appendix 6E.


YEARS OF EXPERIENCE AT STD 10 LEVEL.
(Only 1993 respondents)
MEAN: 10,76 YEARS.
MEDIAN: 8 YEARS.
MODE: 2 YEARS.
NUMBER OF RESPONDENTS: 139.
139/158 = 87,97% OF RESPONDENTS.
NUMBER OF TEACHERS
TEACHING EXPERIENCE (YEARS)

Appendix 7.

Method 1 for classifying respondents who are predominantly inductively orientated.



Appendix 8.

The rating scale for determining the respondent's position on the continuum.

+1 & +2 indicate a constructivist view.

-1 & -2 indicate an inductivist view.

Question 1 was considered problematic, so it was omitted.

	I STRONGLY AGREE	I TEND TO AGREE	I NEITHER AGREE NOR DISAGREE	I TEND TO DISAGREE	I STRONGLY DISAGREE	
1. A good scientist aims to make objective observations.						Omitted
2. Doing regular practical work enables pupils to improve their observational skills.						Neutral
3. Scientific knowledge is objective and value-free.	-2	-1		+1	+2	Inductivst/ Constructivist
4. There is a set pattern for scientific procedure: guesswork and intuition play no part.	-2	-1				Inductivist
5. Inevitably all observation is influenced by what the observer already knows.	+2	+1		-1	-2	Constructivist/ Inductivist
6. Valid scientific theories can only be formulated on the basis of sufficient observation.	-2	-1				Inductivist
7. The validity of observational statements are dependent on the opinions and expectations of the observer.	+2	+1		-1	-2	Constructivist/ Inductivist
8. Practical assessments should always include assessment of scientific observation.						Neutral
9. Inevitably observation produces subjective data.	+2	+1				Constructivist
10. Scientific facts are merely interpretations.	+2	+1		-1	-2	Constructivist/ Inductivist
11. The method of science consists of a sequence of processes: observation --> data collection --> classification --> inference --> hypothesis.	-2	-1		+1	+2	Inductivist/ Constructivist
12. Pupils observe things in terms of what they already know.	+2	+1				Constructivist

Appendix 9.

Allocation of ratings for Pomeroy's questions on the tradition and non-traditional views on the nature of science education.

	I STRONGLY AGREE	I TEND TO AGREE	I NEITHER AGREE NOR DISAGREE	I TEND TO DISAGREE	I STRONGLY DISAGREE	T OR NT
13. The process of scientific discovery often involves an ability to look at things in ways which are not commonly accepted.	+2	+1		-1	-2	NT
14. Intuition plays an important role in scientific discovery.	+2	+1		-1	-2	NT
15. Science is the ideal of knowledge in that it is a set of statements which are objective; i.e. their substance is determined entirely from observation.	-2	-1		+1	+2	T
16. Scientists rigorously attempt to eliminate human perspective from our picture of the world.	-2	-1		+1	+2	T
17. Insofar as a theory cannot be tested by experience it ought to be revised so that its predictions are restricted to observable phenomena.	-2	-1		+1	+2	T
18. Legitimate scientific ideas sometimes come from dreams and hunches.	+2	+1		-1	-2	NT
19. Because of the validity of scientific method, knowledge obtained by its application is determined more by nature itself than by the choices the scientists make.	-2	-1		+1	+2	T
20. The process of scientific discovery often involves purposeful discard of accepted theory.	+2	+1		-1	-2	NT
21 The purpose of science is to establish intellectual control over experience in terms of precise laws which can be formally set out and empirically tested.	-2	-1		+1	+2	T
22. It is not unusual for scientists to get ideas from seemingly unrelated scientific and non-scientific sources.	+2	+1		-1	-2	NT
23. The best way to prepare to become a scientist is master the scientific body of knowledge available in the finest texts.	-2	-1		+1	+2	T
24. Non-sequential thinking, i.e. taking conceptual leaps, is characteristics of many scientists.	+2	+1		-1	-2	NT
25. Scientists integrate many processes concurrently.	+2	+1		-1	-2	NT
26. Most scientists believe nature strictly obeys laws	-2	-1		+1	+2	T

Key: T indicates a traditional view on the nature of science.
NT indicates a non-traditional view on the narure of science.
The raw scores divided by 2 gives the position on the continuum.

Appendix 10.
<u>Allocation of ratings for Nott & Wellington's questions on the nature of science.</u>

	I STRONGLY AGREE	I TEND TO AGREE	I NEITHER AGREE NOR DISAGREE	I TEND TO DISAGREE	I STRONGLY DISAGREE	RP ID IR
27. The results that pupils get from their experiments are as valid as anybody else's.	+2	+1		-1	-2	RP
28. Science facts are what scientists agree that they are.	+2	+1		-1	-2	RP
29. The object of scientific activity is to reveal reality.	-2	-1		+1	+2	IR
30. Scientists have no idea of the outcome of an experiment before they do it.	-2	-1		+1	+2	ID
31. Scientific theories are valid if they work.	+2	+1		-1	-2	IR
32. Science proceeds by drawing generalisable conclusions (which later become theories) from available data.	-2	-1		+1	+2	ID
33. There is such a thing as a true scientific theory.	-2	-1		+1	+2	RP IR
34. Scientific theories describe a real external world which is independent of human perception.	-2	-1		+1	+2	RP IR
35. Scientific theories have changed over time simply because experimental techniques have improved.	-2	-1		+1	+2	RP
36. In practice, choices between competing theories are made purely on the basis of experimental results.	-2	-1		+1	+2	RP
37. Scientific theories are as much a result of imagination and intuition as inference from experimental results.	+2	+1		-1	-2	ID
38. Scientific knowledge is different from other kinds of knowledge in that it has a higher status.	-2	-1		+1	+2	RP
39. All scientific experiments and observations are determined by existing theories.	+2	+2		-1	-2	ID

Key: Questions labelled RP refer to Relativist/Positivist continuum
ID refer to Inductivist/Deductivist continuum.
IR refer to Instrumentalist/Realist continum.

How to calculate total on continuum: RP is the total obtained for the 7 "RP" questions.
ID and IR uses the formula x/8 X 14 where x is the raw score from the questions. If the answer is a fraction less or equal to 0,5 round down and greater than 0,5 round up.

Appendix 11.

Table of teachers' positions on a continuum ranging from strongly positivist (-14) through to strongly post-positivist (+14)

POSITIVIST POST-POSITIVIST

		-14	-13	-12	-11	-10	-9	-8	-7	-6	-5	-4	-3	-2	-1	0	+1	+2	+3	+4	+5	+6	+7	+8	+9	+10	+11	+12	+13	+14
a	d																													
b	e																													
c	f																													
	g																													
	h																													

Key:

a. Serial number of respondent.

b. Classification according to 1993 methods for questionnaire Version 1993.

c. Classification according to 1993 methods for questionnaire Version 1994c.

d. Inductivist/Constructivist Continuum. The method used is described in appendix 8. "IC3" is the position using data collected from questionnaire Version 1993 and "IC4" from Version 1994c of the questionnaire.

e. Positivist/Relativist Continuum. "RP" represents the position on the continuum according to the method described in appendix 10. "X" represents the position where the respondent thought their views could be placed on the continuum.

f. Inductivist/Deductivist Continuum. "ID" represents the position on the continuum according to the method described in appendix 10. "X" represents the position where the respondent thought their views could be placed on the continuum.

g. Realist/Instrumentalist Continuum. "IR" represents the position on the continuum according to the method described in Appendix 10. "X" represents the position where the respondent thought their views could be placed on the continuum.

h. Traditional/Non-Traditional Continuum. "T" indicates the degree of traditional approach that the respondent has towards Science Education and"NT" indicates the degree of non-traditional approach that the respondent has towards Science Education (appendix 9).

