DESCRIPTIONS OF THE TERM "SCIENTIFIC EXPERIMENT" HELD BY NIGER STATE, NIGERIA, POST-PRIMARY SCHOOL SCIENCE TEACHERS

A thesis submitted to the Graduate School of the University of Wisconsin-Madison in partial fulfillment of the requirements for the degree of Doctor of Philosophy

BY

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ABSTRACT

DESCRIPTIONS OP THE TERM "SCIENTIFIC EXPERIMENT"
HELD BY NIGER STATE, NIGERIA, POST-PRIMARY
SCHOOL SCIENCE TEACHERS

BY

MOHAMMED ABDULRAHMAN

Under the Supervision of Professor Milton 0. Pella

Statement of the Problem

The main objective of this study was to determine the descriptions of "scientific experiment" that are held by Niger State, Nigeria, post-primary school science teachers. An attempt was also made to determine if differences in a) teachers' educational background, b) teachers' numbers of years of teaching experience, and c) the subjects the teachers teach, are accompanied by differences in the statements they included in their descriptions of scientific experiments.

Procedure

A new instrument consisting of 62 statements on "scientific experiments" that had been identified or not

identified with 10 selected philosophers of science was prepared and administered to 103 science teachers in Niger State, post-primary schools. The frequency and percentage of "yes" responses (indicating a teacher's desire to include the particular statement in his/her description of scientific experiments) to each of the 62 statements on the questionnaire were computed for: (1) the teachers as a group, (2) teachers with different educational backgrounds: a) the Nigerian Certificate of Education (NCE) and b) a university degree; (3) teachers with different numbers of years of teaching experience: a) 0-2 years and b) over 2 years (for the teachers as a group and for those with different educational backgrounds) and (4) teachers who teach different subjects: a) biological science and b) physical science (for the teachers as a group and for those with different educational backgrounds).

The statements to which 75% or more of the teachers responded "yes" were selected for inclusion as a part of the descriptions of scientific experiments held by the teachers as a group. Differences in the statements which the various comparison groups included in their descriptions were determined on the basis of two criteria: a) 75% or more of the individuals in only one of two comparison groups must have given "yes" responses to the

statements and b) the percent difference in "yes" responses by the two comparison groups to a given statement must equal or exceed 20%.

Findings

1. Just as the 10 selected philosophers of science whose opinions formed the basis for most of the content of the questionnaire used in the study hold diverse and sometimes conflicting views of scientific experiments, so does the group of teachers studied. Furthermore, in their descriptions, the teachers included statements not identified with any of the selected philosophers.
2. The teachers were fairly consistent in their selection of statements to be included in their descriptions.
3. The groups of teachers with NCE and degree qualifications generally selected the same statements to be included in their descriptions.
4. Biological and physical science teachers as a group and within each educational background level differed slightly in the statements they selected for inclusion in their descriptions. However, these differences did not follow a clear-cut pattern.

5. There were few differences between teachers with 0-2 years and those with over 2 years of teaching experience in the lists of statements they included in their descriptions of scientific experiments. This is true of the teachers as a group and those with either NCE or degree qualifications.
6. The teachers clearly made distinctions in the use of terms describing the role of experiments in science, terms such as "confirmation," "falsification," "discovery," or "formulation" of "scientific laws," "scientific hypotheses" or "scientific theories." While they endorsed the idea of experiments as being capable of confirming or verifying scientific laws and hypotheses, they rejected the idea of falsification.

Approved _____

Date _____

JUL 30 1979

CHAPTER I

THE PROBLEM

Introduction

Since political independence in 1960, Nigerians have been witnessing an era of unprecedented social, economic, and educational change. There has been a continuous increase in the number of primary and secondary schools, universities, and technical colleges.

The increased emphasis on education at both post-primary and post-secondary school levels is said to hold the promise that Nigerians may become their own doctors, engineers, teachers, technicians, etc.

It is therefore not surprising that the science curriculum reform conferences of 1969 and 1973; and the 1977 Federal Government position statement on education all expressed concern for finding ways of increasing the scientific awareness of the Nigerian society as a whole. A major theme of the prescriptions for overcoming these concerns, has been the specific emphasis on "knowledge of the nature of science".

Abubakar (1970) reflected the general view of the 1969 conferees when he proposed that

> The content of science courses should be such that it is interesting, it is relevant to the

> child's experiences with the physical world, it is structured into continuous development of scientific concepts and skills from primary school up to the university level. The methodology must be such that it discourages rote memorization, it fires the imagination, it eliminates authoritarian teaching, it inculcates the spirit of inquiry, to experiment, to discover, to draw conclusions, and to predict (p. 34).

Ogunyemi (1969) reiterated the importance of a science curriculum based on the understanding of the nature of science for an African culture when he argued that

> It is quite confusing to young pupils, whose first school lessons in science usually involve a dogmatic and sweeping denunciation of all "superstitions", "herbalists", and "witch doctors", but who sometimes find in the real life of the community that some diseases and illnesses defy treatment in reputable hospitals only to be cured by the so-called witch-doctors. There is therefore cynicism among literate and many illiterate people arising from a dubious understanding of what science can or can not do. These misconceptions can be corrected by a curriculum that lays stress on the understanding of the nature of science (p. 142).

Similar views have been expressed by other Nigerian educators like Fafunwa (1967), Yoloye (1969, Cookey (1970), and Bajah (1975).

An examination of the expressed view of Nigerian educators that specific emphasis be placed on "the understanding of the nature of science" reveals its similarity to views expressed by several American science educators, scientists, teachers, and other groups either as individuals or through various educational organizations and forums (The National Science Teachers' Association, 1961,

1964, and 1971; Conant, 1950; Schwab, 1960; Carey and Stauss, 1965; Connelly, 1968; and Hurd, 1969).

One major reason often suggested for stressing the understanding of the nature of science is the continual and exponential explosion of scientific knowledge which makes it difficult to keep science curriculum content abreast of the latest scientific facts and realities (National Society for the Study of Education, 59th Yearbook; Hurd, 1969; Schwab, 1962; Conant, 1951; and Ogunyemi, 1969).

The expressed concern for the understanding of the nature of science has been instrumental in the proliferation of several elementary and secondary school programs in the United States and Great Britain (examples include - Physical Science Study Curriculum, Science - A Process Approach, Biological Science Curriculum Study, and Nuffield Foundation Program: 5-13). Robinson (1969) described the aims of the new curricula

> as striving for greater sophistication from a philosophy and history of science perspective, avoiding the naivete of older texts and their representation of the scientific method. The new programs tried to portray the fluidity and dynamism of science in contrast to its image as a collection of immutable truths. These objectives can be summarized as directing instruction towards the students' understanding of the nature of science, possibly the focal element of scientific literacy (Shulman and Tamir, 1973, p. 1101).

Although there is a general agreement on the need for a basic understanding of the nature of science as a major

goal of science teaching, a number of science educators have raised very serious questions about the manner in which science is presented in science textbooks and other curriculum materials (Robinson, 1965; Ivany, 1969; Herron, 1969; Martin, 1972; and Connelly, 1973). Connelly (1973) maintains that the

> limitations of the curriculum reform efforts of the fifties and sixties can be identified as resulting from implicit embodying conceptions of knowledge and knowing in curriculum materials which were derived from psychological notions of cognitive structure and how they develop and function in fields of inquiry and in the mind (p. 279-280).

Herron (1969) points out that

> Educational objectives of the new curricula materials are no more precisely stated than those of preceding decades. The net result of this ambiguity is that such terms as "scientific inquiry" have tended to become mere trite cliches, bandied about in the discussions of science educators and other "in the know" but ignored in the main, by the classroom teacher. A serious and sophisticated epistimological problem, i.e., the nature of scientific knowledge seems to be moving through successive levels of generality to take its place along such timeworn and dependable catch-phrases as "democratic", "creative", motherhood and apple pie", and "scientific method" (p. 106).

There is general agreement that the teaching of science should aim at getting students to "understand the nature/structure of science" and existing curriculum materials have failed to "adequately" represent "the nature/structure of science."

Among the many possible conditions that may have contributed to failure to "adequately" represent the "nature/structure of science" in curriculum materials, there are four that seem to stand out:

1. The concept "nature/structure of science" is so broad that a single attempt at representing the nature/structure of science may not be feasible. Schwab (1962) and Robinson (1965) have argued that no single description of structure exists which can be applied equally well to each of the scientific disciplines. Thus, a model of science used in the teaching of physics may be improper for the teaching of biology.
2. Since the new curricula valued the way scientists make discoveries as a model for student activity, science curriculum developers have generally chosen to equate discovery teaching with the process of induction. In the process, the curriculum developers have ignored the views of many contemporary philosophers and historians of science who clearly reject any characterization of science as an objective inductive process (Medawar, 1962; Kuhn, 1962; Hempel, 1966; and Popper, 1969). The general view of these philosophers is that science is hypothetico-deductive in nature.

3. The existence of disparity among philosophers, scientists, and science educators investigating "structure/nature of science" at the philosophical level and those who apply psychological connotations to the word. Thus, while philosophers tend to discuss the nature of science in terms of its products, processes, and ethical systems, psychological discussions have centered around "learning structures", "cognitive structures", etc.
4. Science educators investigating the nature/structure of science at the philosophical level generally distinguish between two highly interrelated aspects of structure which Schwab (1962) calls: "the substantive or conceptual" and "the syntactic or methodological" aspects of structure. Curriculum developers and science textbook writers have tended to emphasize one aspect of this structure to the exclusion of the other. This is true of many of the science programs of the last two to three decades that emphasized the so-called "processes of science."

The problem of analyzing what is meant by "the nature/structure of science" is paralleled by an equally important problem of determining what descriptions of "the nature/

structure of science" science teachers hold. Knowledge of such descriptions is needed because the teachers serve as the mediators between any notions of the structure/nature of science and the students.

A number of educators have pointed to the significance of the relationship between descriptions of the nature of science possessed by science teachers and those possessed by their pupils. Hurd (1969) has argued that "it is undoubtedly true that the teacher's concept of what science is, influences not only what he teaches but how he teaches" (p. 16).

Carey and Stauss (1970) point out that

> if the teaching of science is to reflect the nature of science, then, it becomes obvious that science teachers possess an understanding of the nature of science.... If the teacher's understanding and philosophy of science is not congruent with current interpretations of the nature of science, then instructional outcomes will not be representative of science in spite of all efforts that may be expended by those charged with the development of relevant curriculum materials (p. 368).

Bajah (1975) expressed the importance of a proper understanding of the nature of science on the part of the African science teacher when he argued that

> It is an educational truism that a teacher, graduate or non-graduate can only teach what he knows.... Whichever way we look at it, a secondary school physical science teacher for the African environment must liken himself to a peddler who has certain commodities to sell.

> He must be prepared to advertise and demonstrate his knowledge of the subject he is entrusted to teach (p. 89).

The published literature in science education contains several reports of investigations designed to measure understandings of the nature of science held by students, teachers, scientists, science educators, and other groups. An extensive review of this literature as it relates to science teachers is presented in Chapter II. An analysis of these studies reveals three trends:

1. Many of the conclusions drawn were conflicting and at times outright insignificant.
2. Some of the studies were either nonreplicable or the generalizations were based on poorly drawn samples.
3. The instruments used in most of the studies were either poorly designed or were based on the views of science held by one or two scholars. In consequence, such instruments fail to represent the many divergent opinions of the nature of science (Connelly, 1969; Welch, 1969; Shulman and Tamir, 1973; and Lucas, 1975).

As pointed out earlier, the concept "nature of science" is broad. Because of this, recent investigators (Rowe, 1975; Ogunniyi, 1977; and Cotham and Smith, 1979) have based their studies on selected concepts like "laws",

"theories", "concepts", hypotheses", etc., that are subsumed under the nature of science. It is against this background that the investigation reported here was undertaken.

Statement of the Problem

The main objective of this study was: To determine the descriptions of the term "scientific experiment" that are held by Niger State, Nigeria, post-primary school science teachers (relative to a published writing of each of 10 selected philosophers of science).

Sub-problems

As pointed out earlier, a number of investigators have argued that the structure of science appropriate for each of the disciplines of science may be different (Schwab, 1961; and Robinson, 1965). In addition, there is the general assumption that teachers with more academic preparation in science are more likely to exhibit greater knowledge of science than those with less preparation in science. For these reasons, a number of investigations concerned with science teachers' understandings of the nature of science were focused on relationships between such understandings, and selected independent variables like educational background, number of years of teaching experience, credits in science, subjects taught by the teachers, and other variables. Because of

problems of poor sampling, instrument validity, etc. (outlined earlier) many of the studies have produced unreliable and sometimes insignificant results. For these reasons, answers were sought to the following questions:

1. Do teachers with a university degree describe scientific statements differently from those with a Nigerian Certificate of Education?
2. Do teachers with 0-2 years of teaching experience describe scientific experiments differently from those with over 2 years of teaching experience?
3. Do teachers with a given educational background who have 0-2 years of teaching experience describe scientific experiments differently from those with the same educational background who have over 2 years of teaching experience?
4. Do teachers who teach physical science courses describe scientific experiments differently from those who teach biological science courses?
5. Do teachers with a given educational background who teach physical science courses describe scientific experiments differently from those with the same educational background who teach biological science courses?

Focus of the Study

The investigation being reported here involved the development of a new instrument to be used to obtain descriptions of scientific experiments held by a population of science teachers. The content of the instrument was based on a published writing of each of 10 selected philosophers of science to provide content validity.

Significance of the Problem

In the 1977 Federal Republic of Nigeria National Policy on Education publication, post-primary school level was specifically identified as the level at which students should be "equipped to live effectively in our modern age of science and technology" (p. 10). In addition, the proposed educational reform at post-primary school level in Nigeria at which specific emphasis is placed on developing intermediate manpower, points to the need for science teachers who have adequate knowledge of science.

The three points justifying this study dealing specifically with the term "scientific experiment" are listed below:

1. Knowledge of the nature of scientific experiment is considered as central to knowledge of the nature of science.

2. Experimentation occupies a central part of the classroom activities of students in the science curriculum materials of the last three decades.
3. The science teacher's selection of content and the way he represents science to his students may be influenced by his knowledge of the term "scientific experiment".

These three points are discussed in detail below:

Knowledge of the Nature of Science

Historians of science, philosophers of science and science educators have emphasized the intimate relationship between science and experiment. Conant (1951) describes science as "an interconnected series of concepts and conceptual schemes that have been developed as a result of experimentation and observation and are fruitful of further experimentation and observation" (p. 25). Such relationships have been stressed by other philosophers and historians of science (Butterfield, 1957; Lachman, 1960; and Fiebleman, 1972).

Conant (1957) argues that students require an understanding of science that will help them relate developments in the natural sciences to those in other fields of human activity. He maintains that:

> To do so demands an understanding of the methods of experimental science and the growth of scientific research as an organized activity

> of society. Experience shows that a man who has been a successful investigator in the field of experimental science, approaches a problem in pure and applied science even in an area in which he is quite ignorant with a special point of view. One may designate this point of view "understanding science" (p. vii).

Watson (1953), a science educator, presents the idea that:

> Throughout the literature are pleas for making instruction "functional" and for implanting the "scientific method". These are vague labels for certain operating abilities which we hold as desirable. The activities of scientific investigation are not going to become significant to pupils through the chanting of incantations or filling in any five-step laboratory report forms. Only direct experience with factors, preferably unnamed, involved in creating some order in the complex world will provide pupils with internal awareness of what science is like. At the core of such efforts to create some understanding of scientific inquiry is the most important invention of the past four hundred years--<u>experimentation</u> (p. 100).

Similar views have been expressed by Hurd (1969) and Schwab (1962).

<u>Curriculum Development</u>

In developing "the nature of science" oriented curricula of the past three decades, emphasis was placed on individual laboratory experience. One central feature of these laboratory experiences is the emphasis on student performance and knowledge of the nature of experimentation in science. Hurd (1969) has stated that as a result of laboratory experiences, students should gain knowledge of:

1. The variety, characteristics and limitations of experimental options and the nature of data obtained.
2. The relationship between observed data, experimental results, and inferences based on data and results.
3. The tools of measurement and their influence on experimental results and inferences based on data and results.
4. The use of data in generating hypotheses and defining questions and conversely, the use of hypotheses to guide data collection.
5. Analyzing, ordering, and displaying data in precise and valid ways.

In general, while the "new curricula" differ from one another in structure, sequence and content, they all share an emphasis on demonstration and experimentation resulting from the general dictum that "we learn by doing".

Influence on Teacher's Classroom Behavior

A number of science educators have pointed to the possible influence that knowledge of the nature of scientific experiments might have on the science teacher's classroom behavior (Eccles, 1963; Robinson, 1969; and Wagner and Lucas, 1977).

Eccles (1963) noted the danger of a lack of proper knowledge of the term "experiment" on the part of the science teachers;

> when a student encounters an activity labeled "experiment", he naturally assumes that this is an examplar of the class "experiment" and consciously or unconsciously, it contributes to whatever conception he has of this type of human activity. It is difficult to believe that students can develop a reasonably accurate understanding of experimentation and experimental science if they are constantly confronted with examples which do not have the essential qualities (p. 85).

Wagner and Lucas (1977) present the idea that:

> Whereas the scientist is concerned with the actual conduct of scientific research, the teacher's main task is to give an account of scientific investigation. There is a negotiable difference between simply illustrating the use of the scientific method and helping students understand the nature of that methodology (p. 50).

Summary

Despite the expressed importance of the term "experiment" to knowledge of the nature of science, the teacher's classroom behavior, and the fact that it occupies a central position in the classroom activities of students, no investigation has been undertaken to determine how science teachers, science educators, scientists, students, and other groups conceptualize the term. Research studies that mention it at all, give it only a superficial treatment under the so-called "processes of science". The present investigation is considered significant because:

1. It will provide some descriptions of scientific experiments which Niger State post-primary school science teachers possess.
2. It will provide information regarding inconsistencies in the descriptions of scientific experiments which the teachers hold. This information will help in the planning of training programs in advanced teacher training colleges and universities with a view of removing such inconsistences.
3. The study might suggest the need to emphasize the divergent philosophical views of the nature of scientific experiments rather than a single stereotype model.
4. The descriptions of scientific experiments held by the teachers could be compared with the descriptions that are presented in science textbooks. The results of such comparisons may be useful in designing science teachers' preservice and inservice programs related to the "nature of scientific experiments".

Definition of Terms

Throughout this report, the following terms are used. Basic knowledge of the definitions of these terms as they are used in the context of this paper is essential:

1. Post-primary school science teachers - teachers of science in secondary schools and teacher training colleges.
2. NCE teachers - science teachers with a maximum qualification of the Nigerian Certificate of Education (NCE).
3. Degree teachers - science teachers with a minimum qualification of the Bachelor of Science (B.Sc.) degree.
4. Scientific generalizations - refer to scientific hypotheses, scientific laws, and scientific theories.
5. Characteristics of scientific experiments - all statements related to the definition of scientific experiments, design of scientific experiments, procedures for performing scientific experiments, and analyses and interpretation of the results of scientific experiments.
6. Dependent variables - the response scale used on the questionnaire (Appendix I).

7. Independent variables - the characteristics of the science teachers examined in the study--specifically their educational background, number of years of teaching experience, and the subjects they teach.
8. Nature of science - the nature of science is a complex concept which has been described in a variety of ways. It is viewed here to involve a) the processes by which scientific information is obtained (e.g., observing, experimenting, etc.; b) the products of science (e.g., laws and theories) and the linguistic components of the products (types of concepts found in the products); and c) the ethical systems which control and guide scientific activities (e.g., empiricism, openmindedness, parsimony, etc.).

CHAPTER II

REVIEW OF RELATED LITERATURE

Introduction

In the previous chapter, a summary of the shortcomings of past research studies on science teachers' understandings of the nature of science was provided. It was pointed out that the models of science selected by most of the investigators failed to account for the diverse philosophical views of the nature of science.

This review examines five questions related to the issues presented in the previous chapter. Those five questions are:

1. What are the arguments for using philosophical writings as the basis for studies related to understandings of the nature of science?
2. What does the research literature say about the nature of scientific experiments?
3. What are the designs employed in some of the past instruments used for measuring understandings of the nature of science?
4. What does the current research literature say about science teachers' understandings of the nature of science?

5. What does the current literature say about the understandings of the nature of science possessed by science teachers relative to selected independent variables?

An account of the implications of the reviews outlined above on the present study is provided at the end of this chapter.

PHILOSOPHY OF SCIENCE AS A BASIS FOR STUDIES RELATED TO THE UNDERSTANDING OF THE NATURE OF SCIENCE

Several authors have stressed the specific importance of the philosophy of science to science education (Shulman and Tamir, 1973; Robinson, 1969; Connelly, 1968; and Wagner and Lucas, 1977).

Wagner and Lucas (1977) contend that

> The case for utilizing philosophical analysis as an introduction to science education takes its force from a vital difference between the role of the scientist and that of the science educator as teacher. Whereas the scientist is concerned with the actual conduct of scientific research, the teachers' main task is to give an account of what is involved in the conduct of scientific investigations. There is a negotiable difference between simply illustrating the use of scientific method and helping students understand the nature of that methodology. So too is there an important distinction to be preserved between having information about the substantive content of a scientific discipline, and possessing insight into the nature and status of scientific knowledge. Philosophy is uniquely fitted to analyzing what it is scientists do when they engage in inquiry and what sort of conclusions they can draw (p. 557).

Dingle (1947) suggests that there should be "a critical school" within the disciplines of science in order to overcome the prevalent lack of critical understanding of the nature of science. Schaffler (1964) in commenting on Dingle's suggestion, argues that the critical school within the disciplines of science

> should consist of those scientists who specialize in making intelligible, the structure of their disciplines and relating it to knowledge as a whole. They would be scientific philosophers, and philosophers of science, and it would be through their studies and writings that we might broaden and deepen our comprehension of the proper method of teaching and understanding science (p. 441).

These arguments have been fundamental to a number of past research studies related to the present study (Schwab, 1960; Connelly, 1968; Robinson, 1965; Martin, 1969; Herron, 1969; Rowe, 1976; Ogunniyi, 1977; Cotham and Smith, 1979).

DESCRIPTIONS OF SCIENTIFIC EXPERIMENTS

Historically, modern science came into being when the Aristotelian idea of "a fixed and correct" world picture based on speculations about what ought to happen in nature, was extended to "actual experiment"--testing of ideas (Butterfield, 1957).

Beginning with the late 16th century and through the influence of people like Decartes and Bacon, human knowledge and ideas about the world have been built upon the foundation of experiment.

The following descriptions are designed to indicate the diversity of views on the nature of scientific experiments.

Descriptions of Scientific Experiments by Science Educators

Generally, while science educators have been foremost in urging that experiment be central to science teaching, they have paid little attention to analyzing what the term means. Textbook writers have generally tended to mention it only in passing.

Woodburn and Obourn (1965) describe experiments as "efforts to observe an event under conditions where as many extraneous factors as possible are eliminated or their possible influence taken into account. These efforts, if successful, accumulate bit by bit, evidence for or against a hypothesis."

Plants (1966) considers an experiment as "the process of testing a hypothesis with no known results predictable" (p. 22).

Pella (1961) describes an experiment as "a systematic series of observations under controlled conditions and the products of experiments are data or facts."

Science textbooks tend to represent "steps" of scientific experiments as consisting of: i) a statement of the problem, ii) a single trial with an accompanying observation, and iii) a conclusion.

In a more elaborate description, the National Science Teachers' Association (1964) identified the "sequence" of scientific experiments as consisting of:

1. manipulating apparatus to make pertinent observations,
2. Identifying observations which are relevant to the experiment,
3. distinguishing useful from extraneous data,
4. describing the problems involved in making desired observations,
5. identifying relevant variables in an experimental situation,
6. maintaining an accurate record of experimental procedures and results,
7. controlling those variables not a part of the hypothesis being tested,
8. identifying sources of experimental error, and
9. describing the limitations of experimental apparatus.

A critical examination of this "sequence" shows that no mention is made of the interrelationships between these syntactical (procedural) aspects of scientific experiments and substantive (conceptual) aspects of science. This is generally true of all educational discussions of the nature of scientific experiments. Thus, despite the importance

that science educators have attached to the role of experiment in promoting an understanding of the nature of science, they have paid no attention to any systematic analysis of this role.

Descriptions of Scientific Experiments Held by Philosophers of Science

In the days of Bacon, experiments were basically considered as contrived experiences; invented happenings. The function of experimentation is "to nourish the senses, to enrich the repertoire of factual information out of which inductions are to be compounded" (Medawar, 1968, p. 35).

In modern philosophical discourse, views on scientific experiments are diverse. For descriptive convenience, the following descriptions of scientific experiments held by philosophers of science have been organized under two headings:

1. The general characteristics of scientific experiments.
2. The relationship between scientific experiments and scientific generalizations.

These are discussed in detail below.

General Characteristics of Scientific Experiments

Philosophers of science tend to address different aspects of the characteristics of scientific experiments. For this reason, the following account is provided to

indicate the variety of the characteristics of scientific experiments often mentioned in philosophical discussions.

In the Dictionary of Philosophy, Runes (1942) defines an experiment as "any situation set up by an investigator with a view of verifying a theory or hypothesis." Poincare (1921) describes a "good" experiment as that "which informs us of something besides an isolated fact, it is that which enables us to foresee, that is, that which enables us to generalize" (Nash, 1963, p. 109).

Lachman (1965) defines an experiment as an arranged series of observations usually made under controlled conditions which are designed to produce particular items of data that are repeatable and verifiable" (p. 80).

Medawar (1968) identifies four kinds of experiments in science:

1. Inductive or Baconian experiments which attempt to answer questions like: "I wonder what would happen if ....?"
2. Deductive experiments which attempt to see the effect of varying the axioms or propositions in a scheme of deductive reasoning.
3. Critical experiments - actions carried out to test a hypothesis or preconceived opinion by examining the logical consequences of holding it.

4. Demonstrative experiments - intended to illustrate a preconceived truth and convince others of its validity.

Other characteristics of scientific experiments often mentioned by philosophers of science include:

1. Porterfield (1941) maintains that the procedures of an experiment "can be repeated to the last item by any one who cares to do so" (p. 122). For Hanson (1957), this is not possible. He maintains that

> Experiments are designed to be as chain like as possible. It takes long training to master the technique of design. To bring together, a cluster of theoretical considerations in a single, tersely expressed hypothesis, to ensure that when these vary to a certain degree, they initiate another phase of experiment, where again everything is is held constant save one factor, to have arranged that these in turn play roles in further phases of the demonstration--not just anyone, not every physicist can juggle all this into an efficient laboratory operation (p. 67).

2. Many philosophers maintain that a good scientific experiment must be repeatable or reproducible (Beveridge, 1950; Nash, 1963).
3. Popper (1959) and Fiebleman (1972) argue that a scientific experiment can never be repeated with precisely the same set of results.
4. The results of scientific experiments are valid only for the precise conditions under which they were obtained.

were obtained (Beveridge, 1950; Frank, 1957; Popper, 1959).

5. The results of scientific experiments are probabilities whose credibility increases with increase in the number of similar results (Hempel, 1966; Nash, 1963; Frank, 1957; and Carnap, 1976).
6. The same experimental data could have several possible valid interpretations (Nash, 1963; Fiebleman, 1972; Frank, 1957; Kemeny, 1959).
7. A decision to accept or reject one of two conflicting sets of experimental results is dependent on the one which is able to withstand the severest test (Popper, 1959).
8. There are no distinct universal steps of procedure which are followed in the conduct of scientific experiments (Hanson, 1957; Carnap, 1976, Hempel, 1966). For Fiebleman (1972), the process of conducting a scientific experiment consists of four well defined steps of procedure: a) preparation of the experimental materials, b) preparation of the apparatus or instruments, c) removal of factors which might interfere with the conduct of experiments, and d) running of the experiment.

9. Frank (1957) maintains that the consequences of cause and effect relationships can not be checked by experimental means. Carnap (1976) argues that it is possible to use experiments to check cause and effect relationships only by the manner in which the experiment confirms or disconfirms related scientific laws.
10. The results of scientific experiments pose more questions than answers (Fiebleman, 1972; Hanson, 1957).
11. The conditions that are likely to affect the outcome of scientific experiments can neither be completely determined nor completely controlled (Nash, 1963).

Descriptions of Relationships Between Scientific Experiments and Scientific Generalizations

The major source of disagreement among philosophers of science on the nature of scientific experiments, relates to the relationships of experiments and scientific generalizations.

Most philosophers agree that a primary purpose for performing scientific experiments is to test hypotheses (Toulmin, 1953; Duhem, 1953; Beveridge, 1950; Medawar, 1968; Hempel, 1966; Fiebleman, 1972). In this respect, a hypothesis is viewed as an empirically testable proposition.

According to Hempel (1966), "an experimental test of a hypothesis consists of varying the values of the independent variables and checking whether the dependent variable assumes the values implied by the hypothesis" (p. 20).

Hempel (1966) and Fiebleman (1972) maintain that where no specific hypotheses have as yet been proposed, "an experiment could be used as a guide to the discovery of a more definitive hypothesis."

There appear to be two diverging views on the relationship between scientific experiments and scientific theories. On the one hand, there are such philosophers as Fiebleman (1972), Nash (1963), Toulmin, 1953), Harre (1972), and Kemeny (1959), who maintain that experiments serve as a means of the "corroboration", "demonstration" or "verification" of scientific theories. In this respect, scientific experiments are considered to be "theory ladden" or "theory directed". Hanson (1957) maintains that "experiments are infused with concepts and loaded with theories" (p. 157).

In a second view, experiment is considered as a generative source of theory (Duhem, 1953). In this respect, experiment is viewed as capable of providing its own direction. Claude (1895) asserts that

> it is necessary to obliterate one's opinions, as well as that of others, when facing decisions of the experiment; ...that we must accept the results of experiments just as they

> present themselves with all that is unforeseen and accidental in them (Duhem, 1953, p. 236).

For Toulmin (1953), "the need for a theoretical framework in the conduct of scientific experiments is required only in the physical sciences. In the biological sciences, the experimenter goes about the world with an open eye and mind, prepared to notice anything of interest that may occur in his path" (p. 67).

According to conventionalists like Poincare, experiments may have sufficient power to refute "young theories" but not to refute "old established theories" since as science grows, the power of empirical evidence diminishes. For Popper (1959),"once the results of experiments contradict a theory such a theory has to be given up"--experimental falsification of scientific theories (p. 38).

Contrary to Popper's view of the possibility of experimental falsification of scientific theories, Duhem (1953) and Toulmin (1953) maintain that experimental results do not lead to the falsification of scientific theories. Duhem (1953) argues that when a theory is considered as a proposition, "it can be saved from counter instances either by some auxilliary hypothesis or suitable reinterpretation of its terms."

While Popper (1959) subscribes to the idea of a single "crucial" experiment as capable of deciding between

two conflicting theories or hypotheses, a number of philosophers disagree. Hempel (1966) maintains that

> even the most careful and extensive test can neither disprove one of two hypotheses nor prove the other; thus, strictly construed, a crucial experiment is impossible in science... an experiment may be crucial in less strict, practical sense, it may lend support to its rival, and as a result, it may exert a decisive influence upon the direction of subsequent theorizing and experimentation (p. 28).

Quinn (1974) takes a position similar to Hempel's. He argues that "scientific theories can not in isolation be conclusively verified or falsified by experiment" (p. 71).

Lakatos (1970) argues that there are no such things as crucial experiments, at least not if these are meant to be experiments which can instantly overthrow a research program" (p. 173). He maintains that

> Within a research programme "minor crucial experiments" between subsequent version are quite common. Experiments easily 'decide' between the n-th and n+1-th scientific version, since the n+1-th version is not only inconsistent with the n-th, but also supersedes it (p. 157).