		-14	-13	-12	-11	-10	-9	-8	-7	-6	-5	-4	-3	-2	-1	0	+1	+2	+3	+4	+5	+6	+7	+8	+9	+10	+11	+12	+13	+14
001	d								IC3						IC4															
93I	e										X						RP													
94I	f												ID													X				
	g								X					IR																
	h													T					NT											

002	d													IC3	IC4															
93I	e											X						RP												
94I	f															ID											X			
	g			X																	IR									
	h													T								NT								

		-14	-13	-12	-11	-10	-9	-8	-7	-6	-5	-4	-3	-2	-1	0	+1	+2	+3	+4	+5	+6	+7	+8	+9	+10	+11	+12	+13	+14
003	d														IC3				IC4											
93-	e													X				RP												
94C	f															ID				X										
	g											X									IR									
	h												T					NT												
007	d																	C34												
93-	e														RP					X										
94-	f									X						ID														
	g																	IR						X						
	h													T							NT									
010	d																	IC3	IC4											
93C	e																			RP			X							
94C	f									X										ID										
	g																			IR			X							
	h														T							NT								
014	d															IC3	IC4													
93I	e						X												RP											
94-	f													ID										X						
	g				X													IR												
	h														T							NT								

		-14	-13	-12	-11	-10	-9	-8	-7	-6	-5	-4	-3	-2	-1	0	+1	+2	+3	+4	+5	+6	+7	+8	+9	+10	+11	+12	+13	+14
021	d															IC3		IC4												
93-	e												X						RP											
94-	f									X						ID														
	g								X					IR																
	h														T							NT								
022	d																								IC4				IC3	
93C	e																			RP								X		
94C	f																	ID										X		
	g																								IR			X		
	h														T									NT						
024	d													IC4				IC3												
93-	e								X				RP																	
94I	f											ID						X												
	g										IR			X																
	h											T										NT								
025	d															IC4				IC3										
93C	e											X		RP																
94I	f										ID											X								
	g						X											IR												
	h															T						NT								

		-14	-13	-12	-11	-10	-9	-8	-7	-6	-5	-4	-3	-2	-1	0	+1	+2	+3	+4	+5	+6	+7	+8	+9	+10	+11	+12	+13	+14
039	d								IC34																					
93I	e			X																										
94I	f																					X								
	g				X																									
	h	Questions 14 - 39 were omitted																												
041	d														IC3				IC4											
93-	e																	X	RP											
94-	f															ID		X												
	g												X				IR													
	h															T		NT												
044	d																									IC4	IC3			
93C	e																		RP			X								
94C	f															X							ID							
	g														X						IR									
	h													T								NT								
045	d														IC3			IC4												
93-	e									X				RP																
94-	f																	X			ID									
	g							X								IR														
	h													T							NT									

		-14	-13	-12	-11	-10	-9	-8	-7	-6	-5	-4	-3	-2	-1	0	+1	+2	+3	+4	+5	+6	+7	+8	+9	+10	+11	+12	+13	+14
046	d																					IC34								
93C	e																						X	RP						
94C	f															X		ID												
	g																	IR					X							
	h															T		NT												
047	d																			IC4				IC3						
93C	e																	RP			X									
94C	f															ID							X							
	g												IR										X							
	h														T									NT						
051	d															IC3	IC4													
93-	e														RP					X										
94C	f															X		ID												
	g										IR	X																		
	h															T			NT											
053	d												IC34																	
93I	e							X				RP																		
94-	f													ID		X														
	g									X			IR																	
	h													T								NT								

		-14	-13	-12	-11	-10	-9	-8	-7	-6	-5	-4	-3	-2	-1	0	+1	+2	+3	+4	+5	+6	+7	+8	+9	+10	+11	+12	+13	+14
058	d															IC4			IC3											
93-	e												X			RP														
94-	f												ID			X														
	g											X		IR																
	h														T						NT									
059	d													IC4		IC3														
93-	e													RP		X														
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063	d															IC4			IC3											
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066	d										IC3						IC4													
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	g				X													IR												
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		-14	-13	-12	-11	-10	-9	-8	-7	-6	-5	-4	-3	-2	-1	0	+1	+2	+3	+4	+5	+6	+7	+8	+9	+10	+11	+12	+13	+14
068	d																IC4	IC3												
93-	e																		RP					X						
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070	d					IC4								IC3																
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94I	f										ID						X													
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	h												T					NT												
073	d																		IC4				IC3							
93C	e													X			RP													
94-	f															ID							X							
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		-14	-13	-12	-11	-10	-9	-8	-7	-6	-5	-4	-3	-2	-1	0	+1	+2	+3	+4	+5	+6	+7	+8	+9	+10	+11	+12	+13	+14
076	d														IC4	IC3														
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078	d											IC4			IC3															
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94I	f								X			ID																		
	g					X						IR																		
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084	d																	IC3				IC4								
93-	e																		RP		X									
94C	f																	ID			X									
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086	d					IC3				IC4																				
93I	e					X																								
94I	f										ID																	X		
	g							X			IR																			
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		-14	-13	-12	-11	-10	-9	-8	-7	-6	-5	-4	-3	-2	-1	0	+1	+2	+3	+4	+5	+6	+7	+8	+9	+10	+11	+12	+13	+14
094	d												IC3	IC4																
93I	e					X										RP														
94I	f													ID									X							
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096	d																	IC4			IC3									
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	g																	IR	X											
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098	d																				IC3			IC4						
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94C	f																			ID					X					
	g																				IR	X								
	h														T							NT								
099	d																IC4			IC3										
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	g																								IR			X		
	h															T						NT								

		-14	-13	-12	-11	-10	-9	-8	-7	-6	-5	-4	-3	-2	-1	0	+1	+2	+3	+4	+5	+6	+7	+8	+9	+10	+11	+12	+13	+14
100	d																			IC3	IC4									
93C	e												X		RP															
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	g															X		IR												
	h													T							NT									
101	d																						IC3				IC4			
93C	e																					X				RP				
94C	f																						ID			X				
	g																	X		IR										
	h															T							NT							
102	d									IC3						IC4														
93I	e																			X	RP									
94-	f															X				ID										
	g																			IR	X									
	h															T										NT				
104	d															IC3								IC4						
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94C	f											ID																		
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		-14	-13	-12	-11	-10	-9	-8	-7	-6	-5	-4	-3	-2	-1	0	+1	+2	+3	+4	+5	+6	+7	+8	+9	+10	+11	+12	+13	+14
105	d															IC4				IC3										
93-	e												X		RP															
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	h													T					NT											
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93C	e															X		RP												
94C	f											X				ID														
	g											X						IR												
	h													T						NT										
115	d														IC3				IC4											
93-	e																	RP		X										
94C	f											X		ID																
	g											IR															X			
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118	d									IC3					IC4															
93I	e						X		RP																					
94I	f													ID							X									
	g				X						IR																			
	h													T					NT											

		-14	-13	-12	-11	-10	-9	-8	-7	-6	-5	-4	-3	-2	-1	0	+1	+2	+3	+4	+5	+6	+7	+8	+9	+10	+11	+12	+13	+14
168	d																IC4													
XXX	e											X						RP												
94C	f						X							ID																
	g										X							IR												
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169	d																		IC4											
XXX	e										X				RP															
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172	d															IC4														
XXX	e						X											RP												
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205	d														IC4															
XXX	e																RP					X								
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	g													IR						X										
	h														T							NT								

		-14	-13	-12	-11	-10	-9	-8	-7	-6	-5	-4	-3	-2	-1	0	+1	+2	+3	+4	+5	+6	+7	+8	+9	+10	+11	+12	+13	+14
207	d												IC4																	
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94C	f																						ID				X			
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	h														T								NT							
209	d																IC4													
XXX	e													RP		X														
94-	f											ID				X														
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210	d																				IC4									
XXX	e						X													RP										
94C	f													ID												X				
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	h												T								NT									

		-14	-13	-12	-11	-10	-9	-8	-7	-6	-5	-4	-3	-2	-1	0	+1	+2	+3	+4	+5	+6	+7	+8	+9	+10	+11	+12	+13	+14
211	d													IC4																
XXX	e																		RP											
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94I	f																	ID												
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94C	f													X		ID														
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	h														T								NT							
214	d																	IC4												
XXX	e															RP														
94-	f										ID																			
	g															IR														
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		-14	-13	-12	-11	-10	-9	-8	-7	-6	-5	-4	-3	-2	-1	0	+1	+2	+3	+4	+5	+6	+7	+8	+9	+10	+11	+12	+13	+14
215	d																			IC4										
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94C	f																			ID					X					
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216	d												IC4																	
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94I	f															ID			X											
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217	d																		IC4											
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94-	f							X								ID														
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	h													T					NT											
218	d																				IC4									
XXX	e																						X	RP						
94-	f															ID										X				
	g																	IR										X		
	h														T												NT			

		-14	-13	-12	-11	-10	-9	-8	-7	-6	-5	-4	-3	-2	-1	0	+1	+2	+3	+4	+5	+6	+7	+8	+9	+10	+11	+12	+13	+14
219	d				IC4																									
XXX	e									RP																		X		
94I	f															ID													X	
	g	IR		X																										
	h						T														NT									
220	d									IC4																				
XXX	e			X											RP															
94-	f																		ID							X				
	g								X									IR												
	h										T									NT										
221	d																											IC4		
XXX	e																					RP		X						
94C	f																											ID		X
	g																									X	IR			
	h															T								NT						
222	d												IC4																	
XXX	e			X								RP																		
94-	f		X																	ID										
	g	X									IR																			
	h									T									NT											

		-14	-13	-12	-11	-10	-9	-8	-7	-6	-5	-4	-3	-2	-1	0	+1	+2	+3	+4	+5	+6	+7	+8	+9	+10	+11	+12	+13	+14
223	d																	IC4												
XXX	e						X				RP																			
94-	f																						ID			X				
	g					X					IR																			
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224	d															IC4														
XXX	e						X					RP																		
94-	f								X									ID												
	g						X							IR																
	h												T				NT													
225	d																						IC4							
XXX	e											RP																X		
94-	f																	ID												
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Appendix 12.

Pearson r correlation coefficients comparing the responses to Version 1993 Part 5 and Version 1994c Part 2 questions 1-12 of each respondent who responded to the questionnaire in 1993 and 1994.

REFERENCE	PEARSON r	REFERENCE	PEARSON r
001	0,59	068	0,63
002	0,77	070	0,75
003	0,70	073	0,81
005	0,77	074	0,71
007	0,88	076	0,89
010	0,75	078	0,76
014	0,63	080	0,72
021	0,19##	084	0,87
022	0,72	086	0,77
024	0,68	087	0,75
025	0,40	094	0,70
039	0,92	096	0,81
041	0,57	098	0,21##
044	0,90	099	0,71
045	0,73##	100	0,36
046	0,89	101	0,80
047	0,78	102	0,43
051	-0,24##	104	0,21
053	0,70	105	0,44
058	0,83	114	0,29
059	0,65	115	0,44
063	0,74	118	0,61
066	-0,08	138	0,38
		Average	0,62 σ=0,25

Number: 46 Median: 0,71

If the respondents who claimed that their views had changed during the previous year were excluded, then the results became:
Mean (Average): 0,66 σ = 0,21. Number: 42. Median: 0,72

Respondents who claimed that their views had changed:

021: Claimed a change of views because of a more mature approach to science education.
045: Was now more concerned about the nature of science.
051: Views had changed as a result of changing schools.
098: Views had changed as a result of starting an MEd at Leeds University.

104: Had major criticisms of the whole questionnaire.

Appendix 13.

Rating scale to enable different pairs of questions to be compared.

The ratings are such that 1 indicates and inductivist approach to the nature of science and a 5 indicates a more constructivist approach.
These ratings were used to carry out Pearson r correlations on the pairs of questions.

Question 3 Question 28	1 5	2 4	3 3	4 2	5 1
Question 10 Question 28	5 5	4 4	3 3	2 2	1 1
Question 4 Question 11	1 1	2 2	3 3	4 4	5 5
Question 9 Question 15	5 1	4 2	3 3	2 4	1 5

Appendix 14.
Responses to Version 1993 Part 4A.

Is practical laboratory science work essential for effective science learning? Comment.

The number of useful responses: 142

YES	132	92,96%
NO	10	7,04%

Commments:

YES: (132)

Respondents who felt that practical work was essential to support the theory, or essential for promoting understanding and concept development or that pupils had to "do" to "learn".	43,94% (58)
Respondents who simply answered "yes" or added that doing practical work was "important, essential, vital, crucial".	25,00% (33)
Other comments included: For the development of skills and processes. Important to do but not essential. For motivation. Only if well structured and directed. Only with 'good' or senior pupils Creates the correct attitude in pupils. Promotes further study. Other reasons.	 (14) 10,61% (5) (4) (4) (2) (2) (2) (8)

NO: (10)

A good demonstrations is as good or better. Not essential but can be used for motivation. Science can be learnt without practical work. Not with the current examination system.	(4) (3) (2) (1)

Appendix 15.
Form that assessment takes.
(Only for respondents who say that they actually assess practical work)

	STD 6	STD 7	STD 8	STD 9	STD 10	TOTALS
FORMATIVE *(only)	36,96% (17)	39,62% (21)	44,74% (34)	38,75% (31)	38,09% (24)	39,93% (127)
SUMMATIVE $(only	41,30% (19)	28,30% (15)	32,89% (25)	35,00% (28)	39,68% (25)	35,22% (112)
FORMATIVE AND SUMMATIVE	17,39% (8)	26,42% (14)	19,74% (15)	21,25% (17)	17,46% (11)	20,44% (65)
NOT SPECIFIED	4,35% (2)	5,66% (3)	2,63% (2)	5,00% (4)	4,77% (3)	4,40%
TOTALS	46	53	76	80	63	318

* Formative assessment is defined here as being used by all those teachers who said that they assessed the practical worksheets of practicals done during the year. Usually a mark was allocated out of 10.

$ Summative assessment is defined here as taking the form of a practical examination given at the end of a course/term/semester/year. In many cases the form was that of a stations examination.

Appendix 16A.
Formative assessment.

All respondents who claim to assess in both a formative and a summative manner are added to those who only assess in a formative manner.

SURVEY	STD 6	STD 7	STD 8	STD 9	STD 10	TOTALS
MEIRING (1993)	20,66% 25 OUT OF 121	26,52% 35 OUT OF 132	34,75% 49 OUT OF 141	33,57% 48 OUT OF 143	25,18% 36 OUT OF 139	54,73% 370 OUT OF 676
DROST (1982:109)	45,99% 487 OUT OF 1 059	52,50% 536 OUT OF 1 021	48,81% 452 OUT OF 926	63,21% 500 OUT OF 791	40,36% 291 OUT OF 721	50,15% 2 366 OUT OF 4 518

Appendix 16B.
Summative assessment.
All respondents who claim to assess in both a formative and a summative manner are added to those who only assess in a summative manner.

SURVEY	STD 6	STD 7	STD 8	STD 9	STD 10	TOTALS
MEIRING (1993)	22,31% 27 OUT OF 121	21,97% 39 OUT OF 132	28,37% 40 OUT OF 141	31,47% 45 OUT OF 143	25,90% 36 OUT OF 139	26,18% 177 OUT OF 676
DROST (1982:115)	15,29% 169 OUT OF 1 105	15,61% 163 OUT OF 1 044	17,18% 150 OUT OF 873	27,19% 217 OUT OF 798	25,99% 190 OUT OF 731	19,53% 889 OUT OF 4 551

Appendix 17.
Additional categories added by some respondents to Part 3.

The number of respondents who added the "new" category is given first. The number in brackets is the serial number of the original six given categories that the respondent might have chosen instead of adding their own differently worded category.

The majority of respondents allocated less than 15% of their total mark to these new categories, or they simply noted that these additional categories could be included without allocating an assessment mark to them.

* Ability to apply new knowledge. 2 (1).
* Problem solving, designing an experiment to solve problem. 4 (1).
* Precision and care in practical work. 5 (2).
* Answering quest on procedure,error,precautions. 3 (5).
* Neatness in presentation. 3 (4).
* Cleaning up afterwards. 4 (1).
* Relevance & relation to larger sect of work. 2.
* Co-operation with others in a group. 2.
* Oral/written reporting of results. 2 (4).
* Creativity/innovation. 2 (1).

Appendix 18.
Responses to the parts of the questionnaires that dealt with the most important reason for doing practical work at school.

* Version 1993.
Number of useful responses: 144. Percentages were calculated using only respondents who chose one of the three reasons used in later versions of the questionnaire, therefore useful responses 139.

1.	To support or to understand the theory. Application of the theory.	58,27% (81)
2.	For the development of practical skills.	27,34% (38)
3.	To motivate by promoting excitement, fun and curiosity.	14,39% (20)
	Other responses:	
	Experiment is the interpreter of nature.	(2)
	Practical work is what scientists do.	(1)
	To promote self confidence.	(2)

* All 1994 Versions.
60 useful responses

1.	To support or to understand the theory. Application of the theory.	55,00% (33)
2.	For the development of practical skills.	8,33% (5)
3.	To motivate by promoting excitement, fun and curiosity.	36,67% (22)

* The results of all the respondents.
199 useful responses

1.	To support or to understand the theory. Application of the theory.	57,29% (114)
2.	For the development of practical skills.	21,61% (43)
3.	To motivate by promoting excitement, fun and curiosity.	21,10% (42)

Appendix 19.
Rank order from Tomlinson (1977:8) for the reasons for doing practical work.

Out of twenty possible aims the following were ranked in order of priority by both physicists and chemists.

1st To encourage accurate observation and description.

2nd To make phenomena more real through experience.

3rd To promote logical reasoning methods of thought and to develop a critical attitude.

Rankings for the aims

To verify facts and principles already taught.
Physicists 18 th.
Chemists 19 th.

To elucidate theoretical work as an aid to comprehension.
Physicists 6 th.
Chemists 13 th.

To develop specific manipulative skills.
Physicists 6 th.
Chemists 4 th.

To arouse and maintain interest.
Physicists 5 th.
Chemists 6 th.

Appendix 20A.

Analysis of the individual responses to Versions 1993 Part 5, 1994a Part 4, 1994b Part 3, and 1994c Part 2 questions 1-12 using the 1993 method of classification.

Notes: Ratings taken from table 4.4
"X" indicates no responses.

Key: A - Years experience 0 - 5 years a.
6 - 10 years b.
11 - 15 years c.
16 - 20 years d.
> 20 years e.