Duhem (1953) takes the position that

> The only thing the experiment teaches us is that among the propositions used to predict the phenomenon and to establish whether it would be produced, there is at least one error, but where this error lies, is just what it does not tell us (p. 183).

Kemeny (1959) considers the verification of scientific theories as the third and final step of the scientific method and also maintains that the more predictions

from the theory are verified by the outcomes of scientific experiments, the greater the credibility of the theory.

Carnap (1976) argues that experiments do not provide a direct basis for the confirmation of scientific theories. Rather, it is "the indirect confirmation of empirical laws by experiments which provides for the confirmation of theories" (p. 42).

Toulmin (1953) maintains that the scientist aims at expressing the results of his experiments in the form of generalized statements (laws). This view is similar to that of Carnap (1976). For Fiebleman (1972), the results of scientific experiments can be used to predict new scientific laws.

Campbell (1952) asserts that laws are not capable of being proved by experiments, but are capable of being disproved by them.

The descriptions of scientific experiments presented above show the variety and sometimes conflicting nature of views on this aspect of science. This issue of variety of views on aspects of the nature of science is one factor which past researchers have failed to take into account in the design of their studies.

ANALYSES OF SOME SELECTED INSTRUMENTS THAT HAVE BEEN DESIGNED TO MEASURE UNDERSTANDINGS OF THE NATURE OF SCIENCE

Over the last two decades, several instruments have been developed for the expressed purpose of measuring understandings of the nature of science held by science teachers, science educators, students, scientists, and other groups. The issue of the validity of several of these instruments has been raised by Aikenhead (1973), Lucas (1975), Doran, Guerin and Cavalieri (1974), Doran (1978a and 1978b), and Rowe (1976). Some of these instruments include:

Nature of Science Scale (NOSS) - Kimball (1967): This instrument is based on the views of Conant and Bronowski. It was developed as a tool for "determining whether or not science teachers have the same views of science as those of the two scientists." The validation panel consisted of scientists, science teachers, philosophy majors, and science majors. The model of the nature of science was based on statements prepared on the basis of eight assumptions about important characteristics of science. In an extensive study, the odd-even reliability coefficient of the instrument was found to be 0.54. The development, validation, and reliability measures were carried out with college graduates.

Processes of Science Test (POST) - This instrument consists of 40 multiple choice items designed by the Biological Science Curriculum Study (BSCS) to measure the

ability of respondents to a) recognize adequate criteria for accepting or rejecting hypotheses, and b) evaluate the general structure of experimental design in science (including the need for control, reliability, adequate sampling, and careful measurement).

Test for Science Process (TOSP) - This instrument was developed by Tannenbaum (1971) "to assess achievement and diagnose weaknesses of science process skills possessed by grades seven, eight, and nine pupils." The 96 items on the test were based on Science - A Process Approach model of science process skills: observing, comparing, quantifying, measuring, experimenting, inferring, and predicting. Three thousand students were involved in validating the instrument which had a KR-20 reliability of 0.91.

Scientific Observation and Comparison Test (SOCT) - This instrument was developed by Hungerford and Miles (1969). The observation part of the instrument was scored on three dimensions: a) excellence in drawing, b) ability to communicate biological features, and c) labeling of these features. The comparison portion of the instrument involved ability to reasonably and accurately compare.

Wisconsin Inventory of Science Process (WISP) and Science Process Inventory (SPI) - are composed of 93 and 135 items, respectively. Both instruments are designed to be used to secure information relative to a) the assumptions

of science, and b) the operations of science. The possible responses are: "accurate", "inaccurate" and "I don't know or understand" for WISP, and "agree" or "disagree" for SPI. Scores on the instruments are based upon "wrong" or "correct" response to each of the items.

Science Process Skills Test (SPST) - was developed by Molitor and George (1976). The instrument consists of 18 items intended to assess a) inference, and b) verification skills of pupils in grades four, five, and six.

Test on Understanding Science (TOUS) - This was developed in two different versions (Form W: Cooley and Klopfer, 1961; and Form Jw: Klopfer and Carrier, 1970). TOUS consists of 60 items of the multiple choice type that are categorized into three subscales: a) understanding about scientific enterprise, b) the scientists, and c) methods and aims of science. Content was based on the views of scientists, science educators, historians and philosophers on each of the subscales.

Science Support Scale (SSS) - This instrument was developed by Schwarian (1968) on the basis of Barber's "Science and Social Order" (rationality, utilitarianism, individualism, progress and meliorism). An item analysis of students' responses to the items on the instrument led to the selection of eight items for inclusion in the final version of the instrument.

Test on the Social Aspects of Science (TSAS) - This instrument was developed by Korth on the basis of the following assertions:

a) Science and technology interact with each other and the society,

b) the scientific enterprise is an internally regulated institution, and

c) the changes in society resulting from advanced science and technology may produce social, economic, political problems which must be merged through appropriate social and political processes.

TSAT was intended for detecting "differences between science oriented and non-science oriented aspects of science."

Nature of Scientific Laws, and Theories (NSLT) and Nature of Scientific Conceptions, Laws, and Theories (NSCLT).

NSLT was developed by Rowe (1976) while NSCLT was developed by Ogunniyi (1977). Both NSLT (56 statements) and NSCLT (68 statements) were designed to determine understandings of the nature of science by using statements related to the philosophical nature of scientific concepts, laws, and theories. The items were arranged on a modified Likert-type scale (agree, disagree, don't know, and

incomprehensible) and were based on published positions of five (NSLT) and six (NSCLT) selected philosophers of science.

Some other instruments related to measures of the understandings of the nature of science include:

Understanding the Nature of Scientific Inquiry Test (UNSE): Jungwirth, 1970.

Science Attitude Inventory (SAI): Moore and Sutman, 1970.

Science Attitude Scale (SAS): Allen, 1959.

Science Attitude Questionnaire (SAQ): Wilson, 1954.

Burmester Test of Aspects of Scientific Thinking (BTAST): Burmester, 1953.

Facts About Science Test (FAST): Educational Testing Service, 1958.

Inventory of Science Attitudes, Interests, and Appreciations (ISAIA): Swan, 1966.

Nature of Science Test (NOST): Billeh and Hasan, 1975; and Billeh and Malik, 1977.

In general, the range of instruments that have been developed to measure understandings of the nature of science exhibit a wide variety of patterns, ideas and titles. The response modes range from "correct answer" or "multiple choice" formats, to Likert-type scales. Criticisms which

have been directed towards the majority of these instruments include:

1. Multiple choice or correct answer type instruments which have been based upon a single "model" of science do not adequately reflect the divergent philosophical viewpoints about the nature of science. Such instrument developers fail to realize that answers could be scored differently depending upon the philosophic orientation of the test respondent. Some instruments with such stereo-typed images of science include: TOUS, TOSP, POST, and NOST (Aikenhead, 1973; Doran, Guerin, and Cavalieri, 1974; Lucas, 1975; Connelly, 1969; and Wheeler, 1968).
2. Instruments like NOSS, SAQ, and SSS that utilize a Likert-type scale (i.e., "agree", "disagree", etc.) have generally derived items from the writings of only one or two scholars. Such instruments, therefore, fail to represent the many diverse opinions that exist about the nature of science (Welch, 1969; Connelly, 1969; Aikenhead, 1973; Doran, Guerin, and Cavalieri, 1974; Lucas, 1975).
3. Instruments like TOSP, LSPT, SOCST, UNSE, POST and MPS that attempt to test respondents' abilities to perform process skills, fail to solicit the role

of such "processes" in the development of scientific knowledge.

4. Instruments that solicit an attitude toward science do not necessarily measure understanding of the nature of science. Such instruments include SAS, SSS, SAI, ISAIL, and SAQ (Aikenhead, 1975; Rowe, 1976).
5. Instruments like TOSP (based on science textbooks) and BTAST, and FAST (which lack documentation) have the problem of philosophic validity.

RESEARCH STUDIES ON SCIENCE TEACHERS' UNDERSTANDINGS OF THE NATURE OF SCIENCE

Several studies have been undertaken to ascertain elementary and secondary school science teachers' understandings of the nature of science.

A Study Using the Interview Procedure to Determine Science Teachers' Understanding of the Nature of Science

Herron (1969) taped interviews with 50 high school teachers in an attempt to determine a) the teachers' perceptions of the point of view of scientific inquiry as contained in curriculum materials they were using, and b) the point of view held by the teachers themselves. Of the 50 teachers involved in the study, 17 taught CHEM study or CBA, 17 taught PSSC physics, and 16 taught BSCS biology.

Analysis of the tape recordings led the investigator to conclude that

> only six respondents were able to verbalize concerning the inquiry purposes of their course materials at somewhere near the level of presentation represented by the materials they were using. Only two respondents demonstrated sufficient familiarity with the questions and issues concerning problems of teaching science as inquiry to be able to discuss course materials in some large context.

The implications of Herron's study are weakened by the fact that: 1) it does not appear to be replicable, and 2) the sample was biased. Herron reported that "the format and strategy of the interview could be changed if early questions were not successful in eliciting relevant information." Further, the population was improperly defined--summer institute.

A Study Using the Nature of Science Scale (NOSS) to Measure Science Teachers' Understanding of the Nature of Science

Kimball (1967-68) compared scores of 419 scientists and 78 science teachers of similar academic background on NOSS. He found no significant difference between the scores of the two groups. The fact that Kimball used a non-random sample for the study prohibits any generalizations of his results beyond the subjects actually studied.

Studies Using SPI and WISP to Measure Science Teachers' Understanding of the Nature of Science

In a study in Nigeria, Falayajo (1974) administered SPI, Test of Science Knowledge, Critical Thinking Appraisal and Cognitive Preference Examination to a group of preservice science teachers in four Advanced Teacher Training Colleges. The investigator reported that the general performance of the teachers was "fairly low" on all the instruments. In addition, the investigator found no significant difference between 1st, 2nd and 3rd year preservice teachers. Falayajo attributed the low performance of the pupils to the fact that "no opportunity is provided in the students' programs for gaining such knowledge."

Miller (1969) used SPI to compare the knowledge of the processes of science held by six prospective elementary school science teachers, prospective secondary social studies teachers, high school science teachers, and research scientists. The investigator reported that prospective elementary school science teachers scored higher than high school science teachers, about the same as prospective secondary social studies teachers, and lower than the other groups.

Studies Using TOUS to Determine Science Teachers' Understandings of the Nature of Science

Miller (1963) utilized TOUS to compare the level of understanding of the nature of science possessed by science

teachers and high school students in grades 7-12. The investigator reported that 50% of the teachers scored lower than 38% of the high ability students in grades 11 and 12. The implication of this finding is that a large portion of the teachers had less understanding of the nature of science than the students they teach. The overall mean score was 42.10 for the high ability 11th and 12th grade students and 43.60 for the teachers.

Schmidt (1967-68) repeated Miller's study with grades 9, 10, 11 and 12 high ability students, science teachers and 116 scientists. The mean scores for the students, teachers and scientists were 41.00, 45.50, and 50.80, respectively. The interesting part of the study was that 5% of the high ability 9th grade and 9% of the high ability students in the 11th grade obtained scores higher than those obtained by 50% of the teachers.

Broadhurst (1967) used Form W of TOUS in a study involving 108 senior secondary school chemistry students and their teachers in Australia. The investigator reported that when the scores of all the pupils were compared with those of their teachers, it was found that the teachers' scores were significantly better.

Studies Using Philosophical Descriptions of the Nature of Scientific Concepts, Laws, and Theories to Describe Conceptualizations of the Nature of Science Secondary School Science Teachers Hold

Rowe (1976) constructed a 56-item questionnaire on the nature of scientific laws and theories (based on a published writing of each of five philosophers of science: Lachman, Popper, Hempel, Kemeny, and Carnap). The study involved a randomly selected sample of 50 Wisconsin middle school science teachers. The attempt was to determine i) the teachers' conceptualizations of scientific laws and theories, and ii) the opinions of the teachers relative to the importance and chance attainment of a set of objectives related to the understanding of the nature of the scientific enterprise. The results are as follows.

1. The teachers were inconsistent relative to the meanings they associated with the terms "scientific law" and "scientific theory". The teachers varied greatly in their conceptualizations of laws and theories.
2. The teachers agreed more often with Lachman and least with Popper.
3. Nearly 60% of the teachers considered the understanding of how scientific knowledge is developed as the goal of highest priority or expectation.

4. Nearly 40% of the teachers considered the understanding of scientific laws and theories as the goal most readily achieved by their pupils.
5. Nearly 60% of the teachers considered awareness of the cultural and historical aspects of science as the least attainable goal of science teaching.

Ogunniyi (1977) constructed a 68-item instrument to determine the conceptualizations of "scientific concepts", "scientific laws" and "scientific theories" held by Kwara State, Nigeria, secondary school science teachers. The statements were written to reflect a published writing of seven selected philosophers of science (Nash, Frank, Hempel, Popper, Kemeny and Carnap). The investigator sought to determine the following:

1. The conceptualizations of the teachers relative to definitions, characteristics, formation and function of scientific laws, theories and concepts.
2. The consistency of the teachers' conceptualizations relative to those identified with each of the selected philosophers of science.
3. The similarities or differences which might exist between Kwara State science teachers and Wisconsin middle school science teachers in their responses

to statements about scientific concepts, laws and theories.

The reported results are:

1. The teachers hold conceptualizations of scientific concepts, laws, and theories that are frequently disparate and sometimes contradictory or philosophically inconsistent.
2. The teachers appear to prefer Hempel's conceptualizations of scientific concepts, laws and theories.
3. In contrast to Wisconsin middle school science teachers who prefer inductive conceptualizations of the nature of science, Kwara State secondary school science teachers tend to endorse hypothetico-deductive conceptualizations of the linguistic structure of science.
4. Kwara State science teachers tend to agree with all the selected philosophers of science as a group rather than as individuals on certain aspects of the linguistic structure of science.

Studies like those of Rowe (1976) and Ogunniyi (1977) that attempt to determine which of the selected philosophical views the teachers identify most with, must satisfy both of the following conditions.

1. Utilize equal numbers of statements from each of the selected philosophers.

2. Ensure that any two sets of philosophical statements being compared are on a one-to-one basis, in disagreement with one another. This means that in order to legitimately say that a group of teachers prefer the views of one philosopher over those of the other, the two philosophers must clearly hold opposing views on the same property of the concept of science under discussion.

While Rowe (1976) failed to satisfy both of these conditions, Ogunniyi (1977) satisfied only the first condition.

From analyses of the studies related to elementary and secondary school science teachers' understandings of the nature of science reviewed in this section, it may be concluded that the findings have been conflicting and in a number of cases, insignificant. Carey and Stauss (1969) and Billeh and Hasan (1975) used the findings of most of these studies to conclude that science teachers do not have an adequate understanding of the nature of science. Such claims are questionable for three basic reasons.

1. Most of the researchers have failed to provide an adequate representation of what it is they mean by the "nature of science."

2. As pointed out previously, the instruments used in most of the studies may not necessarily be measuring what they were designed to measure (e.g., the issue of the construct validity of many of the instruments is questionable).
3. In most of the studies, the conclusions have been based on combined responses to a set of unrelated items. Since the nature of science is broad, the researchers have failed to identify the particular aspects of the nature of science the teachers have misconceptions about.

RESEARCH STUDIES ON RELATIONSHIPS BETWEEN SCIENCE TEACHERS' UNDERSTANDINGS OF THE NATURE OF SCIENCE AND VARIOUS INDEPENDENT VARIABLES

Effect of Special Training

Welch and Walberg (1967-68) attempted to determine the understandings of the nature of science held by four groups of physics teachers attending a six-week summer institute. The instruments used in the study included: TOUS, SPI and Test on Selected Topics of Physics (TSTP). The three tests were administered to the teachers at the beginning and end of the six-week institute. The investigators found that:

1. All the four institutes showed significant gains ($p > 0.005$) on at least one of the three

instruments while two of the institutes showed significant gains on all the three institutes.