B - Identification number of respondent.
D - Application of method 1 (question numbers).
E - Classification as a result of method 1.
F - Application of method 2.
G - Classification as a result of method 2.
H - Application of method 3.
J - Classification as a result of method 3.
K - Overall classification.
L - Analysis of question number 6.
M - Serial number of the note(s) made from the questionnaire.

A	B	D										E	F			G	H				J	K	L	M
		1	3	4	5	6	7	9	10	11	12		3	10	T		@	$	§	#			#6	
b	001	1	2	2	2	2	2	0	2	2	0	I	I	I	4	I	I		I	NI	I	I	I I	1
e	002	1	2	0	4	2	2	0	2	2	5	I	I	I	4	I			I	SI	I	I	C I	
b	003	2	4	0	4	2	2	0	2	1	5		C	I	6				I	C			I I	
a	004	2	5	0	1	2	1	4	0	4	0		C		8					NI			I I	
a	005	1	0	0	0	1	1	0	4	1	X			C	7				I				I I	2
b	006	1	2	1	4	1	2	4	4	1	5		I	C	6		I			C			I I	
c	007	1	4	0	4	2	4	4	2	2	4		C	I	6			C		C	C		I I	
b	008	1	4	0	4	0	4	0	2	5	4		C	I	6				I	C			I I	
d	009	2	2	2	5	2	0	4	4	2	5		I	C	6		I			C			I I	
a	010	1	4	0	5	1	0	0	4	1	5	C	C	C	8	C			I	C		C	I I	
e	011	1	4	0	4	2	4	0	0	1	5	C	C		7				I	C			C I	
c	012	2	4	1	2	1	2	0	4	1	5		C	C	8	C	I	I	I		I		I I	
c	013	1	4	1	4	1	4	0	2	1	4		C	I	6		I		I	C	I		I I	
c	014	1	2	0	5	1	4	4	2	1	5	I	I	I	4	I		C		SI		I	I I	
a	015	1	2	2	4	2	5	4	5	1	4		I	C	7		I	C		C	Ç		C C	
b	016	1	2	2	5	2	4	4	0	2	5	I	I		5		I	C		C	C	I	I I	
a	017	2	0	0	4	2	2	0	2	4	4	I		I	5		C	I	I	C			I I	
a	018	2	2	0	4	1	2	4	2	1	4	I	I	I	4	I				SI		I	C I	
a	019	2	4	0	5	0	0	5	5	5	5	C	C	C	9	C	C			C	C	C	I I	3
a	020	1	1	0	5	2	4	4	2	2	4	I	I	I	3	I		C		SI		I	C I	

A	B	D										E	F			G	H				J	K	L	M
		1	3	4	5	6	7	9	10	11	12		3	10	T		@	$	§	#			#6	
c	021	1	2	0	4	1	4	4	2	2	5		I	I	4	I		C		SI			I I	
b	022	2	4	0	5	0	5	5	5	5	5	C	C	C	9	C	C	C		C	C	C	I I	
b	023	1	4	0	4	0	4	0	2	2	4		C	I	6				I	C			I I	
b	024	1	X	0	4	2	4	0	2	4	5			I			C		I	C	C		C I	
e	025	1	0	0	4	1	0	4	5	4	4	C		C	8		C			C	C	C	I I	4
a	026	1	4	0	4	1	0	0	2	2	5		C	I	6				I	C			I I	
b	027	2	0	0	2	0	2	4	2	2	4	I		I	5								I C	
c	028	1	2	0	2	0	2	0	2	2	4	I	I	I	4	I		I	I		I	I	I C	
d	029	1	1	2	2	1	2	0	2	1	0	I	I	I	3	I	I	I	I	I	I	I	I I	
c	030	1	2	0	2	0	2	0	0	2	4	I	I		5			I	I		I	I	I I	
b	031	1	5	0	2	1	2	0	2	1	0	I	C	I	7			I	I	I	I	I	- -	
c	032	1	X	0	5	2	2	0	4	2	5			C				I	I	C	I		I I	
e	033	2	0	0	4	2	4	0	0	2	4				6				I	C			I I	5
c	034	2	0	0	2	2	2	4	2	2	4	I		I	5								C I	
a	035	2	4	0	4	0	2	0	0	2	4		C		7			I	I	C	I		C I	
a	036	1	5	0	5	1	4	0	4	1	5	C	C	C	9	C			I	C		C	I I	
a	037	1	0	0	4	1	4	0	4	2	5			C	7				I	C			I I	6/7
a	038	1	5	0	5	1	4	4	2	2	5		C	I	7			C		C	C		C C	
c	039	1	1	0	2	2	2	0	1	2	4	I	I	I	2	I		I	I		I	I	C C	
b	040	1	1	0	2	1	4	0	4	1	0	I	I	C	5				I	I	I	I	- -	8

A	B	D										E	F			G	H				J	K	L	M
		1	3	4	5	6	7	9	10	11	12		3	10	T		@	$	§	#			#6	
b	041	2	0	0	0	2	0	0	0	0	0								I				I I	9
a	042	1	2	2	4	1	4	4	4	2	5		I	C	6		I	C		C	C		C I	
b	043	1	4	0	4	0	2	0	4	4	4	C	C	C	8	C	C	I	I	C	C	C	I I	10
d	044	2	5	0	5	0	4	5	5	0	5	C	C	C	10	C		C		C	C	C	C I	
c	045	1	2	0	4	2	0	0	0	2	5		I		5				I	C			I C	11
a	046	0	4	0	5	1	5	4	4	2	5	C	C	C	8	C		C	C	C	C	C	I I	
b	047	1	4	0	5	0	4	4	4	4	4	C	C	C	8	C	C	C		C	C	C	I I	
e	048	1	4	1	2	2	2	0	2	2	4	I	C	I	6		I	I	I		I	I	I I	12
a	049	2	0	0	4	2	2	4	2	2	4	I		I	5					C			I I	
e	050	1	1	2	4	1	4	4	2	2	4	I	I	I	3	I	I	C		SI	I	I	C I	
a	051	2	0	0	0	0	4	0	2	2	4			I	5				I				I I	13
c	052	0	2	1	4	2	4	0	2	2	5	I	I	I	4	I	I			SI	I	I	C I	
e	053	2	2	2	0	2	0	0	2	2	4	I	I	I	4	I	I		I		I	I	I I	14
b	054	1	5	0	5	2	0	4	4	2	5	C	C	C	9	C				C		C	I I	
d	055	2	0	0	4	0	2	0	2	4	4			I	5		C	I	I	C			I I	15
c	056	1	4	0	5	1	5	4	5	1	4	C	C	C	9	C		C		C	C	C	I I	
b	057	1	1	0	5	0	5	4	4	1	5		I	C	5			C		C	C		I I	
c	058	2	4	0	4	2	4	0	0	0	4		C		7				I	C			I I	16
b	059	2	0	0	4	1	4	0	2	2	5	I		I	5				I	C			I I	
e	060	1	0	2	0	1	2	0	1	1	4	I		I	4		I	I	I		I	I	I I	

A	B	D										E	F			G	H				J	K	L	M
		1	3	4	5	6	7	9	10	11	12		3	10	T		@	$	§	#			#6	
c	061	1	0	0	4	0	1	0	0	2	4							I	I	C	I		I I	17
a	062	1	5	0	4	2	2	5	5	0	5	C	C	C	10	C	C			C	C	C	I I	18
d	063	1	X	0	4	1	4	4	0	4	4		I		4			C		C	C		I I	19
a	064	1	4	0	4	2	2	0	2	0	4	I	C	I	6			I	I	C	I	I	I I	20
-	065	X	X	X	X	X	X	X	X	X	X												- -	XXXXX
c	066	1	4	0	4	1	1	0	2	1	5		C	I	6			I	I	C	I		I I	
c	067	1	1	0	4	2	2	0	2	2	4	I	I	I	3	I		I	I	SI	I	I	I I	
c	068	1	2	0	4	0	4	0	2	2	5		I	I	4	I			I	C			I I	
a	069	1	5	0	2	2	0	5	1	1	4		C	I	6								I I	
b	070	1	1	0	1	0	1	0	1	1	0	I	I	I	2	I		I	I	I	I	I	- -	
a	071	1	X	0	2	2	2	4	5	2	4			C	5		C				C		I I	
d	072	1	1	0	4	2	4	X	0	2	4	I	I		4				I	C			I I	21
a	073	1	4	0	5	2	4	0	4	4	5	C	C	C	8	C	C		I	C	C	C	I I	
c	074	2	X	0	4	2	4	0	4	2	5	C		C	7		C		I	C	C	C	I I	22
b	075	1	X	2	5	0	2	4	2	1	5	I		I	2		I			C			I I	23
c	076	1	4	0	5	1	4	0	2	1	4		C	I	6				I	C			I I	24
b	077	0	4	0	2	0	2	0	5	1	4		C	C	9	C	C	I					C C	25
e	078	1	2	0	4	1	4	0	4	1	4		I	C	6		C		I	C	C		I I	
a	079	2	2	1	4	1	4	5	5	1	5		I	C	7			C		C	C		I I	
a	080	1	0	2	5	2	0	0	4	2	5	C		C	7				I	C			I I	

A	B	D										E	F			G	H				J	K	L	M
		1	3	4	5	6	7	9	10	11	12		3	10	T		@	$	§	#			#6	
b	081	1	0	0	5	0	4	4	2	1	5	C		I	5			C		C	C	C	I I	26
d	082	1	2	0	4	0	4	0	2	2	4	I	C	I	6				I	C			I I	
b	083	1	0	2	4	2	4	0	2	2	4	I		I	5		I		I	C	I	I	C C	
b	084	2	4	0	5	2	4	0	2	2	4		C	I	6				I	C			I I	
a	085	1	2	0	4	1	4	0	4	2	4		I	C	6				I	C			I I	
d	086	1	1	2	0	1	1	0	1	1	4	I	I	I	2	I	I	I	I		I	I	I I	27
a	087	1	2	0	4	0	4	0	2	2	4	I	I	I	4	I			I	SI	I	I	I C	
d	088	1	4	0	5	2	4	4	4	1	5	C	C	C	8	C		C		C	C	C	I I	
c	089	1	2	0	5	1	2	0	5	1	0		I	C	7			I	I		I		I I	
b	090	2	4	0	4	0	4	X	2	0	4		C	I	6				I	C			I I	
b	091	2	2	2	4	2	4	4	4	2	4		I	C	6		I	C		C	C		I I	28
b	092	2	2	2	2	2	2	0	2	2	4	I	I	I	4	I	I	I	I		I	I	I I	
d	093	1	1	0	5	1	5	5	4	1	5		I	C	6			C		C	C		I C	
e	094	2	5	0	2	2	2	4	2	1	0	I	C	I	7					I	I	I	I I	29
a	095	2	2	0	4	2	4	0	4	2	4		I	C	6				I	C			C I	
c	096	1	5	0	5	2	4	0	2	4	4		C	I	7		C		I	C	C		I I	
a	097	2	4	0	4	2	2	0	2	4	0		C	I	7		C	I	I		I		C I	30
a	098	1	4	0	4	2	4	4	4	2	5	C	C	C	8	C		C		C	C	C	I I	31
d	099	1	4	0	5	1	4	0	2	4	5		C	I	6		C		I	C	C		I I	
d	100	1	4	2	4	1	4	5	5	2	5	C	C	C	9	C	I	C		C	C	C	I I	

A	B	D										E	F			G	H				J	K	L	M
		1	3	4	5	6	7	9	10	11	12		3	10	T		@	$	§	#			#6	
a	101	0	4	0	4	0	5	4	2	4	5	C	C	I	6		C	C	C	C	C	C	I I	32
e	102	1	2	0	0	1	2	5	1	1	0	I	I	I	3	I						I	I I	33
d	103	1	5	0	5	1	5	5	5	1	5	C	C	C	10	C		C		C	C	C	I I	
e	104	1	5	0	1	0	1	0	5	1	5	I	C	C	10	C		I	I		I	???	I I	34
d	105	2	0	0	4	0	4	0	4	0	4	C		C	7				I	C			I I	
d	106	X	X	X	X	X	X	X	X	X	X												- -	XXXXX
a	107	0	4	1	4	0	4	0	4	2	4	C	C	C	8	C	I			C		C	I I	
a	108	1	4	2	4	1	5	5	1	5	5		C	I	5			C		C	C		C C	
X	109	X	X	X	X	X	X	X	X	X	X												- -	XXXXX
X	110	X	X	X	X	X	X	X	X	X	X												- -	XXXXX
X	111	X	X	X	X	X	X	X	X	X	X												- -	XXXXX
c	112	1	2	0	4	2	0	0	2	2	4	I	I	I	4	I			I	SI	I	I	C I	
b	113	1	2	2	4	1	2	0	4	1	4	I	I	C	6		I	I	I	C	I	I	I I	35
d	114	X	5	0	5	X	4	5	5	4	5	C	C	C	10	C	C	C	C	C	C	C	I I	36
a	115	0	5	0	1	0	0	0	4	1	0		C	C	9	C				I	I		C C	37
a	116	1	2	2	4	1	5	4	4	1	5		I	C	6		I	C		C	C		C I	
c	117	1	0	1	5	1	5	5	5	1	5	C		C	6		I	C		C	C	C	I I	
d	118	1	2	0	2	2	1	0	2	2	4	I	I	I	4	I		I	I		I	I	I I	38
b	119	1	1	0	4	2	4	4	4	2	4		I	C	5			C		C	C		I I	39
b	120	1	X	1	1	1	1	0	1	1	0	I		I	1		I	I	I	I	I	I	I I	

A	B	D										E	F			G	H				J	K	L	M
		1	3	4	5	6	7	9	10	11	12		3	10	T		@	$	§	#			#6	
a	121	2	X	0	2	1	2	X	4	2	4			C	4			I	I		I		I I	
b	122	2	X	0	2	1	4	0	2	1	0	I		I	2				I	I	I	I	I I	
a	123	2	2	1	4	1	2	0	4	1	0	I	I	C	6		I	I	I		I	I	- I	40
c	124	1	1	2	2	0	2	0	4	2	4	I	I	C	5		I	I	I		I	I	I I	
c	125	X	X	0	4	2	X	X	X	X	X												I C	XXXXX
c	126	1	4	0	4	0	4	4	4	0	5	C	C	C	8	C		C		C	C	C	I I	
b	127	1	4	2	1	1	2	0	4	2	0		C	C	8	C	I	I	I	I	I		I I	41
c	128	2	4	0	5	0	4	4	0	2	5	C	C		7			C		C	C	C	I I	
e	129	1	5	0	4	0	0	0	1	0	0		C	I	6				I		I		I I	
a	130	0	4	2	4	2	4	4	4	2	4	C	C	C	8	C	I	C	C	C	C	C	C I	
a	131	2	0	0	2	0	0	0	2	2	4	I		I	5				I		I	I	I I	
c	132	2	4	0	4	0	4	0	4	2	5	C	C	C	8	C			I	C		C	I I	
b	133	1	4	0	4	1	4	4	2	2	4		C	I	6			C		C	C		C I	
e	134	1	4	0	4	0	4	0	2	2	4	I	C	I	6				I	C			I I	42
e	135	1	2	0	4	1	1	0	4	4	4	I	I	C	6		C	I	I	C			C C	43
a	136	1	2	0	2	2	4	5	1	X	0	I	I	I	3	I		C		I		I	I I	
a	137	0	5	0	5	0	4	0	0	5	4	C	C		8		C			C	C	C	I I	
c	138	1	2	0	4	2	4	0	4	1	5		I	C	6				I	C			- -	
b	139	1	5	0	5	0	1	0	2	5	5		C	I	7		C	I	I	C			I I	44
b	140	1	4	2	4	2	4	4	0	2	4	C	C		7		I	C		C	C	C	I I	

A	B	D										E	F			G	H				J	K	L	M
		1	3	4	5	6	7	9	10	11	12		3	10	T		@	$	§	#			#6	
b	141	1	0	0	5	0	4	5	5	1	5	C		C	8			C		C	C	C	I C	
c	142	1	2	0	4	1	1	0	1	1	5	I	I	I	3	I		I	I	SI	I	I	- I	
d	143	2	0	0	2	1	2	4	0	2	4	I			6								I I	
b	144	1	2	0	2	2	4	0	2	2	4	I	I	I	4	I			I		I	I	C C	
b	145	1	2	2	4	0	1	0	2	2	4	I	I	I	4	I	I	I	I	SI	I	I	I I	
e	146	1	5	0	5	0	5	0	1	4	4		C	I	6		C		I	C	C		I I	
b	147	1	2	2	4	1	2	0	1	2	4	I	I	I	3	I	I	I	I	SI	I	I	I I	45
a	148	1	4	2	4	1	2	0	X	4	4		C		4			I	I	C	I		C I	
c	149	1	0	0	2	2	4	4	2	2	4	I		I	2			C			C		I I	
e	150	2	5	0	5	0	4	0	0	5	5	C	C		5		C		I	C	C	C	I I	
a	151	1	0	0	4	2	4	0	2	1	4			I	2				I	C			I I	
XXX	152	2	4	0	0	0	2	0	2	4	0		C	I	6		C	I	I		I		I I	
d	153	1	2	0	4	1	4	0	5	5	4		I	C	7		C		I	C	C		I I	
b	154	1	X	0	2	1	1	X	1	2	4	I	C	I	6			I	I		I	I	C C	46
e	155	1	0	0	4	2	2	0	1	2	0	I		I	1			I	I		I	I	I I	47
a	156	1	4	0	4	2	0	0	2	2	4	I		I	1				I	C			I I	48
a	157	1	4	0	5	0	0	4	4	1	4	C	C	C	8	C				C	C	C	I I	
c	158	1	4	0	2	2	4	0	2	2	0		C	I	6				I	I	I		I I	
b	159	1	0	0	4	0	4	0	0	2	4	C			6				I	C				
e	160	X	1	X	2	0	4	X	X	1	0	I	I		1									