2. Scores of TOUS closely paralleled that on SPI.

Billeh and Hasan (1975) attempted to determine the effects of special instruction on secondary school science teachers' understanding of the nature of science. The investigators also attempted to identify the variables that might contribute to gains in understanding of the nature of science. The instrument used in the study is a modified version of TOUS (Nature of Science Test). The population consisted of 171 teachers in Jordan who were attending a summer training course. The investigators reported that there was no significant difference between teachers' gain scores and any of the investigated variables: educational qualification, the subject(s) they teach, their science teaching experience, and previous inservice training experience (at 0.05 level of significance).

Kennedy (1973) studied the effect of "process approach instruction" on changing pre-service elementary science teachers' attitude toward science. The factors utilized for measuring the attitudinal changes include: (1) observation, (2) measurement, (3) process approach, (4) controlling variables (5) interpreting data, and (6) formulating a problem. The entire course structure was individualized and it required the teachers to develop

and implement science process experiments that would account for all the variables considered. The investigator reported that the overall attitude of the preservice teachers toward science became significantly more receptive and their attitude strengthened greatly after instruction utilizing a "process approach." He interpreted this to be an indication that special instruction results in improved understanding of the nature of science.

Other Independent Variables

Very few investigations were undertaken to determine the relationship between teachers' understanding of the nature of science and selected variables like teaching experience, academic background, subjects taught, sex, etc.

Jerkins (1967) reported a study designed "to measure understanding of science and scientists by selected academic groups." This investigation was conducted at three institutions of higher learning and involved a number of classes in each of the following categories.

1. Freshmen and sophomores enrolled in general education science courses for non-science majors.
2. Elementary school science teachers enrolled in graduate level science education courses.
3. Upperclassmen enrolled in special methods courses for prospective secondary school science teachers.

4. Secondary school science teachers enrolled in graduate level science education courses.

In terms of overall performance, Jerkins reported that: "The analysis of data showed that 85% of the classes were remarkably similar with regard to average TOUS total scores." He further reported that comparable academic groups at a given school were not different with regard to understanding of the nature of science and scientists as measured by TOUS-Form W, while there were significant differences in overall comparisons involving comparable groups at different schools.

Carey and Stauss (1968) reported a study concerning prospective secondary school science teachers' understanding of the nature of science as measured by WISP. The investigators attempted to determine the teachers' understanding of the nature of science as related to the following independent variables: (1) number of quarter credit hours of course work in various college-level science and mathematics courses, and (2) grades achieved in these respective areas. The results of the study with 17 prospective teachers revealed no significant relationship between understanding of the nature of science (as measured by WISP) and the academic variables considered (with the exception of WISP pre-test scores and the biological science averages). This led the investigators to conclude that

"an understanding of the nature of science may not necessarily be achieved through the completion of college science courses, or not participating in the activities of science in these courses."

In a more elaborate study, Carey and Stauss (1969) used TOUS and WISP in an attempt to determine the relationships between the teachers' understandings of the nature of science and selected academic variables: (1) high school science units, (2) college mathematics hours, (3) college biological science hours, (4) college physical science hours, (5) college mathematics grade point average, (6) college biological science grade point average, (7) college physical science grade point average, (8) total college science grade point average, and (9) total college grade point average. The study involved 35 prospective secondary school science teachers. Analyses of the scores on the two instruments led the investigators to conclude that:

1. Little, if any, relationship exists between the prospective secondary and elementary school science teachers' understanding of the nature of science and the academic variables.
2. Little, if any, relationship exists between the academic variables and the prospective secondary and elementary school science teachers' understandings of the assumptions on which science is

based and the processes by which it operates and progresses.

However, the investigators were quick to point out that these findings are generalizable only to the population of teachers studied.

Meinhold (1961) used the Test of the Methodology of Science to test the relationship between science teachers' understanding of the nature of science and certain selected variables: professional training and teaching experience. The investigators reported no significant relationship.

Lavach (1968) designed an inservice program on the historical development of selected physical science concepts for teachers representing several disciplines and various levels of professional experience. The purpose of the study was to "examine any changes in attitude toward an understanding of the nature of science, scientists, the scientific enterprise and the objectives or aims of science on the part of students after exposure to an historically oriented program." The investigator reported that teachers made statistically significant changes in their attitude towards the nature of science. This gain was, however, not related to the subjects they teach, undergraduate major, previous inservice participation, or length of teaching experience in the same subject.

Using a population of prospective elementary and secondary school science teachers in five Wisconsin universities, Wood (1972) found that (as measured by WISP):

1. Prospective elementary school science teachers scored lower than prospective secondary school science teachers (65.35:68.67).
2. No significant correlation existed between factors like sex, number of university credits, years of high school science and teachers' understanding of the nature of science.
3. There was significant correlation between average grade point of science courses taken at university level, and scored on WISP (at 0.01 level of significance).

Mackay (1971), working in Australia, used TOUS to measure how teacher understanding of the nature of science is related to the following selected variables: (1) teaching experience, (2) subject(s) taught, (3) sex, and (4) in service training course attendance. The investigator reported that teacher understanding of the nature of science was related to each of these variables.

Billeh and Malik (1977) developed an instrument based on a modification of TOUS and WISP. The instrument contained 55 items and was administered to three groups of teachers in different training programs in Pakistan. The

three programs are: Bachelor of Education (B.Ed.), Master of Education (M.Ed.) and Master of Arts in Education (M.A.Ed.). The investigators sought to determine:

1. the relative levels of understanding of the nature of science as well as each of its components among prospective science teachers, and
2. any significant difference in understanding of the nature of science and understanding of its components among prospective science teachers who have completed a certain program and those are just enrolled in that program.

Analysis of the scores on the tests led the investigator to conclude that:

1. the level of understanding of the nature of science possessed by prospective science teachers was generally unsatisfactory, and
2. The M.Ed. and M.A.Ed. programs are equally effective in developing a better understanding of the nature of science. The two programs were more effective than the B.Ed. program in promoting an understanding of the nature of science.

Studies of the relationships between science teachers' understanding of the nature of science and selected independent variables have produced inconclusive results. In addition to the problems related to the validity of the measuring instruments outlined previously, the

inconclusiveness of most of the findings can be attributed to the fact that the conclusions have been based upon analyses of responses to a combination of test items. Thus, while it may be possible for an investigator to find differences in responses to individual items, such differences might be confounded by responses to other items on the questionnaire.

IMPLICATIONS FOR THE PRESENT STUDY

In Chapter I and the previous sections of this chapter, criticisms were leveled against many of the past research efforts at measuring science teachers' understandings of the nature of science. The studies were specifically criticized on the following grounds:

1. Many of the instruments used were based on particular interpretations of the nature of science. Thus, such researchers failed to include other existing legitimate interpretations of the nature of science in the design of their studies. This criticism goes for many of the studied where "correct answers" were sought to items based on narrow views of science.
2. Since the nature of science is a broad concept, a single instrument designed to measure all aspects of science is doomed to fail.

3. Many of the studies which examined relationships between science teachers' understandings of the nature of science and various independent variables, have arrived at their conclusions by combining responses to different items on the instrument. Such researchers overlooked the possibility of inter-item interaction when examining responses.

For these reasons, the procedures adopted in the current study were designed to overcome the shortcomings of past research studies on the understandings of aspects of the nature of science. Specifically;

1. a new instrument was to be developed for use in obtaining descriptions of scientific experiments held by science teachers,
2. the pattern of response was to be such that it did not solicit "correct answers",
3. the instrument was to be based on the views of a larger number of philosophers of science than in most of the previous studies. However, it must be pointed out that this does not mean that the items on the instrument used in the study being reported represent the universe of views on the nature of scientific experiments,
4. each of the items on the instrument was to describe only one particular property of scientific experiments, and

5. where comparisons of respondents are made, conclusions are to be drawn on the basis of responses to individual items.

As in many of the previous studies reviewed, the instrument used in the current study was designed in the form of a questionnaire for the following reasons:

1. It assures respondents of their anonymity. Kendall (1954) has argued that "the questionnaire has the distinct advantage of decreasing motivations to give dishonest and evasive answers" (p. 115).
2. All the respondents receive the same set of questions phrased in exactly the same way. This procedure yields data which are easily comparable.
3. The procedure is economical and thus allows the investigator to reach a greater number of respondents with minimum cost (Sax, 1968; Nesbitt, 1970).

A questionnaire does have the disadvantage of yielding information on what people say, not necessarily what they do. In addition, there is the problem of the content validity of the instrument as well as the consistency of the individual's responses. The procedure of including "check questions" (Chapter III) is supposed to help in assessing the consistency of the individual's responses (Goode and Hatt, 1952; Berdie and Anderson, 1974; and Engelhart, 1972). Content validity can be taken care of during the development of the instrument (Chapter III).

CHAPTER III

PROCEDURES

Nature of the Study

The purpose of this study was to determine the descriptions of scientific experiments held by Niger State, Nigeria, post-primary school science teachers during the 1978-79 school year. In addition, an attempt was made to determine if differences in educational background, number of years of teaching experience, and the subject(s) taught are accompanied by differences in the way the teachers describe scientific experiments.

Design of the Study

Instrument Development

In order to answer the questions addressed in the current study, a new instrument consisting of statements on the nature of scientific experiments was developed.

The statements on the instrument were obtained as follows:

1. Each statement was written as a summary of a set of sentences or paragraphs dealing with specific aspects of the nature of scientific experiments (see 2 below) in any one of the following 10 selected philosophical publications.

a) The Art of Scientific Investigation. W.I.B. Beveridge (1950).

b) An Introduction of the Philosophy of Science. Rudolph Carnap, edited by Martin Gardner (1976).

c) Philosophy of Science. Phillipp Frank (1962).

d) Patterns of Discovery. Norwood Hanson (1958).

e) Philosophy of Natural Science. Carl R. Hempel (1966).

f) Scientific Method: The Hypothetico-Experimental Procedure of the Physical Sciences. James K. Fiebleman (1972).

g) A Philosopher Looks at Science. John G. Kemeny (1959).

h) The Logic of Scientific Discovery. Karl Popper (1959).

i) The Nature of the Natural Sciences. Leonard Nash (1963).

j) The Philosophy of Science: An Introduction. S. Toulmin (1960).

The 10 texts were selected from an initial list of over 25 philosophical publications on the basis of the fact that they contained specific sections dealing with aspects of scientific experiments.

2. Each of the 10 texts was critically examined page by page for discussions of issues related to one or more of the following categories:
   a) definitions of scientific experiments,
   b) procedures for conducting exientific experiments,
   c) analyses of the results of scientific experiments,
   d) interpretation of the results of scientific experiments,
   e) design of scientific experiments, and
   f) functions of scientific experiments (with specific reference to relationships between scientific experiments and scientific generalizations like hypotheses, laws and theories).
3. The statements were compiled and submitted to a panel of three philosophers of science at the University of Wisconsin for independent and critical examination (validation).
   a) Statements considered by two or more of the members of the panel as having been quoted out of context were re-written and resubmitted to them for examination.
   b) Statements identified by two or more of the members of the panel as not representing the

views of the philosophers with whom they were identified were eliminated.

c) One of any two statements considered by the members of the panel as being duplications was eliminated.

At the end of the validation process, an initial list of 60 statements was obtained.

4. In addition to the 60 statements, five statements were written by the investigator and included on the instrument. These statements reflected views that are essentially contradictory to statements identified with the 10 selected philosophers of science or commonplace usage of the term "scientific experiment". Example of such contradictory statements:

> The results of a particular scientific experiment can have several possible interpretations.
>
> The results of a particular scientific experiment can have only one possible interpretation.

These sets of contradictory statements were included on the instrument to serve as "check-questions". These "check-questions" were meant to help determine the consistency of the individuals' responses to the items on the instrument. This is in line with the suggestions of

of Ackoff (1953), Goode and Hatt (1952), Birdie and Anderson (1974) and Engelhart (1972). The specific assumption here is that a consistent respondent would not give a positive response to both members of pairs of contradictory statements.

4. The 65 statements making up the initial instrument were pilot-tested by submitting it to:

   1) Twelve prospective science teachers at the Advanced Teachers' College, Zaria, Nigeria.

   b) Twelve prospective science teachers at the University of Ibadan, Nigeria.

   This was done in order to:

   a) ascertain if respondents had difficulty following the directions for the completion of the instrument, and

   b) identify those statements with which the respondents had language difficulty.

   In addition, the respondents in the pilot-study were asked to include any comments they might have on the questionnaire as a whole. From analyses of the responses and comments of the respondents in the pilot-study, it was found that six statements needed to be reworded while three were cancelled because over 90% of the members of the pilot group expressed difficulties with them.

The 62 statements which made up the final questionnaire were arranged in such a way that no two statements related to the same aspect of scientific experiments occurred in sequence. For example, no two statements describing relationships between scientific experiments and scientific laws were allowed to occur in immediate sequence.

The 62 statements making up the final questionnaire (Appendix I) were of two types:

1. Statements related to the characteristics of scientific experiments. Specifically, these statements refelected views related to definitions and design of scientific experiments, analyses and interpretations of the results of scientific experiments, and procedures for conducting scientific experiments. Examples follow:
   a) All observations made during the conduct of scientific experiments are always planned before hand.
   b) Scientific experiments involve only the process of induction.
   c) There are no universally accepted steps of procedure that are followed when performing scientific experiments.
   d) There are universally accepted steps of procedure that are followed when performing scientific experiments.

e) Scientific experiments always involve quantitative observations.

2. Statements describing relationships between scientific experiments and scientific generalizations. Specifically, such statements describe relationships between scientific experiments and scientific theories, laws and hypotheses. Examples follow:
   a) A single scientific experiment could be crucial in any decision to accept or reject one of two conflicting scientific laws.
   b) Scientific experiments are performed to falsify scientific hypotheses.
   c) Scientific experiments are performed to confirm scientific theories only by the indirect confirmation of the consequences of the theories.
   d) Scientific experiments are performed to predict new scientific laws.
   e) Scientific experiments are performed to confirm scientific laws.

   In addition, there is one statement (Number 10, Appendix I) that does not fit into any of the above groups. However, since no rigid categorizations of the statements was made on the final questionnaire, this was not considered as a

problem. Further, the distinctions referred to above were made merely for the purpose of descriptive convenience. The statements are so interrelated that they can not be classified into independent categories.

Population of Teachers Studied

In order to answer the questions addressed in the current study, the instrument containing the 62 statement on scientific experiments was administered to a population of 103 science teachers in 22 of the 28 post-primary schools in Niger State at the time the study was conducted. Figure 1 shows the location of the towns visited while Appendix II lists the names of the schools involved. Figure 2 shows the distribution of the teachers according to the variables examined in the study.