A	B	D											E		F				G		H					J		K	L	M
		1	3	4	5	6	7	9	10	11	12				3	10	T				@	$	§	#					#6	
a	181	1	2	0	1	2	1	0	1	2	0		I		I	I	3		I			I	I	I		I		I		
a	182	1	1	0	1	1	1	5	4	1	0				I	C	5							I						
b	183	1	2	1	2	1	5	0	0	1	0		I		I		2				I		I	I		I		I		
a	184	1	4	0	4	1	4	0	0	2	4		C		C		4						I	I		I				
b	185	1	2	0	5	0	5	0	1	1	5		I		I	I	3		I				I	C				I		
a	186	1	2	0	5	2	0	0	1	1	0		I		I	I	3		I				I			I		I		
a	187	2	2	0	2	1	4	5	1	2	0		I		I	I	3		I			C		I				I		
a	188	1	1	1	5	1	4	4	2	1	0		I		I	I	3		I		I	C						I		
?	189	1	4	0	1	2	2	0	2	1	4				C	I	6					I	I			I				
b	190	X	2	X	5	2	4	4	4	1	0				I	C	6					C				C				
a	191	1	4	0	2	0	4	4	2	2	4				C	I	6					C				C				
a	192	1	2	0	2	2	4	X	4	1	0				I	C	6							I		I				
a	193	1	2	1	2	2	1	0	4	2	0		I		I	C	6				I	I	I	I		I		I		
a	194	1	1	X	5	2	4	5	4	1	4				I	C	5					C		C		C				
a	195	1	1	0	5	2	4	4	1	2	4		I		I	I	2		I			C		C		C		I		
a	196	1	X	X	X	X	X	X	5	X	X					C	5													
a	197	2	2	2	0	2	0	4	0	2	4		I		I		2		I		I					I		I		
a	198	1	0	0	4	2	0	0	0	2	4		I				0						I	C						
a	199	1	2	2	5	1	4	4	4	1	5				I	C	6				I	C		C		C				
?	200	1	5	1	4	2	1	4	1	1	5				C	I	6				I			C						

A	B	D										E	F			G	H				J	K	L	M
		1	3	4	5	6	7	9	10	11	12		3	10	T		@	$	§	#			#6	
a	201	1	2	2	5	1	4	5	4	2	X		I	C	6		I	C						
a	202	1	2	1	1	2	1	0	5	1	0	I	I	C	7		I	I	I	I	I	I		
a	203	0	5	2	5	2	5	5	5	1	5	C	C	C	10	C	I	C	C	C	C	C		
0	204	2	4	0	2	1	1	4	2	2	0		C	I	6					I	I			
0	205	2	2	0	4	2	2	0	4	2	4		I	C	6			I	I	C	I			
0	206	2	0	0	1	1	4	0	5	2	5			C	5				I		I			
c	207	1	0	0	5	1	1	4	1	1	5	I		I	1	I				NI	I	I		
d	208	2	5	0	5	2	4	4	1	4	5	C	C	I	6		C	C		C	C	C		
d	209	2	4	0	2	2	4	0	4	2	4		C	C	8	C			I		I			
0	210	1	5	0	4	2	4	0	4	2	5	C	C	C	9	C			I	C		C		
b	211	1	1	0	0	2	4	0	0	1	5	I	I		1			C	I					
c	212	1	1	2	0	0	4	0	2	1	4	I	I	I	3		I		I		I	I		
a	213	2	0	0	5	2	4	4	4	1	5	C		C	4			C		C	C	C		
a	214	2	1	2	5	1	4	5	2	4	5		I	I	3	I		C		C	C			
a	215	2	5	0	4	0	0	4	0	2	4	C	C		5					C	C	C		
a	216	1	2	0	2	1	4	0	2	2	5	I	I	I	4	I			I		I	I		
b	217	2	X	2	5	2	4	4	0	2	5						I	C	I	C				
b	218	1	5	0	5	0	4	0	2	2	5		C	I	7				I	C				
b	219	1	1	1	1	1	1	5	1	1	4	I	I	I	2	I	I				I	I		
a	220	2	1	0	2	1	2	0	5	1	0	I	I	C	6			I	I	I	I	I		

A	B	D											E		F				G		H					J		K	L	M
		1	3	4	5	6	7	9	10	11	12				3	10	T				@	$	§	#					#6	
b	221	0	4	0	5	0	5	5	5	4	5		C		C	C	9		C		C	C	C	C		C		C		
c	222	1	1	0	0	1	4	4	0	1	4		I		I		1					C				C				
b	223	1	2	0	5	1	5	0	4	1	5				I	C	6						I	C						
e	224	1	2	2	0	2	4	5	4	1	4				I	C	6				I	C								
a	225	2	4	0	5	2	0	5	5	0	4		C		C	C	9		C					C		C		C		

Appendix 20B.

Analysis of the individual responses to Version 1994c Part 2 questions 1-12, using the 1993 method of classification, for all the 1993 respondents who responded to both 1993 and 1994 surveys.

Notes: Ratings taken from table 4.4
"X" indicates no responses.

Key: A - Years experience; Refer to appendix 20A.
B - Identification number of respondent.
D - Application of method 1 (question numbers).
E - Classification as a result of method 1.
F - Application of method 2.
G - Classification as a result of method 2.
H - Application of method 3.
J - Classification as a result of method 3.
K - Overall 1994 classification.
L - Overall 1993 classification (appendix 20A).

A	B	D										E	F			G	H				J	K	L
		1	3	4	5	6	7	9	10	11	12		3	10	T		@	$	§	#			
	001	1	2	2	4	2	2	0	0	4	4	I	I		2	I		I	I	SI	I	I	I
	002	1	2	0	4	2	2	0	2	4	4	I	I	I	4	I	C	I	I	SI	I	I	I
	003	1	4	0	4	2	4	4	4	1	4	C	C	C	8	C		C		C	C	C	-
	007	1	4	0	4	1	4	4	2	2	5		C	I	6			C		C	C	-	-
	010	1	4	2	5	1	4	0	4	2	4	C	C	C	8	C	I		I	C	I	C	C
	014	1	4	0	4	0	2	0	0	1	5		C		4		C	I	I	SI	I	-	I
	021	1	2	0	4	0	0	4	4	2	4		I	C	6				C		C	-	-
	022	2	5	0	5	2	4	4	4	4	5	C	C	C	9	C	C	C		C	C	C	C
	024	1	2	0	4	1	5	0	2	1	4	I	I	I	4	I			I	SI	I	I	-
	025	1	2	0	5	1	4	0	1	0	4	I	I	I	3	I			I	C		I	C
	039	1	2	2	2	0	2	0	1	1	4	I	I	I	3	I	I	I	I		I	I	I
	041	2	0	0	2	0	4	4	0	4	0						C	C		NI		-	-
	044	2	5	0	5	2	5	5	5	2	5	C	C	C	10	C		C		C	C	C	C
	045	1	4	0	4	0	0	0	2	2	5		C	I	6					SI		-	-
	046	0	5	0	5	1	5	5	0	2	4	C	C		5	C		C	C	C	C	C	C
	047	1	0	0	4	0	4	0	0	4	4	C					C		I	C	C	C	C
	051	2	0	2	4	2	0	0	4	0	4	C		C	4	C			I	C		C	-
	053	1	4	0	2	2	0	0	1	2	4		C	I	5				I			-	I
	058	2	4	0	4	1	4	0	2	2	4		C	I	6				I	C		-	-

A	B	D										E	F			G	H				J	K	L
		1	3	4	5	6	7	9	10	11	12		3	10	T		@	$	§	#			
	059	1	2	0	0	2	4	0	2	2	4	I	I	I	4	I			I		I	I	-
	063	1	2	0	4	1	4	0	4	2	4		I	C	6				I	C		-	-
	066	1	2	2	4	2	5	0	1	5	4		I	I	3	I			I	C		-	-
	068	2	0	0	4	2	4	4	2	2	4	I		I	2	I		C		C	C	I	-
	070	1	2	0	0	0	2	0	2	4	0	C	I	I	4	I	C	I	I		I	I	I
	073	1	4	0	5	1	4	0	2	4	4		C	I	6		C		I	C	C	-	C
	074	1	2	0	4	2	0	0	4	2	4		I	C	6				I	C		-	C
	076	1	4	0	5	1	2	0	2	1	5		C	I	6			I	I	C	I	-	-
	078	1	2	0	2	1	4	0	2	2	4	I	I	I	4	I			I		I	I	-
	084	2	5	0	5	2	4	0	0	4	4	C	C		5	C	C		I	C	C	C	-
	086	1	2	0	4	1	2	0	1	2	4	I	I	I	4	I		I	I	SI	I	I	I
	094	2	X	0	0	1	4	4	2	2	4	I	X	I	2	I		C			C	I	I
	096	1	5	0	2	2	4	0	2	X	4		C	I	7				I		I	-	-
	098	0	5	0	5	0	X	4	4	4	4	C	C	C	9	C	C		C	C	C	C	C
	099	1	2	0	5	1	4	0	4	4	5		I	C	6		C		I	C	C	-	-
	100	1	5	0	5	0	4	4	1	2	5		C	I	6			C		C	C	-	C
	101	2	5	0	5	0	5	4	4	4	5	C	C	C	9	C	C	C		C	C	C	C
	102	1	4	0	5	0	2	0	1	2	4		C	I	5			I	I	C	I	-	I
	104	1	5	0	5	X	5	0	X	X	5	C?	C	X	5	C			I	C		C	-

A	B	D										E	F			G	H				J	K	L
		1	3	4	5	6	7	9	10	11	12		3	10	T		@	$	§	#			
	105	2	1	0	5	2	4	0	0	2	4	I	I	X	1	I		C	I	C	C	I	-
	114	2	0	0	5	1	0	0	4	1	4	C	X	C	4	C			I	C		C	C
	115	2	0	0	5	1	4	4	4	1	5	C	X	C	4	C		C		C	C	C	-
	118	1	0	0	2	2	2	0	2	4	5		X	I	2	I	C	I	I		I	I	I

<u>Notes on the comments and observations made on some of the respondent's questionnaires.</u>

Note 1: Question 12: "Pupils do sometimes observe subjectively. They need to be taught the skills of scientific observation." This would seem to confirm the "inductive" classification of this respondent.

Note 2: Question 5. "What one knows could lead to subjectivity or biasness (sic)."

Note 3: Question 1. "If 'good' is in inverted commas then (tend to agree) otherwise (tend to disagree)." The respondent tended to be constructively orientated, scoring "correctly" for a constructivist classification. Question 1 was problematic for this respondent. The respondent seemed to imply that a "good" or careful scientist would attempt to make objective observations, realising that this is not actually possible. If "good" implied that only scientists, who were able to make "objective" observations could be regarded as good scientists then the respondent would have disagreed. This question was therefore only used to confirm the status of a potentially inductively orientated respondent as determined by other questions. Question 1 was not used to confirm potential constructivist respondents as determined by other more definitive questions, because a respondent who has a constructivist orientation may have the same idea as this respondent.

Note 4. Question 7. Although the respondent chose the option "I neither agree nor disagree" the person added the word "sometimes". This inclined the response towards a constructivist classification.
Question 11. The respondent added that the method of science "sometimes is, but not that predictable sequence."
These two comments would support the classification of "constructive."

Note 5. According to the classification method used this respondent should be classified as having a predominantly inductivist orientation. The person chose the option "neither agreed nor disagree" for most of the "key" questions, so no definite classification was made.

Note 6. This respondent picked up two of the consistency checks. Questions 4 and 11 and questions 5 and 12 were linked by lines. The respondent did not agree with the cross-check in questions 4 and 11. This might confirm the idea that there was agreement on the concept of a set method of science, but the addition of the words "...guesswork and intuition play no part" may have caused the supposed contradiction in responses.

Note 7. According to the classification this respondent should have fallen into the constructivist category. On closer scrutiny it would appear as if there were sufficient ambiguous responses or responses that tended towards the inductivist orientation to make a definite classification impossible.

Note 8. Although there was a contradiction between questions 3 and 10, the rest of the responses tended to indicate a strong inductivist orientation. The respondent was classified as inductive, overiding the classification method that indicated that no classification could be made.

Note 9. This respondent made too few meaningful responses to allow for a classification. The person "neither agreed nor disagreed" with six of the questions.

Note 10. This respondent responded in a constructivist way to questions 3, 5, 10, 11 and 12. The strongly inductivist response to question 1, is possible for a constructively orientated respondent. In question 7 the respondent responded in an inductivist way, but not strongly. The respondent is much more constructively orientated than inductively orientated. The response to question 7 contradicts responses to questions 9 and 12. The person was classified as a constructivist.

Note 11. Although the classification tended to support an inductivist classification, there were too many neutral responses to make a definite classification possible.

Note 12. The respondent does show a difference in responses to questions 3 and 10. The constructivist response to question 3 contradicts the inductivist response to question 10. These were, however, not strong responses. When the remaining responses were considered, a predominantly inductivist response was evident. Therefore a classification of "inductive" was made.

Note 13. There were too many neutral responses to "key" questions to make any definite classification valid.

Note 14. This respondent showed inductivist tendencies. For question 9 a neutral response was chosen by the respondent but "but can happen" was added. This seemed to imply that observations can be subjective but attempts should be made to avoid this subjectivity. This addition by the respondent tended to support the responses to questions 5, 7, 9 and 12.

Note 15. The classification tended to support an inductivist approach. A closer inspection of the responses revealed that there were not sufficient definite and strong responses to make any classification valid.

Note 16. The classification tended to show a constructivist approach. A closer inspection showed no strong responses to "key" questions. No valid classification could be made.

Note 17. Although the classification scheme indicated an inductivist orientation, there were too few useful and too many neutral responses to claim that the respondent showed a predominantly inductivist orientation.

Note 18. This respondent placed him/herself firmly in the constructivist camp by adding to question 1 "All observations are subjective" and by strongly agreeing with questions 9 and 10. The person did qualify questions 9 and 10 by saying "Yes but what is subjective can also be a general truth" and "what is an interpretation a can also be a fact." This respondent seemed to be embracing the constructivist orientation and then tried to justify the acceptability of a subjective observation, or perhaps the respondent is saying that of the set of the subjective we can have an element which is actually a general truth - but we cannot be sure. This is a strong Popperian view and probably indicates that this respondent is a sophisticated constructivist.

Note 19. This respondent could be classified as a constructivist teacher. The comments made by the respondent tended to support this conclusion. Question 10: "Models on which we base other models. How bigoted are we about our knowledge?". Other comments suggested that the respondent believed that the inductivist approach is seriously flawed because it cannot be achieved, but claimed that it could still be of some use. Comment on question 3: "This is idealistic." Question 9: "Depends on the ethics of the observer." All these comments suggested that, although the respondent showed a great deal of understanding of the problems of the inductivist approach, the person did not appear to be ready to reject it and consequently no classification was made.

Note 20. This respondent added to question 3 that scientific knowledge is "supposed to be" objective and value-free. Most of the rest of the responses tended to indicate that this respondent was inclined towards an inductivist approach.

Note 21. This respondent felt very strongly about the objectivity of scientific knowledge. In other questions where the person chose constructivist answers, (questions 5, 7 and 12) the choice was only to agree and an inductively orientated person could make constructivist choices here and still justify an inductivist approach. On the basis of the very strong answer to question 3, the person was classified as predominantly "inductive".

Note 22. The classification seemed to indicate a constructivist orientation. The respondent did not respond to question 3, except to place a question mark in "neither agree nor disagree". This could indicate a problem with the statement. A classic inductivist would have no problem supporting the statement in question 3.

Note 23. Although the respondent did not respond to question 3 the responses to questions 7 and 10 tended to indicate an inductivist approach.

Note 24. This respondent supported a number of constructivist statements, but in question 10 the person tended to support an inductivist approach. No valid classification could be made.

Note 25. The strong constructivist approach in questions 3 and 10 tended to support the classification of constructivist. The inductivist responses to questions 5 and 7 tended to contradict the constructivist classification. The respondent is probably more constructive than inductive, but it would be difficult, based on only on these responses, to make a definite classification.

Note 26. The classification put this respondent in the category of "inductive". The main reason for this is the response to question 10. "Scientific facts are not merely interpretations." Many of the responses to some of the other questions tended to indicated a more constructivist approach. This is supported by the respondent's comment: "My teaching strategies predominantly incorporates the views of David Ausubel, ie. 'Anchor knowledge' to be ascertained and to teach accordingly." A revised classification of constructivist was made.

Note 27. This respondent, in a note at the end, wished the researcher: "Many objective observations". An indication of an inductivist orientation?

Note 28. The reliability of this respondent was suspect. Crosses were made straight down one column. No classification was made.