Dependent Variables

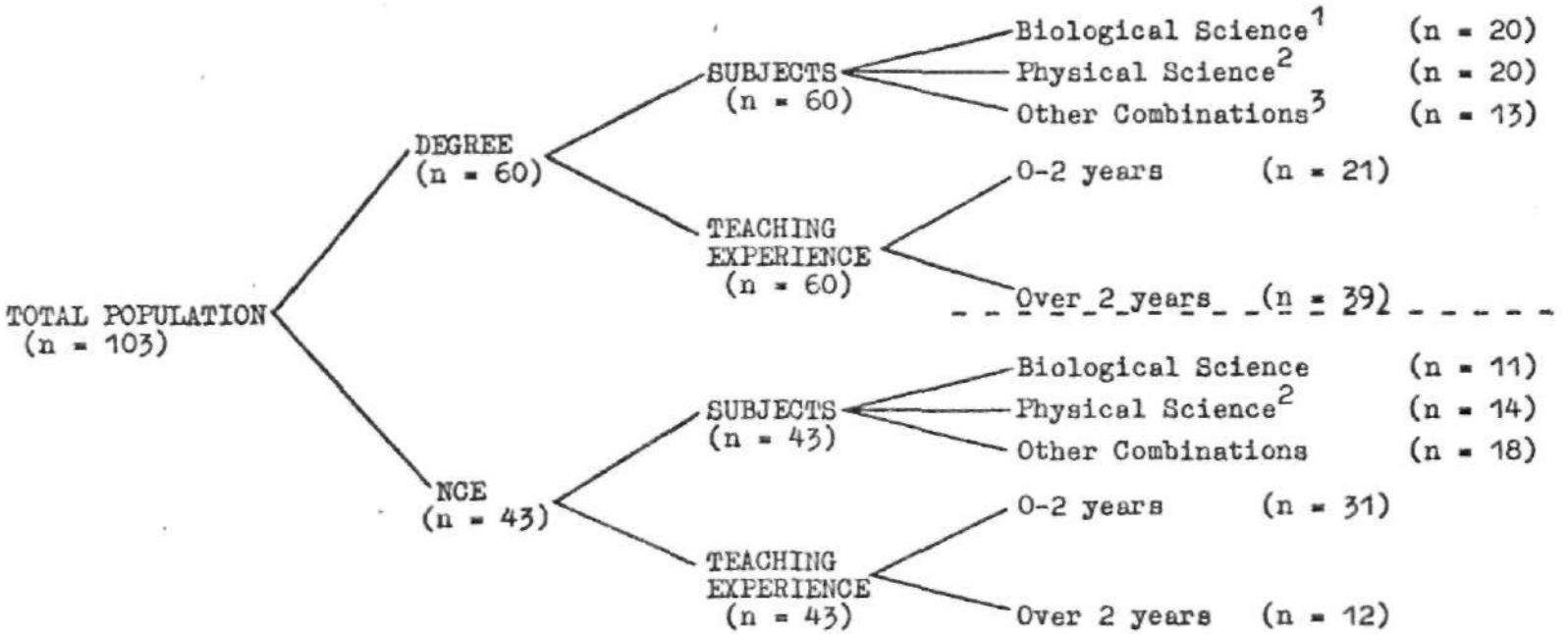
In order to solicit the descriptions of scientific experiments which the population of teachers involved in the current study hold, the teachers were asked to respond to one of two ways to each of the 62 statements on the questionnaire (Appendix I).

1. "Yes" - indicating that the respondent would include the particular statement in his/her description of scientific experiments.

MAP OF STUDY AREA - NIGER STATE, NIGERIA.



Figure 2. DESCRIPTIONS OF THE POPULATION OF TEACHERS STUDIED.



N.B.

Biological Science[1] - Biology, Health Science, Agricultural Science, or any of their combinations.

Physical Science[2] - Physics, Chemistry or their combination.

Other combinations[3] - Combinations which can not be classified as either physical or biological science.

2. "No" - indicating that the respondent would not include the particular statement in his/her description of scientific experiments.

The "yes" responses of the teachers to each of the items on the questionnaire were used in obtaining the descriptions of scientific experiments that they hold.

Independent Variables

In order to address the three sub-problems in the study, the "yes" responses of the teachers to each of the 62 statements on the questionnaire were classified according to their educational background, years of teaching experience, and the subject(s) they teach (Figure 2).

Education Background

Each of the teachers involved in the current study has one of two educational qualifications: (i) university degree, or (ii) Nigerian Certificate of Education (NCE).

There are four basic differences between the two groups of teachers.

1. Prospective NCE teachers enter the three-year training program following five years of post-primary school while prospective degree teachers enter the three-year university training program following six to seven years of post-primary school.

2. The amount of science which prospective NCE science teachers studied by the end of their training is usually equal to the amount of science studied during the first university year.
3. More emphasis is placed on education and psychology courses at the NCE level (in proportion to the amount of science) than at the university level.
4. In almost all cases, teachers with NCE qualification are assigned to teach the junior grades (grades 1-3) while teachers with university degree teach the senior grades (grade 4 and above).

In order to determine if a difference in educational background is accompanied by differences in the way the teachers describe scientific experiments, the "yes" responses of teachers with a university degree were compared to the "yes" responses of those with the NCE qualification on each of the 62 statements.

Teaching Experience

In order to determine if differences in numbers of years of teaching experience are accompanied by differences in the way the teachers describe scientific experiments, the 103 teachers were classified according to two levels of teaching experience (as a group, and within each educational background): (i) 0-2 years, and (ii) over 2 years.

The two levels of teaching experience were selected because two years represents the minimum number of years that teachers have to serve before they can qualify to go for further training. This is particularly true of teachers with NCE qualifications who wish to go into the university to earn a degree.

In order to specifically address this problem, comparisons of the "yes" responses to each of the 62 statements by the following groups were made.

1. All teachers - 0-2 years experience vs over 2 years experience.
2. NCE teachers - 0-2 years experience vs over 2 years experience.
3. Degree teachers - 0-2 years experience vs over 2 years experience.

Subjects the Teachers Teach

Teacher training programs in Nigerian universities and advanced teacher training colleges generally emphasize what is often referred to as "combined honors." Under this system, preservice teachers are required to specialize in more than one (usually two) science subject. Because the teachers could not be examined on the basis of individual subjects, a decision was made to categorize them into three groups.

1. Biological science teachers (biology, health science, and agricultural science combinations).
2. Physical science teachers (physics, mathematics, and chemistry combinations).
3. Other teachers (combinations of biological and physical science subjects).

In order to determine if differences in the subjects the teachers teach are accompanied by differences in the way the teachers describe scientific experiments, the following comparisons of percentage "yes" responses to each of the 62 statements on the questionnaire were made.

1. All teachers - Biological Science vs Physical Science
2. NCE teachers - Biological Science vs Physical Science
3. Graduate teachers - Biological Science vs Physical Science

Data Collection

About four months prior to the intended time of data collection, a letter was written to the Permanent Secretary Niger State Ministry of Education, outlining the intent of the study and requesting his permission to conduct the study (Appendix IV). No reply was received from the Ministry. However, prior to the time when the study was undertaken, information was received from one of the principals

of the schools involved in the study to the effect that they had been instructed to cooperate with me in any way possible. As a result of this information, no follow-up request was made to the Ministry of Education.

The investigation was undertaken during the months of January and February 1979. This period was chosen because it is early in the school term and therefore the teachers were expected to be less occupied with their teaching responsibilities. All the teachers involved in the current study were contacted individually by visits to the schools.

On the first visit to each school, the questionnaires were distributed to the teachers (under the direction of the principal or his assistant) with a request that they be completed and returned to the respective principals by the following day. A day or two later, a return visit was made to the schools to collect the completed questionnaires. Because of the cooperation of many of the principals, there were only five misplaced questionnaires. New ones were given to this group of teachers to be completed almost immediately.

A total of 115 questionnaires was distributed among the teachers in the 22 of the 28 post-primary schools that offer science courses. The remaining six schools were not visited because:

1. They are loacted in remote parts of the state.

2. At the time the data were collected, there was an acute fuel shortage in Nigeria. This made travel to remote parts impossible.

Of the 115 questionnaires distributed among the teachers, 106 were returned and of these, three did not respond to all the items as requested in the directions for completion of the questionnaire. The three were therefore dropped from the study.

Treatment of Data

The procedure adopted for analyzing any research data depends on the questions asked, and the design adopted. The intent of this study was to:

1. Determine the descriptions of scientific experiments that are held by Niger State post-primary school science teachers.
2. Determine if teachers with a university degree describe scientific experiments differently from those with the Nigerian Certificate of Education.
3. Determine if teachers with 0-2 years of teaching experience describe scientific experiments differently from those with over 2 years teaching experience.
4. Determine if teachers with a given educational background and 0-2 years of teaching experience

describe scientific experiments differently from those with the same educational background and over 2 years of teaching experience.

5. Determine if teachers who teach physical science courses describe scientific experiments differently from those who teach biological science courses.
6. Determine if teachers with a given educational background who teach physical science courses describe scientific experiments differently from those with the same educational background who teach biological science courses.

In order to specifically address the first problem, a particular statement was considered as being a part of the description of scientific experiments held by the teachers as a group, if 75% or more of them responded "yes" to the particular statement. The figure of 75% was set arbitrarily, however, it was found to be in general use in survey studies of this nature.

Because this study involved all of the available population of science teachers in post-primary schools, it was not possible to use inferential statistics in order to address questions 2-5. However, Cohen (1969, p. 242) suggests three conventional definitions of minimum difference (effective size) for comparisons of proportions in contingency

tables: a) small effective size - 0.05; medium effective size - 0.10; and c) large effective size - 0.20. While the comparisons of the percent "yes" responses by the groups of teachers examined in this study were not done using inferential statistics, a decision was made to adopt Cohen's large effective size (0.20). This means that a difference in the percent "yes" responses of two given comparison groups to each statement is said to exist if there is a difference of 20% or more in the percent "yes" responses of the two groups to the statement. The comparisons were made for only those statements which 75% or more of the individuals in only one of the two comparison groups gave "yes" responses (i.e., only the statements which only one of the two comparison groups included in its description of scientific experiments--as outlined above).

CHAPTER IV

RESULTS

The results of the data treatment reported in this chapter have been organized and presented in two parts. Part A reports the descriptions of scientific experiments held by Niger State post-primary school science teachers. Part B reports the results of comparisons of the percent "yes" responses to statements about scientific experiments by groups of teachers:

1. with different educational background--NCE vs degree,
2. with different numbers of years of teaching experience--0-2 years vs over 2 years,
3. with the same educational background but different numbers of years of teaching experience,
4. teaching physical science courses and those teaching biological science courses, and
5. with a given educational background teaching physical science courses and those with the same educational background teaching biological science courses.

In keeping with the descriptive pattern used in the previous chapters, the descriptions of scientific experiments held by the teachers is presented in a way that

reflects the teachers' percent "yes" responses to statements about:

1. the characteristics of scientific experiments, and
2. the relationships between scientific experiments and scientific generalizations.

Since the representativeness of the responses of each of the statements relative to the total population of Niger State post-primary school science teachers can not be ascertained, and since no sample was taken, the results are generalizable only to the population of 103 teachers studied.

Science Teachers' Descriptions of Scientific Experiments

The results of the analysis of the descriptions of scientific experiments held by the teachers as a group presented in this section consist of statements to which 75% or more of the teachers responded "yes" (as described in Chapter III).

Table 1 records the frequency and percentage of "yes" responses to statements about scientific experiments by the teachers as a group and with regard to their educational backgrounds. An examination of Table 1 reveals that the teachers as a group included the characteristics described in items 8, 13, 16, 22, 23, 29, 30, 33, 35, 39, 46, 47, 51, 58 and 60 in their descriptions of scientific experiments. The teachers as a group also included items

TABLE 1

FREQUENCY AND PERCENTAGE OF SCIENCE TEACHERS' "YES" RESPONSES TO STATEMENTS ABOUT SCIENTIFIC EXPERIMENTS ACCORDING TO EDUCATIONAL BACKGROUND.

Statement number*	Statements about scientific experiments	All the teachers (N = 103)		Teachers with NCE (N = 43)		Teachers with degree (N = 60)	
		n	%	n	%	n	%
1.	The outcome of a scientific experiment depends on the technique of measurement employed	73	71	33	77	40	67
2.	A single scientific experiment could be crucial in a decision to accept or reject one of two conflicting scientific hypotheses.	87	85	36	84	51	85
3.	Scientific experiments can not conclusively prove or disprove a scientific law.	67	65	29	67	38	63
4.	Scientific experiments are always based on theoretical principles.	78	75	31	71	47	78
5.	Statements expressing the results of any given scientific experiment can refer only to that particular experiment.	36	35	16	37	20	33
6.	Scientific experiments involve only the process of induction.	21	20	11	26	10	17

*Statement numbers correspond to the enumeration used in the questionnaire in Appendix I.

TABLE 1 (continued)

Statement numbers*	Statements about scientific experiments	All the teachers (N = 103) n	%	Teachers with NCE (N = 43) n	%	Teachers with degree (N = 60) n	%
7.	Scientific experiments are performed to confirm scientific hypotheses.	84	82	27	86	47	78
8.	One primary prerequisite for the conduct of a scientific experiment is the formulation of the problem to be investigated.	96	93	40	93	56	93
9.	All the observations made during the conduct of scientific experiments are always planned before hand.	21	20	8	19	13	22
10.	The results of scientific experiments are the only basis for the formulation of scientific concepts.	68	66	30	70	38	63
11.	A single scientific experiment could be crucial in any decision to accept or reject any one of two conflicting scientific laws.	87	85	34	79	53	88
12.	Scientific experiments involve only the process of deduction.	20	19	10	23	10	17

TABLE 1 (continued)

Statement number*	Statements about ecientific experiments	All the teachers (N = 103)		Teachers with NCE (N = 43)		Teachers with degree (N = 60)	
		n	n%	n	%	n	%
13.	The results of a particular scientific experiment can have several possible interpretations.	87	85	36	84	51	85
14.	Scientific experiments are performed to falsify scientific hypotheses.	22	21	14	35	8	13
15.	The results of scientific experiments are interpreted only on the basis of present knowledge.	54	52	24	56	30	50
16.	Scientists working with similar experimental material may obtain conflicting results.	92	89	38	88	54	90
17.	Scientific experiments are performed to falsify scientific theories.	15	15	9	21	6	10
18.	The results of scientific experiments do not, on their own, lead to new knowledge.	29	28	17	40	12	20
19.	All but one of the factors involved in a scientific experiment are always held constant.	45	43	20	47	25	42
20.	Scientific experiments are performed to discover scientific hypotheses.	55	53	22	51	33	55

TABLE 1 (continued)

Statement numbers*	Statements about scientific experiments	All the teachers (N = 103)		Teachers with NCE (N = 43)		Teachers with degree n = 60)	
		n	%	n	%	n	%
21.	Scientific experiments are performed to formulate scientific theories.	72	70	30	70	42	70
22.	A decision to accept or reject one of two conflicting sets of experimental results is solely dependent on the one which is able to withstand the severest test.	82	80	33	77	49	82
23.	Experimentation in science involves the separation of complex phenomena into simple ones.	79	76	35	81	44	73
24.	All the conditions that could affect the outcome of a scientific experiment can not be completely controlled.	74	72	25	58	49	82
25.	The results of scientific experiments usually pose more questions than answers.	73	71	34	79	39	65
26.	Only the results of scientific experiments which agree with prediction are useful.	18	17	4	9	14	23
27.	There are no universally accepted steps of procedure that are followed in the conduct of all scientific experiments.	49	48	27	63	22	37

TABLE 1 (continued)

Statement numbers*	Statements about scientific experiments	All the teachers (N = 103) n	%	Teachers with NCE (N = 43) n	%	Teachers with degree (N = 60) n	%
28.	A scientific experiment consists of making an event occur under known conditions.	76	74	35	81	41	68
29.	Scientific experiments involve both inductive and deductive processes.	94	91	38	88	56	93
30.	The results of scientific experiments are useful only if they are repeatable or reproducible.	93	90	37	86	56	93
31.	It is impossible to completely determine all the factors that could affect the outcome of a scientific experiment.	79	76	36	84	43	72
32.	Scientific experiments are performed to discover scientific laws.	69	67	31	72	38	63
33.	Scientific experiments are special forms of observations.	87	85	36	84	51	85
34.	Statements expressing the results of scientific experiments can be applied to any of several related experiments.	60	58	23	54	37	62
35.	Scientific experiments can be used to check cause and effect relationships.	94	91	39	91	55	92

TABLE 1 (continued)

Statement numbers*	Statements about scientific experiments	All the teachers (N = 103)		Teachers with NCE (N = 43)		Teachers with degree (N = 60)	
		n	%	n	%	n	%
36.	No scientific experiment can on its own lead to a decision to accept or reject one of two conflicting scientific theories.	66	64	32	74	34	57
37.	Scientific experiments always involve qualitative observations.	47	46	24	56	23	38
38.	The results of scientific experiments always lead to new knowledge.	62	60	31	72	31	52
39.	Statements expressing the results of scientific experiments always include ideas for testing the implications of such results.	82	80	33	77	49	82
40.	Scientific experiments are performed to confirm scientific laws.	77	75	37	86	40	67
41.	Scientific experiments can never reveal all the possible differences between two contrasting phenomena.	63	61	27	63	36	60
42.	Scientific experiments can be used to check cause and effect relationships.	27	26	10	23	17	28

TABLE 1 (continued)

Statement numbers*	Statements about scientifi experiments	All the teachers (N = 103)		Teachers with NCE (N = 43)		Teachers with degree (N = 60)	
		n	%	n	%	n	%
43.	Scientific experiments are performed to establish scientific theories.	84	82	37	86	47	78
44.	Scientific experiments are performed to formulate scientific laws.	72	70	28	65	44	73
45.	No scientific experiment can conclusively prove or disprove a scientific hypothesis.	35	34	19	44	16	27
46.	The results of all scientific experiments are in one way or another useful.	96	93	39	91	57	95
47.	Scientific experiments are performed to verify scientific theories.	94	91	37	86	57	96
48.	The results of scientific experiments are accepted only after several trials agree with prediction.	87	85	40	93	47	78
49.	It is not possible to vary only one factor at a time in a scientific experiment.	41	40	22	51	19	32
50.	Scientific experiments are performed to verify scientific hypotheses.	77	75	29	65	48	80

TABLE 1 (continued)

Statement numbers*	Statements about scientific experiments	All the teachers (N = 103)		Teachers with NCE (N = 43)		Teachers with degree (N = 60)	
		n	%	n	%	n	%
51.	The products of scientific experiments are facts	82	80	37	86	45	75
52.	The results of scientific experiments are probabilities.	42	41	14	38	28	47
53.	Scientific experiments are performed to falsify scientific laws.	15	15	5	12	10	17
54.	Scientific experiments can not be used to prove or disprove scientific theories	44	43	17	40	27	45
55.	Scientific experiments are performed to predict new scientific laws	51	50	19	44	32	53
56.	The results of a particular scientific experiment can have only one possible interpretation.	24	23	11	26	13	22
57.	Scientific experiments involve only quantitative observations.	20	19	10	23	10	17
58.	Scientific experiments can be performed to test the fundamental assumptions of nature.	85	83	35	81	50	83

TABLE 1 (continued)

Statement numbers*	Statements about scientific experiments	All the teachers (N = 103)		Teachers with NCE (N = 43)		Teachers with degree (N = 60)	
		n	%	n	%	n	%
59.	Scientific experiments can be used to confirm scientific theories only by the indirect confirmation of the consequences of the theories.	44	43	19	44	25	42
60.	The results of scientific experiments are valid only under the precise set of conditions in which the experiment was conducted.	94	91	39	91	55	92
61.	There are universally accepted steps of procedure which are followed in the conduct of all scientific experiments.	60	58	22	51	38	63
62.	The results of simple scientific experiments are preferred over those of complex ones.	55	53	20	47	35	58

2, 4, 7, 11, 43, 47 and 50 which describe relationships between scientific experiments and scientific generalizations. An examination of the 22 statements that the teachers included in their descriptions reveals that four of the items 2, 11, 46 and 58, were not identified with any of the selected philosophers of science (Appendix II).

Differences in the Descriptions of Scientific Experiments Held by the Teachers According to the Selected Independent Variables

The frequency and percentage of "yes" responses to statements about scientific experiments by teachers with different educational background, different numbers of years of teaching experience, and different subjects taught are presented, respectively, in Tables 1, 2 and 3. Presented in this section is the analysis of differences in the percentage of "yes" responses by the comparison groups to statements that satisfied both of the following criteria:

1. Three-quarters (75%) or more of the individuals in only one of the two comparison groups must have given "yes" responses to the statements.
2. The percent difference between the "yes" responses given by the two comparison groups to a given statement must equal or exceed 20%.

Table 4 records the numbers of the statements on which the "yes" responses of several groups of teachers meeting criteria 1 and 2 differed.

TABLE 2

FREQUENCY AND PERCENTAGE OF SCIENCE TEACHERS' "YES" RESPONSES TO STATEMENTS ABOUT SCIENTIFIC EXPERIMENTS ACCORDING TO NUMBER OF YEARS OF TEACHING EXPERIENCE.

Statement number*	Statements about scientific experiments	All the teachers				Teachers with NCE				Teachers with degree			
		0-2 yrs. (N = 52)		Over 2 yrs. (N = 51)		0-2 yrs. (N = 31)		Over 2 yrs. (N = 12)		0-2 yrs. (N = 21)		Over 2 yrs. (N = 39)	
		n	%	n	%	n	%	n	%	n	%	n	%
1.	The outcome of a scientific experiment depends on the technique of measurement employed.	41	79	32	63	26	84	7	58	15	71	25	64
2.	A single scientific experiment could be crucial in a decision to accept or reject one of two conflicting scientific hypotheses.	45	87	42	82	26	84	10	83	19	91	32	82
3.	Scientific experiments can not conclusively prove or disprove a scientific law.	36	69	31	61	23	74	6	50	13	62	25	64
4.	Scientific experiments are always based on theoretical principles.	40	77	38	75	21	68	10	83	19	91	28	72

*Statement numbers correspond to the enumeration used in the questionnaire in Appendix I.

TABLE 2 (continued)

Statement numbers*	Statements about scientific experiments	All the teachers				Teachers with NCE				Teachers with degree			
		0-2 yrs. (N = 52)		Over 2 yrs. (N = 51)		0-2 yrs. (N = 31)		Over 2 yrs. (N = 12)		0-2 yrs. (N = 21)		Over 2 yrs. (N = 39)	
		n	%	n	%	n	%	n	%	n	%	n	%
5.	Statements expressing the results of any given scientific experiment can refer only to that particular experiment.	20	39	16	31	14	45	2	18	6	29	14	36
6.	Scientific experiments involve only the process of induction.	12	23	9	18	7	23	4	33	5	24	5	13
7.	Scientific experiments are performed to confirm scientific hypotheses.	44	85	40	78	26	84	11	92	18	86	29	74
8.	One primary pre-requisite for the conduct of a scientific experiment is the formulation of the problem to be investigated.	49	94	47	92	30	97	10	83	19	91	37	95
9.	All the observations made during the conduct of scientific experiments are always planned before hand.	10	19	11	22	4	13	4	33	6	29	7	18

TABLE 2 (continued)

Statement numbers*	Statements about scientific experiments	All the teachers				Teachers with NCE				Teachers with degree			
		0-2 yrs. (N = 52)		Over 2 yrs. (N = 51)		0-2 yrs. (N = 31)		Over 2 yrs. (N = 12)		0-2 yrs. (N = 21)		Over 2 yrs. (N = 39)	
		n	%	n	%	n	%	n	%	n	%	n	%
10.	The results of scientific experiments are the only basis for the formulation of scientific concepts.	35	67	33	65	23	74	7	58	12	57	26	76
11.	A single scientific experiment could be crucial in any decision to accept or reject one of two conflicting scientific laws.	42	80	45	88	24	77	10	83	18	86	35	90
12.	Scientific experiments involve only the process of deduction.	11	21	9	18	7	23	3	25	4	19	6	15
13.	The results of a particular scientific experiment can have several possible interpretations.	45	87	42	82	24	77	12	100	21	100	30	77
14.	Scientific experiments are performed to falsify scientific hypotheses.	15	29	7	14	13	42	1	8	2	10	6	15

TABLE 2 (continued)

Statement numbers*	Statements about scientific experiments	All the teachers				Teachers with NCE				Teachers with degree			
		0-2 yrs. (N = 52)		Over 2 yrs. (N = 51)		0-2 yrs. (N = 31		Over 2 yrs. (N = 12)		0-2 yrs. (N = 21)		Over 2 yrs. (N = 39)	
		n	%	n	%	n	%	n	%	n	%	n	%
15.	The results of scientific experiments are interpreted only on the basis of present knowledge.	34	65	20	39	13	42	3	25	13	62	17	44
16.	Scientists working with similar experimental material may obtain conflicting results	46	89	46	90	26	84	12	100	20	95	34	87
17.	Scientific experiments are performed to falsify scientific theories.	9	17	6	12	7	23	2	17	1	10	6	15
18.	The results of scientific experiments do not, on their own, lead to new knowledge.	14	27	15	29	10	32	7	58	4	19	8	21
19.	All but one of the factors involved in a scientific experiment are always held constant.	24	46	21	41	14	45	6	50	10	48	15	39

TABLE 2 (continued)

Statement number*	Statements about scientific experiments	All the teachers				Teachers with NCE				Teachers with degree			
		0-2 yrs. (N = 52)		Over 2 yrs. (N = 51)		0-2 yrs. (N = 31)		Over 2 yrs. (N = 12)		0-2 yrs. (N = 21)		Over 2 yrs. (N = 39)	
		n	%	n	%	n	%	n	%	n	%	n	%
20.	Scientific experiments are performed to discover scientific hypotheses.	29	50	26	51	16	52	6	50	13	62	20	51
21.	Scientific experiments are performed to formulate scientific theories.	39	75	33	65	23	74	7	58	16	76	26	67
22.	A decision to accept or reject one of two conflicting sets of experimental results is solely dependent on the one which is able to withstand the severest test.	42	81	40	78	23	74	10	83	19	91	30	77
23.	Experimentation in science involves the separation of complex phenomena into simple ones.	38	73	41	80	23	74	12	100	15	71	29	74
24.	All the conditions that could affect the outcome of a scientific experiment can not be completely controlled.	37	71	37	73	19	61	7	58	18	86	30	77

TABLE 2 (continued)

Statement numbers*	Statements about scientific experiments	All the teachers				Teachers with NCE				Teachers with degree			
		0-2 yrs. (N = 52)		Over 2 yrs. (N = 51)		0-2 yrs. (N = 31)		Over 2 yrs (N = 12)		0-2 yrs. (N = 21)		Over 2 yrs. (N = 39)	
		n	%	n	%	n	%	n	%	n	%	n	%
25.	The results of scientific experiments usually pose more questions than answers.	40	77	33	65	24	77	10	83	16	76	23	59
26.	Only the results of scientific experiments which agree with prediction are useful.	12	23	6	12	4	13	0	0	8	38	6	15
27.	There are no universally accepted steps of procedure that are followed in the conduct of all scientific experiments.	26	50	23	45	22	71	5	42	4	19	18	46
28.	A scientific experiment consists of making an event occur under known conditions.	41	79	35	69	25	81	11	92	16	76	25	64
29.	Scientific experiments involve both inductive and deductive processes.	45	87	49	96	26	84	12	100	19	91	37	95

TABLE 2 (continued)

Statement number*	Statements about scientific experiments	All the teachers				Teachers with NCE				Teachers with degree			
		0-2 yrs. (N = 52)		Over 2 yrs. (N = 51)		0-2 yrs. (N = 31)		Over 2 yrs. (N = 12)		0-2 yrs. (N = 21)		Over 2 yrs. (N = 39)	
		N	%	n	%	n	%	n	%	n	%	n	%
30.	The results of scientific experiments are useful only if they are repeatable or reproducible.	48	92	45	88	28	90	9	75	20	95	36	92
31.	It is impossible to completely determine all the factors that could affect the outcome of a scientific experiment.	42	81	37	73	26	84	10	83	16	76	27	69
32.	Scientific experiments are performed to discover scientific laws.	42	81	27	53	26	84	5	42	16	76	22	56
33.	Scientific experiments are special forms of observations.	45	87	42	82	26	84	10	83	19	91	32	82
34.	Statements expressing the results of scientific experiments can be applied to any of several possible related experiments.	30	58	30	59	18	58	5	42	12	57	25	64

TABLE 2 (continued)

Statement numbers*	Statements about scientific experiments	All the teachers				Teachers with NCE				Teachers with degree			
		0-2 yrs. (N = 52)		Over 2 yrs. (N = 51)		0-2 yrs. (N = 21)		Over 2 yrs. (N = 12)		0-2 yrs. (N = 21)		Over 2 yrs. (N = 39)	
		n	%	n	%	n	%	n	%	n	%	n	%
35.	Scientific experiments can be used to check cause and effect relationships.	48	92	46	90	28	90	11	92	20	95	35	90
36.	No scientific experiment can on its own lead to a decision to accept or reject one of two conflicting scientific theories.	38	73	28	55	23	74	9	75	15	71	19	49
37.	Scientific experiments always involve qualitative observations.	27	52	20	39	16	52	8	67	11	52	12	31
38.	The results of scientific experiments always lead to new knowledge.	34	65	28	55	23	74	8	67	11	52	20	51
39.	Statements expressing the results of scientific experiments always include ideas for testing the implications of such results.	40	77	42	82	23	74	10	83	17	81	32	82

TABLE 2 (continued)

Statement numbers*	Statements about scientific experiments	All the teachers				Teachers with NCE				Teachers with degree			
		0-2 yrs. (N = 52)		Over 2 yrs. (N = 51)		0-2 yrs. (N = 31)		Over 2 yrs. (N = 12)		0-2 yrs. (N = 21)		Over 2 yrs. (N = 39)	
		n	%	n	%	n	%	n	%	n	%	n	%
40.	Scientific experiments are performed to establish scientific theories.	43	83	33	65	27	87	9	75	16	76	24	62
41.	Scientific experiments can never reveal all the possible differences between two contrasting phenomena.	34	65	29	57	21	68	6	50	13	62	23	59
42.	Scientific experiments can be used to check cause and effect relationships	18	35	9	18	8	26	2	17	10	48	7	18
43.	Scientific experiments are performed to establish scientific theories.	45	87	39	77	28	90	9	75	17	81	30	77
44.	Scientific experiments are performed to formulate scientific laws.	31	60	41	80	18	58	10	83	13	62	31	80

TABLE 2 (continued)

Statement numbers*	Statements about scientific experiments	All the teachers				Teachers with NCE				Teachers with degree			
		0-2 yrs. (N = 52)		Over 2 yrs. (N = 51)		0-2 yrs. (N = 31)		Over 2 yrs. (N = 12)		0-2 yrs. (N = 21)		Over 2 yrs. (N = 39)	
		n	%	n	%	n	%	n	%	n	%	n	%
45.	No scientific experiment can conclusively prove or disprove a scientific hypothesis.	16	31	19	37	12	39	7	58	4	19	12	31
46.	The results of all scientific experiments are in one way or another useful.	49	94	47	92	28	90	11	92	21	100	36	92
47.	Scientific experiments are performed to verify scientific theories.	49	94	45	88	28	90	9	75	21	100	36	92
48.	The results of scientific experiments are accepted only after several trials agree with prediction.	46	89	41	80	18	90	12	100	18	86	29	74
49.	It is not possible to vary only one factor at a time in a scientific experiment.	22	42	19	37	16	52	6	50	6	29	13	33

TABLE 2 (continued)

Statement numbers*	Statements about scientific experiments	All the teachers				Teachers with NCE				Teachers with degree			
		0-2 yrs. (N = 52)		Over 2 yrs. (N = 51)		0-2 yrs. (N = 31)		Over 2 yrs. (N = 12)		0-2 yrs. (N = 21)		Over 2 yrs. (N = 39)	
		n	%	n	%	n	%	n	%	n	%	n	%
50.	Scientific experiments are performed to verify scientific hypotheses.	37	71	40	78	22	71	7	58	15	71	33	85
51.	The products of scientific experiments are facts.	42	81	40	78	26	84	11	92	16	76	29	74
52.	The results of scientific experiments are probabilities.	17	33	25	49	9	29	5	42	8	38	20	51
53.	Scientific experiments are performed to falsify scientific laws.	3	6	12	24	2	7	3	25	1	5	9	23
54.	Scientific experiments can not be used to prove or disprove scientific theories.	16	31	28	55	9	29	8	67	7	33	20	51
55.	Scientific experiments are performed to predict new scientific laws.	20	39	31	61	9	29	10	83	11	52	21	54

TABLE 2 (continued)

Statement numbers*	Statements about scientific experiments	All the teachers				Teachers with NCE				Teachers with degree			
		0-2 yrs. (N = 52)		Over 2 yrs. (N = 51)		0-2 yrs. (N = 31)		Over 2 yrs. (N = 12)		0-2 yrs. (N = 21)		Over 2 yrs. (N = 39)	
		n	%	n	%	n	%	n	%	n	%	n	%
56.	The results of a particular scientific experiment can have only one possible interpretation.	11	21	12	24	8	26	3	25	3	14	10	26
57.	Scientific experiments involve only quantitative observations.	14	27	6	12	8	26	2	17	6	29	4	10
58.	Scientific experiments can be performed to test the fundamental assumptions of nature.	42	81	43	84	23	74	12	100	19	91	31	80
59.	Scientific experiments can be used to confirm scientific theories only by the indirect confirmation of the consequences of the theories.	20	39	24	47	13	42	6	50	7	33	10	26

TABLE 2 (continued)

Statement numbers*	Statements about scientific experiments	All the teachers				Teachers with NCE				Teachers with degree			
		0-2 yrs. (N = 52.		Over 2 yrs. (N = 51)		0-2 yrs. (N = 31)		Over 2 yrs. (N = 12)		0-2 yrs. (N = 21)		Over 2 yrs. (N = 39)	
		n	%	n	%	n	%	n	%	n	%	n	%
60.	The results of scientific experiments are valid only under the precise set of conditions in which the experiment was conducted.	48	92	46	90	27	87	12	100	21	100	34	87
61.	There are universally accepted steps of procedure which are followed in the conduct of all scientific experiments.	30	58	30	59	14	45	8	67	16	76	22	56
62.	The results of simple scientific experiments are preferred over those of complex ones.	26	50	29	57	11	36	9	75	15	71	20	51

TABLE 3

FREQUENCY AND PERCENTAGE OF SCIENCE TEACHERS' "YES" RESPONSES TO STATEMENTS ABOUT SCIENTIFIC EXPERIMENTS ACCORDING TO THE SUBJECTS THEY TEACH.