Note 29. The responses to the questions gave mixed signals. If the comment that the respondent wrote for Part 6 is considered, then the inductivist orientation appeared to dominate. "From the observation they could not say that the gas was hydrogen or that sodium hydroxide was formed."

Note 30. This respondent claimed that student 4's answer in Part 6.1 was "Unrealistic, textbook answer". Surely this respondent is not requiring pupils to ignore textbook answers!

Note 31. To question 7 the respondent added: "unfortunately so". This could imply that the validity of observational statements are dependent on the opinions of the observer and that this is always true, but that does not make it "correct". The other responses were clearly constructivist, so a predominantly constructive rating was given.

Note 32. Apart from question 10, all the other significant responses indicate a constructivist approach. The response to question 10 was a "tend to agree". The response to question 7 was strong and this is a contradiction to the response to question 10. On balance the respondent was classified as "constructive".

Note 33. The respondent was a JMB external examiner.

Note 34. The respondent made a number of comments on some of the questions. In response to question 3, the respondent added that it is an ideal case that scientific knowledge is objective and value-free. In questions 5 and 9 the comment indicated that the subjectivity or objectivity of observations depended on circumstances. In question 10 the comment was "We know a `fact' through our senses therefore a new `fact' is an interpretation by the `discoverer'". Comments that the respondent made in Part 5 indicated that the person discriminated between "observation" and "interpretation". For this reason the respondent was classified as having a predominantly inductivist orientation towards the nature of science.

Note 35. Apart from the response to questions 5 and 12 (constructivist responses, that could be used by a sophisticated inductivist) the only response that had any constructivist flavour was question 10. The other responses tended to indicate a classification of "inductive".

Note 36: The respondent's comment to question 1; "No such thing as an objective observation," places this person in the constructivist camp.

Note 37. Too many neutral answers to make a meaningful classification.

Note 38. External examiner in the CED.

Note 39. The comment added to question 3, "It should be, but it is not." tended to support the inductivist approach, with an appreciation for the limitation of this approach. There is not enough support from the rest of the responses to allow for a meaningful classification.

Note 40. The response to question 10 was a constructivist one, but the rest of the responses tended to support a predominantly inductivist approach.

Note 41. Too many conflicting responses for a meaningful classification.

Note 42. The respondent's response to question 3 indicates a constructivist orientation, but the response to question 11 and the comment in Part 6 that answers that included the word "hydrogen" cannot be observations, placed this respondent in the inductivist camp.

Note 43. To question 7 the respondent felt that the validity of observational statements should not depend on the opinions and expectations of the observer.

Note 44. The comment to question 1 was "Aiming to do so, and doing so, is not the same." The responses varied too much to make a valid classification.

Note 45. The response to question 7 was supplemented by: "Should not be." This tended to support the inductivist approach.

Note 46. The strong inductivist approach in questions 7 and 10 contributed to the inductivist classification.

Note 47. In response to question 12, the respondent disagreed that pupils observed things in terms of what they already know and added "The younger the better." An inductivist classification was made.

Note 48. For Part 6 the respondent added: "This difference between an "observation" and an "explanation" is beyond most of my standard 5 or 6 pupils". This comment implied that the respondent saw that there must be a difference between the two terms. A predominantly inductivist orientation would give rise to a person perceiving a clear distinction between these two ideas.

Appendix 21.
Percentage responses to Version 1994c Part 2 questions 13 - 39.

	I STRONGLY AGREE	I TEND TO AGREE	I NEITHER AGREE NOR DISAGREE	I TEND TO DISAGREE	I STRONGLY DISAGREE	DID NOT RESPOND
13.The process of scientific discovery often involves an ability to look at things in ways which are not commonly accepted.	33,85% (22)	50,79% (33)	10,77% (7)	3,08% (2)	1,54% (1)	(0)
14.Intuition plays an important role in scientific discovery.	35,38% (23)	52,31% (34)	6,15% (4)	3,08% (2)	1,54% (1)	1,54% (1)
15.Science is the ideal of knowledge in that it is a set of statements which are objective; i.e. their substance is determined entirely from observation.	10,77% (7)	15,38% (10)	20,00% (13)	44,62% (29)	6,15% (4)	3,08% (2)
16.Scientists rigorously attempt to eliminate human perspective from our picture of the world.	4,63% (3)	26,15% (17)	24,62% (16)	33,85% (22)	9,13% (6)	1,54% (1)
17.Insofar as a theory cannot be tested by experience it ought to be revised so that its predictions are restricted to observable phenomena.	9,23% (6)	26,15% (17)	16,92% (11)	35,38% (13)	6,15% (4)	6,15% (4)
18.Legitimate scientific ideas sometimes come from dreams and hunches.	24,62% (16)	52,31% (34)	12,31% (8)	4,62% (3)	4,62% (3)	1,54% (1)
19.Because of the validity of scientific method, knowledge obtained by its application is determined more by nature itself than by the choices the scientists make.	7,69% (5)	23,08% (15)	26,15% (17)	36,92% (24)	1,54% (1)	4,62% (3)
20.The process of scientific discovery often involves purposeful discard of accepted theory.	15,38% (10)	49,23% (32)	15,38% (10)	12,31% (8)	3,08% (2)	4,62% (3)
21 The purpose of science is to establish intellectual control over experience in terms of precise laws which can be formally set out and empirically tested.	20,00% (13)	35,38% (23)	13,85% (9)	24,62% (16)	(0)	6,15% (4)
22.It is not unusual for scientists to get ideas from seemingly unrelated scientific and non-scientific sources.	27,69% (18)	50,77% (33)	9,23% (6)	9,23% (6)	1,54% (1)	1,54% (1)
23.The best way to prepare to become a scientist is master the scientific body of knowledge available in the finest texts.	4,62% (3)	18,46% (12)	24,62% (16)	38,46% (25)	10,77 (7)	3,08% (2)
24.Non-sequential thinking, i.e. taking conceptual leaps, is characteristics of many scientists.	18,46% (12)	40,00% (26)	10,77% (7)	27,69% (18)	1,54% (1)	1,54% (1)
25.Scientists integrate many processes concurrently.	29,23% (19)	55,38% (36)	9,23% (6)	4,62% (3)	(0)	1,54% (1)
26.Most scientists believe nature strictly obeys laws	21,54% (14)	43,08% (28)	13,85% (9)	12,31% (8)	3,08% (2)	6,15% (4)

	I STRONGLY AGREE	I TEND TO AGREE	I NEITHER AGREE NOR DISAGREE	I TEND TO DISAGREE	I STRONGLY DISAGREE	DID NOT RESPOND
27. The results that pupils get from their experiments are as valid as anybody else's.	21,54% (14)	36,92% (24)	15,38% (10)	18,46% (12)	4,62% (3)	3,08% (2)
28. Science facts are what scientists agree that they are.	21,54% (14)	32,31% (21)	15,38% (10)	26,15% (17)	3,08% (2)	1,54% (1)
29. The object of scientific activity is to reveal reality.	18,46% (12)	49,23% (32)	10,77% (7)	10,77% (7)	6,15% (4)	4,62% (3)
30. Scientists have no idea of the outcome of an experiment before they do it.	4,62% (3)	1,54% (1)	12,31% (8)	61,54% (40)	15,38% (10)	4,62% (3)
31. Scientific theories are valid if they work.	24,62% (16)	32,31% (21)	18,46% (12)	18,46% (12)	4,62% (3)	1,54% (1)
32. Science proceeds by drawing generalisable conclusions (which later become theories) from available data.	16,92% (11)	56,92% (37)	7,69 (5)	12,31% (8)	1,54% (1)	4,62% (3)
33. There is such a thing as a true scientific theory.	7,69% (5)	44,62% (29)	18,46% (12)	21,54% (14)	3,08% (2)	4,62% (3)
34. Scientific theories describe a real external world which is independent of human perception.	13,85% (9)	23,08% (15)	10,77% (7)	38,46% (25)	9,23% (6)	4,62% (3)
35. Scientific theories have changed over time simply because experimental techniques have improved.	12,31% (8)	40,00% (26)	13,85% (9)	24,62% (16)	6,15% (4)	3,08% (2)
36. In practice, choices between competing theories are made purely on the basis of experimental results.	7,69% (5)	41,54% (27)	15,38% (10)	27,69% (18)	4,62% (3)	3,08% (2)
37. Scientific theories are as much a result of imagination and intuition as inference from experimental results.	15,38% (10)	38,46% (25)	15,38% (10)	21,54% (14)	3,08% (2)	6,15% (4)
38. Scientific knowledge is different from other kinds of knowledge in that it has a higher status.	9,23% (6)	15,38% (10)	18,46% (12)	35,38% (23)	16,92% (11)	4,62% (3)
39. All scientific experiments and observations are determined by existing theories.	9,23% (6)	21,54% (14)	16,92% (11)	44,62% (29)	4,62% (3)	3,08% (2)