Statement number*	Statements about scientific experiments.	All the teachers				Teachers with NCE				Teachers with degree			
		Biol. Sc. (N=31)		Phys. Sc. (N=41)		Biol. Sc. (N=11)		Phys. Sc. (N=14)		Biol. Sc. (N=20)		Phys. Sc. (N=27)	
		n	%	n	%	n	%	n	%	n	%	n	%
1.	The outcome of a scientific experiment depends on the technique of measurement employed.	22	71	26	63	10	91	7	50	12	60	19	70
2.	A single scientific experiment could be crucial in a decision to accept or reject one of two conflicting scientific hypotheses.	24	77	35	85	9	82	11	79	15	75	24	89
3.	Scientific experiments can not conclusively prove or disprove a scientific law.	15	48	31	76	7	64	9	64	8	40	21	78
4.	Scientific experiments are always based on theoretical principles.	24	77	31	76	8	73	11	79	16	80	20	74
5.	Statements expressing the results of any given scientific experiment can refer only to that particular experiment.	16	52	12	29	6	55	3	21	10	50	9	33

TABLE 3 (continued)

Statement number*	Statements about scientific experiments	All the teachers				Teachers with NCE				Teachers with degree			
		Biol. Sc. (N=31)		Phys. Sc. (N=41)		Biol. Sc. (N=11)		Phys. Sc. (N=14)		Biol. Sc. (N=20)		Phys. Sc. (N=27	
		n	%	n	%	n	%	n	%	n	%	n	%
6.	Scientific experiments involve only the processes of induction	9	29	10	24	5	46	4	29	4	20	6	22
7.	Scientific experiments are performed to confirm scientific hypotheses.	23	74	32	78	10	91	9	64	13	65	23	85
8.	One primary pre-requisite for the conduct of a scientific experiment is the formulation of the problem to be investigated.	28	90	38	93	9	82	14	100	19	95	24	89
9.	All the observations made during the conduct of scientific experiments are always planned before hand.	4	13	13	32	2	18	5	36	2	10	8	30
10.	The results of scientific experiments are the only basis for the formulation of scientific concepts.	19	61	29	71	9	82	7	50	10	50	22	82

TABLE 3 (continued)

Statement number*	Statements about scientific experiments	All the teachers				Teachers with NCE				Teachers with degree			
		Biol. Sc. (N=31)		Phys. Sc. (N=41)		Biol. Sc. (N=11)		Phys. Sc. (N=14)		Biol. Sc. (N=20)		Phys. Sc. (N=27)	
		n	%	n	%	n	%	n	%	n	%	n	%
11.	A single scientific experiment could be crucial in any decision to accept or reject one of two conflicting scientific laws.	26	84	36	88	10	91	11	79	16	80	25	93
12.	Scientific experiments involve only the process of deduction.	12	39	6	15	6	55	3	21	6	30	3	11
13.	The results of a particular scientific experiment can have several possible interpretations.	24	77	35	85	9	82	12	86	15	75	23	85
14.	Scientific experiments are performed to falsify scientific hypotheses.	3	10	10	24	2	18	5	36	1	5	5	19
15.	The results of scientific experiments are interpreted only on the basis of present knowledge.	16	52	22	54	5	46	9	64	11	55	13	48

TABLE 3 (continued)

Statement number	Statements about scientific experiments	All the teachers				Teachers with NCE				Teachers with degree			
		Biol. Sc. (N=31)		Phys. Sc. (N=41)		Biol. Sc. (N=11)		Phys. Sc. (N=14)		Biol. Sc. (N=20)		Phys. Sc. (N=27)	
		n	%	n	%	n	%	n	%	n	%	n	%
16.	Scientists working with similar experimental material may obtain conflicting results.	28	90	35	85	9	82	12	86	15	75	23	85
17.	Scientific experiments are performed to falsify scientific theories.	3	10	7	17	2	18	3	21	1	5	4	15
18.	The results of scientific experiments do not, on their own, lead to new knowledge.	10	32	7	17	6	55	6	43	4	22	5	19
19.	All but one of the factors involved in a scientific experiment are always held constant.	16	52	11	27	6	55	9	64	10	50	10	37
20.	Scientific experiments are performed to discover scientific hypotheses.	21	68	24	59	6	55	8	57	15	75	16	59
21.	Scientific experiments are performed to formulate scientific theories.	23	74	27	66	9	82	7	50	14	70	21	78

TABLE 3 (continued)

Statement number*	Statements about scientific experiments	All the teachers				Teachers with NCE				Teachers with degree			
		Biol. Sc. (N=31)		Phys. Sc. (N=41)		Biol. Sc. (N=11)		Phys. Sc. (N=14)		Biol. Sc. (N=20)		Phys. Sc. (N=27)	
		n	%	n	%	n	%	n	%	n	%	n	%
22.	A decision to accept or reject one of two conflicting sets of experimental results is solely dependent on the one which is able to withstand the severest test.	28	90	34	83	11	100	11	79	17	85	23	85
23.	Experimentation in science involves the separation of complex phenomena into simple ones.	23	74	37	90	10	91	13	93	13	65	24	89
24.	All the conditions that could affect the outcome of a scientific experiment can not be completely controlled.	20	65	35	85	5	46	12	86	15	75	23	85
25.	The results of scientific experiments usually pose more questions than answers.	20	65	30	73	7	64	12	86	13	65	18	67
26.	Only the results of scientific experiments which agree with prediction are useful.	1	3	12	29	0	0	1	7	1	5	11	41

TABLE 3 (continued)

Statement number*	Statements about scientific experiments	All the teachers				Teachers with NCE				Teachers with degree			
		Biol. Sc. (N=31)		Phys. Sc. (N=41)		Biol. Sc. (N=11)		Phys. Sc. (N=14)		Biol. Sc. (N=20)		Phys. Sc. (N=27)	
		n	%	n	%	n	%	n	%	n	%	n	%
27.	There are no universally accepted steps of procedure that are followed in the conduct of all scientific experiments	9	29	19	46	4	36	10	71	5	25	9	33
28.	A scientific experiment consists of making an event occur under known conditions.	19	61	34	83	10	91	10	71	9	45	24	89
29.	Scientific experiments involve both inductive and deductive processes.	26	84	40	98	9	82	13	93	17	95	27	100
30.	The results of scientific experiments are useful only if they are repeatable or reproducible.	30	97	28	93	11	100	13	93	19	95	25	93
31.	It is impossible to completely determine all the factors that could affect the outcome of a scientific experiment.	24	77	30	73	11	100	11	79	13	65	19	70
32.	Scientific experiments are performed to discover scientific laws.	25	81	27	66	10	91	8	57	15	75	16	59

TABLE 3 (continued)

Statement number*	Statements about scientific experiments	All the teachers				Teachers with NCE				Teachers with degree			
		Biol. Sc. (N=31)		Phys. Sc. (N=41)		Biol. Sc. (N=11)		Phys. Sc. (N=14)		Biol. Sc. (N=20)		Phys. Sc. (N=27)	
		n	%	n	%	n	%	n	%	n	%	n	%
33.	Scientific experiments are special forms of observations.	26	84	33	81	10	91	10	71	16	60	23	85
34.	Statements expressing the results of scientific experiments can be applied to any of several related experiments.	17	55	21	51	6	55	4	29	11	55	17	63
35.	Scientific experiments can be used to check cause and effect relationships.	26	84	38	93	10	91	12	86	16	80	26	96
36.	No scientific experiment can, on its own, lead to a decision to accept or reject one of two conflicting scientific theories.	17	55	29	71	7	64	12	86	10	50	17	63
37.	Scientific experiments always involve qualitative observations.	15	48	21	51	7	64	11	79	8	40	10	37
38.	The results of scientific experiments always include ideas for testing the implications of such results.	19	61	22	54	6	55	10	74	13	65	12	44

TABLE 3 (continued)

Statement number*	Statements about scientific experiments.	All the teachers				Teachers with NCE				Teachers with degree			
		Biol. Sc. (N=31)		Phys. Sc. (N=41)		Biol. Sc. (=11)		Phys. Sc. (N=14)		Biol. Sc. (N=20)		Phys. Sc. (N=17)	
		n	%	n	%	n	%	n	%	n	%	n	%
39.	Statements expressing the results of scientific experiments always include ideas for testing the implications of such results	26	84	33	81	10	91	11	79	16	80	22	82
40.	Scientific experiments are performed to confirm scientific laws.	23	74	34	83	11	100	12	86	12	60	22	82
41.	Scientific experiments can never reveal all the possible differences between two contrasting phenomena.	21	68	21	51	8	75	8	86	13	65	13	48
42.	Scientific experiments can not be used to check cause and effect relationships.	7	23	13	32	2	18	4	29	5	25	9	33
43.	Scientific experiments are performed to establish scientific theories.	24	77	35	85	9	82	12	86	15	75	23	85
44.	Scientific experiments are performed to formulate scientific laws.	23	74	29	71	6	55	10	71	17	85	19	70

TABLE 3 (continued)

Statement number*	Statements about scientific experiments	All the teachers				Teachers with NCE				Teachers with degree			
		Biol. Sc. (N=31)		Phys. Sc. (N=41)		Biol. Sc. (N=11)		Phys. Sc. (N=14)		Biol. Sc. (N=2-		Phys. Sc. (N=27)	
		n	%	n	%	n	%	n	%	n	%	n	%
45.	No scientific experiment can conclusively prove or disprove a scientific hypothesis.	12	39	14	34	6	55	8	57	6	30	6	22
46.	The results of scientific experiments are in one way or another useful.	29	94	38	93	10	91	11	79	19	95	27	100
47.	Scientific experiments are performed to verify scientific theories.	30	97	34	83	11	100	9	64	19	95	25	93
48.	The results of scientific experiments are accepted only after several trials agree with prediction.	21	68	38	93	10	91	13	93	11	55	25	93
49.	It is not possible to vary only one factor at a time in a scientific experiment.	9	29	17	42	3	27	11	79	6	30	7	26
50.	Scientific experiments are performed to verify scientific hypotheses.	23	74	32	78	9	82	9	64	14	70	23	85
51.	The product of scientific experiments are facts.	26	84	33	81	9	82	13	93	17	85	20	74

TABLE 3 (continued)

Statement* number	Statements about scientific experiments	All the teachers				Teachers with NCE				Teachers with degree			
		Biol. Sc. (N=31)		Phys. Sc. (N=41)		Biol. Sc. (N=11)		Phys. Sc. (N=14)		Biol. Sc. (N=20)		Phys. Sc. (N=27)	
		n	%	n	%	n	%	n	%	n	%	n	%
52.	The results of scientific experiments are probabilities.	11	36	18	44	2	18	6	43	9	45	12	44
53.	Scientific experiments are performed to falsify scientific laws.	5	16	5	12	1	9	1	7	4	20	4	15
54.	Scientific experiments can not be used to prove or disprove scientific theories.	12	39	18	44	5	46	6	43	7	35	12	44
55.	Scientific experiments are performed to predict new scientific laws.	17	55	20	49	7	64	4	29	10	50	16	59
56.	The results of a particular scientific experiment can have only one possible interpretation.	9	29	10	24	6	55	3	21	3	15	7	27
57.	Scientific experiments involve only quantitative observations.	4	13	14	34	3	27	6	43	1	5	8	30

TABLE 3 (continued)

Statement number*	Statements about scientific experiments	All the teachers				Teachers with NCE				Teacher with degree			
		Biol. Sc. (N=31)		Phys. Sc. (N=41)		Biol. Sc. (N=11)		Phys. Sc. (N=14)		Biol. Sc. (N=20)		Phys. Sc. (N=27)	
		n	%	n	%	n	%	n	%	n	%	n	%
58.	Scientific experiments can be performed to test the fundamental assumptions of nature.	23	74	36	88	8	73	12	86	15	75	24	89
59.	Scientific experiments can be used to confirm scientific theories only by the indirect confirmation of the consequences of the theories.	10	32	23	56	4	36	10	71	6	30	1	48
60.	The results of scientific experiments are valid only under the precise set of conditions in which the experiment was conducted.	29	94	35	85	10	91	12	86	19	95	23	85
61.	There are universally accepted steps of procedure which are followed in the conduct of all scientific experiments.	27	87	17	42	11	100	5	36	16	80	12	44
62.	The results of simple scientific experiments are preferred over those of simple ones.	15	48	24	59	6	55	9	64	9	45	15	56

*Statements numbers correspond to the enumerations used in the questionnaire in Appendix I.

TABLE 4.

SUMMARY OF STATEMENTS IN WHICH DIFFERENCES IN THE RESPONSES OF THE TEACHERS WERE FOUND WITH RESPECT TO THE INDEPENDENT VARIABLES.

Nature of the statements	Independent variables						
	Educational background	Teaching experience			Subject(s) taught		
	NCE vs degree	All teachers 0-2 vs. over 2 yrs.	NCE teachers 0-2 vs. over 2 yrs.	Degree teachers 0-2 vs. over 2 yrs.	All teachers Biol. Sc. vs Phys. Sc.	NCE teachers Biol. Sc. vs Phys. Sc.	Degree teachers Biol. Sc. vs Phys. Sc.
Characteristics of scientific experiments	24	-	1, 44, 23, 58, 62	61	24, 28, 48, 61	1, 23, 24, 28, 33, 25, 61	23, 28, 33, 48, 61
Relationships of experiments and scientific generalizations	-	32, 44	55	32	3	7, 21, 10, 36, 47, 49	3, 7, 10, 40

NB - Numbers correspond to the enumeration of the statements in the questionnaire in Appendix I.

Note from Table 1 that when the responses of teachers with NCE are compared with those of degree-holding teachers, the only difference is with reference to "yes" responses to item 24 (NCE 58% : Degree 82%).

From Table 2, the following are noted.

1. Regardless of educational background, the teachers with 0-2 years of teaching experience gave a higher percent "yes" responses to item 32, while those with more than 2 years of teaching experience gave a higher percent "yes" responses to item 44. Note that both items relate to relationships between scientific experiments and scientific laws. Item 32 was not identified with any of the selected philosophers.
2. When NCE teachers with 0-2 years of teaching experience are compared to NCE teachers with more than 2 years of teaching experience, it is found that the latter group gave a higher percent "yes" responses to items 23, 44, 55, 58 and 62, while the former group gave a higher percent "yes" response to item 1.
3. When degree teachers with 0-2 years of teaching experience are compared to degree teachers with more than 2 years of teaching experience, it is found that the former group gave a higher percent

"yes" responses to items 32 and 61. Item 32 was not identified with any of the selected philosophers.

From Table 3, the following are noted.

1. Regardless of educational background, the teachers who teach biological science courses gave a higher percent "yes" responses to items 3 and 61, while those who teach physical science courses gave a higher percent "yes" responses to items 24, 28 and 48.
2. Within the NCE group, the biological science teachers gave a higher percent "yes" responses to items 1, 7, 10, 23, 25, 28, 33, 47, 50 and 61, while the physical science teachers have a higher percent "yes" responses to items 24, 36 and 49.
3. Within the degree group, the physical science teachers gave a higher percent "yes" responses to items 3, 7, 10, 23, 28, 33, 40 and 48, while the biological science teachers gave a higher percent "yes" responses to item 61.

Consistency of the Teachers' Descriptions of Scientific Experiments

Although the consistency of the teachers' descriptions of scientific experiments was not a specific part of the problems addressed by this study, it was an integral part

of the design of the instrument used (Chapter III). Five pairs of contradictory statements were included on the questionnaire to serve as "check-questions" for determining the consistency of the teachers' descriptions of scientific experiments.

A post-hoc analysis was made of the distribution of teachers who responded "yes" to both members of each of the five pairs of contradictory statements (Table 5). Examination of Table 5 reveals the following:

1. Fifty of the 103 teachers included at least one pair of contradictory statements in their descriptions of scientific experiments (18 of the 43 NCE and 32 of the 60 degree teachers). Of the 50 teachers, only seven included both members of more than one pair of contradictory statements in their descriptions.
2. Twenty-eight of the teachers with 0-2 years of teaching experience (16 NCE and 12 degree) and 22 of those with over 2 years of teaching experience (14 NCE and 18 degree) included both members of at least one pair of contradictory statements in their descriptions of scientific experiments.

TABLE 5.

TEACHERS RESPONDING "YES" TO BOTH MEMBERS OF PAIRS OF CONTRADICTORY STATEMENTS.

Respondent number	Pairs of contradictory statements***					Independent variables		
	5 & 34	6 & 12	35 & 42	57 & 37	13 & 56	Educ. background	Subjects**	Experience*
001	x	x			x	NCE	3	1
002	x				x	NCE	5	1
003		x			x	NCE	4	2
004	x		x	x		NCE	3	2
005		x				NCE	3	2
006					x	NCE	3	1
007	x					NCE	3	1
008	x	x				NCE	3	1
009		x			x	NCE	3	2
010	x		x			NCE	5	1
011	x				x	NCE	4	1
012			x			NCE	4	1
013		x				NCE	5	1
014	x		x			NCE	4	1
015	x					NCE	5	1
016			x			NCE	5	1
017			x			NCE	5	1
018	x					NCE	5	1
019					x	Degree	4	2
020		x				Degree	4	2
021	x					Degree	4	2
022	x					Degree	3	2
023	x					Degree	3	1

TABLE 5. (continued)

Respondent number	Pairs of contradictory statements***					Independent variables		
	5 & 34	6 & 12	35 & 42	57 & 37	13 & 56	Educ. background	Subjects**	Experience*
024	x					Degree	3	2
025			x			Degree	3	1
026	x					Degree	3	1
027	x				x	Degree	4	2
028	x					Degree	4	2
029	x		x			Degree	4	1
030	x	x		x		Degree	4	2
031				x		Degree	4	1
032	x	x				Degree	4	2
033			x		x	Degree	5	1
034	x					Degree	4	1
035					x	Degree	4	1
036					x	Degree	4	2
037			x			Degree	4	2
038	x		x			Degree	4	2
039					x	Degree	4	2
040				x		Degree	4	1
041	x					Degree	3	2
042					x	Degree	5	1
043	x					Degree	4	2

TABLE 5. (continued)

Respondent number	Pairs of contradictory statements***					Independentbvariables		
	5 & 34	6 & 12	35 & 42	57 & 37	13 & 56	Educ. back-ground	Sub-jects**	Expe-rience*
044	x					Degree	3	2
045		x				Degree	3	2
046			x			Degree	4	1
047	x					Degree	3	1
048			x	x		Degree	5	1
049			x			Degree	3	2
050			x			Degree	5	2

Experience* - 1 = 0 to 2 years experience.
2 = Over 2 years experience.

Subjects** - 3 = Biological Science.
4 = Physical Science.
5 = Other combinations.

*** Statement numbers correspond to the enumerations used in the questionnaire in Appendix I.

3. Nineteen physical science teachers (5 NCE and 14 degree) and 16 biological science teachers (7 NCE and 9 degree) included both members of at least one pair of contradictory statements in their descriptions of scientific experiments.

CHAPTER V

SUMMARY, CONCLUSIONS AND RECOMMENDATIONS

Summary

A number of science educators have pointed to the significance of the relationship between the descriptions of "the nature of science" possessed by science teachers, and those possessed by their pupils. The basic assumptions are that the knowledge of science possessed by science teachers may reflect 1) how they represent science to their pupils, and 2) what scientific knowledge they represent to their pupils. For these reasons, several researchers have attempted to determine the extent of knowledge that science teachers have about the nature of science. Many of these studies have been criticized for portraying a rather narrow view of science. There are two main reasons for this criticism:

1. the fact that "the nature of science" is a complex concept, and
2. the difficulty of representing all the legitimate but conflicting views of science in a single study.

Because of these reasons, recent investigators have concentrated on examining conceptualizations of individual concepts like "scientific law," "scientific theory,"

"scientific hypothesis," "scientific concept," etc., that are subsumed under "the nature of science" concept.

The purpose of this study was to:

1. Determine which of the 62 statements on the questionnaire (included as Appendix I) Niger State post-primary school science teachers included in their descriptions of scientific experiments.
2. Determine if teachers with a university degree describe scientific experiments differently from those with the Nigerian Certificate of Education.
3. Determine if teachers with 0-2 years of teaching experience describe scientific experiments differently from those with over 2 years of teaching experience.
4. Determine if teachers with a given educational background and 0-2 years of teaching experience describe scientific experiments differently from those with the same educational background and over 2 years of teaching experience.
5. Determine if teachers who teach physical science courses describe scientific experiments differently from those who teach biological science courses.
6. Determine if teachers with a given educational background who teach physical science courses

describe scientific experiments differently from those with the same educational background who teach biological science courses.

In order to obtain answers to these questions, a new instrument was prepared, consisting of 62 statements which cover a wide range of philosophical views on aspects of the nature of scientific experiments. The instrument was administered to 103 science teachers in 22 of the 28 post-primary schools offering science courses in Niger State, Nigeria, during the 1978-79 school year.

The data consisted of "yes" responses which indicated a teacher's desire to include the particular statement in his/her description of scientific experiments. The frequencies and percentages of the teachers' "yes" responses to each of the 62 statements were computed and tabulated 1) for the teachers as a group, 2) according to the teachers' educational background, 3) according to the teachers' number of years of teaching experience, and 4) according to the subjects the teachers teach.

The following is a summary of the findings of the current study:

At least 75% of the teachers included the following statements that describe characteristics of scientific experiments in their descriptions.

a) One primary pre-requisite for conducting scientific experiments is the formulation of the problem to be investigated.

b) The results of a particular scientific experiment can have several possible interpretations.

c) Scientists working with similar experimental material may obtain conflicting results.

d) A decision to accept or reject one of two conflicting experimental results is solely dependent on the one which is able to withstand the severest test.

e) Experimentation in science involves the separation of complex phenomena into simple ones.

f) Scientific experiments involve both inductive and deductive processes.

g) The results of scientific experiments are useful only if they are repeatable or reproducible.

h) Scientific experiments are special forms of observations.

i) Scientific experiments can be used to check cause and effect relationships.

j) Statements expressing the results of scientific experiments always include ideas for testing the implications of such results.

k) The results of all scientific experiments are useful in one way or another.

l) The products of scientific experiments are facts.

m) The results of scientific experiments are accepted only after several trials agree with prediction.

n) Scientific experiments can be performed to check the fundamental assumptions of nature.

o) The results of scientific experiments are valid only under the precise set of conditions in which the experiment was conducted.

At least 75% of the teachers included the following statements which describe relationships between scientific experiments and scientific generalizations in their descriptions.

a) A single scientific experiment could be crucial in any decision to accept or reject one of two conflicting scientific hypotheses.

b) Scientific experiments are always based on theoretical principles.

c) Scientific experiments are performed to confirm scientific hypotheses.

d) A single scientific experiment could be crucial in any decision to accept or reject one of two conflicting scientific laws.

e) Scientific experiments are performed to establish scientific theories.

f) Scientific experiments are performed to verify scientific theories.

g) Scientific experiments are performed to confirm scientific laws.

The statements listed above reflect broad conceptualizations of the nature of scientific experiments. Included among these statements are four descriptions of aspects of scientific experiments not identified with any of the 10 selected philosophers of science--indicative of a lack of affiliation with a particular philosophic view of the nature of scientific experiments known to the author on the part of the teachers.

On the basis of the two criteria outlined in the previous chapter, few differences were found in the descriptions of scientific experiments held by the groups of teachers a) with different educational backgrounds, b) with different numbers of years of teaching experience, and c) who teach different science subjects. In the following summary, the term "significant difference" is used to indicate that the difference in percent "yes" responses of the first mentioned group of teachers and the percent "yes" responses of the second mentioned group of teachers satisfied the two criteria outlined in the previous chapter.

The numbers of the items as used in Appendix I are given in brackets before each of the statements.

1. Within the variable of educational background (NCE vs degree teachers), a significant difference existed with a higher percent "yes" responses from degree teachers to the following statement:
   (24) All the conditions that could affect the outcome of a scientific experiment can not be completely controlled.
2. When the variable of teachers' experience regardless of educational background was examined, the following was found:
   a) A significant difference existed among the percent "yes" responses of teachers with 0-2 years of teaching experience and those with over 2 years of teaching experience, the former having a higher percent "yes" responses to the following statement:
      (32) Scientific experiments are performed to discover scientific laws.
   b) A significant difference existed among the "yes" responses of teachers with over 2 years of teaching experience and teachers with 0-2 years of teaching experience, the former having a higher percentage of "yes" responses to the following statement:

(44) Scientific experiments are performed to formulate scientific laws.

3. When the variable of teachers' experience is evaluated within each of the variables of educational background (NCE vs degree teachers), the following were observed.

a) A significant difference existed among the "yes" responses of NCE teachers with 0-2 years of teaching experience and NCE teachers with more than 2 years of teaching experience, the former having a higher percentage of "yes" responses to the following statement:

(1) The outcome of a scientific experiment depends on the technique of measurement employed.

b) A significant difference existed among the "yes" responses from NCE teachers with more than 2 years of teaching experience and NCE teachers with 0-2 years teaching experience, the former having a higher percent "yes" responses to the following statements:

(23) Experimentation in science involves the separation of complex phenomena into simple ones.

(44) Scientific experiments are performed to formulate scientific laws.

(55) Scientific experiments are performed to predict new scientific laws.

(58) Scientific experiments are performed to check the fundamental assumptions of nature.

c) A significant difference existed among the "yes" responses from the degree teachers with 0-2 years of teaching experience and the degree teachers with over 2 years of teaching experience, the former having a higher percent "yes" responses to the following statements:

(61) There are universally accepted steps of procedure which are followed in the conduct of all scientific experiments.

(32) Scientific experiments are performed to discover scientific laws.

3. When the variable of the subjects the teachers teach, regardless of educational background, was examined, the following were found.

a) A significant difference existed among the "yes" responses from the biological science teachers and the physical science teachers,

the former having a higher percent "yes" responses to the following statement:

(61) There are universally accepted steps of procedure which are followed in the conduct of all scientific experiments.

b) A significant difference existed among the "yes" responses from the physical science teachers and the biological science teachers, with the former having a higher percent "yes" responses to the following statements:

(3) Scientific experiments can not conclusively prove or disprove a scientific law.

(24) All the conditions that could affect the outcome of a scientific experiment can not be completely controlled.

(28) A scinetific experiment consists of making an event occur under known conditions.

(48) The results of scientific experiments are accepted only after several trials agree with prediction.

5. When the variable of the subjects the teachers teach is examined within each of the variable of educational background (NCE or degree teachers)

the following were found:

a) A significant difference existed among the "yes" responses from the NCE teachers who teach biological science courses and the NCE teachers who teach physical science courses, the former having higher percent "yes" responses to the following statements:

   (1) The outcome of a scientific experiment depends on the technique of measurement employed.

   (7) Scientific experiments are performed to confirm scientific hypotheses.

   (10) The results of scientific experiments are the basis for the formulation of scientific concepts.

   (23) Experimentation in science involves the separation of complex phenomena into simple ones.

   (28) A scientific experiment consists of making an event occur under known conditions.

   (33) Scientific experiments are special forms of observations.

   (47) Scientific experiments are performed to verify scientific theories.

(61) There are no universally accepted steps of procedure which are followed in the conduct of all scientific experiments.

b) A significant difference existed among the "yes" responses from NCE teachers who teach the physical science courses and the NCE teachers who teach biological science courses, the former having a higher percent "yes" responses to the following statements:

(24) All the conditions that could affect the outcome of a scientific experiment can not be completely controlled.

(25) The results of scientific experiments usually pose more questions than answers.

(36) No scientific experiment can, on its own, lead to a decision to accept or reject one of two conflicting scientific theories.

(49) It is not possible to vary only one factor at a time when performing scientific experiments.

c) A significant difference existed among the "yes" responses from the degree teachers who teach biological science courses and the degree teachers who teach physical science courses,

the former having a higher percent "yes" responses to the following statements:

(3) Scientific experiments cannot conclusively prove or disprove scientific laws.

(7) Scientific experiments are performed to confirm scientific hypotheses.

(10) The results of scientific experiments are the only basis for the formulation of scientific concepts.

(23) Experimentation in science involves the separation of complex phenomena into simple ones.

(28) A scientific experiment consists of making an event occur under known conditions.

(33) Scientific experiments are special forms of observations.

(40) Scientific experiments are performed to confirm scientific laws.

(48) The results of scientific experiments are accepted only after several trials agree with prediction.

d) A significant difference existed in the "yes" responses of degree teachers who teach biological science courses and degree teachers

who teach physical science courses, the former having a higher percent "yes" responses to the following statement:

(61) There are universally accepted steps of procedure which are followed in the conduct of all scientific experiments.

In general, while biological and physical science teachers as a group and within each educational background exhibited some differences in the statements they included in their descriptions of scientific experiments, these differences did not follow a clear-cut pattern.

Conclusions

Since the representativeness of the responses received from the population of science teachers studied relative to the total population of Niger State science teachers can not be ascertained, and since no sample was taken, any conclusions arrived at as a result of this study can be generalizable only to the 103 teachers studied.

From the findings of this study, the following conclusions can be made.

1. Just as the 10 selected philosophers of science whose opinions formed the basis for the content of the questionnaire used in this study hold diverse and sometimes conflicting views on the

nature of scientific experiments, so do the group of science teachers studied. Furthermore, in their descriptions of scientific experiments, the teachers included statements that were not identified with any of the selected philosophers.

2. The groups of teachers with NCE and degree qualifications generally selected the same statements to be included in their descriptions of scientific experiments.
3. Biological and physical science teachers as a group and within each educational background level differed slightly in the statements they selected for inclusion in their descriptions of scientific experiments.
   a) The biological and physical science teachers as a group did not indicate preference for a common list of statements to be included in their descriptions of scientific experiments.
   b) The biological and physical science teachers with the NCE and the biological and physical science teachers with a degree did not indicate preference for a common list of statements to be included in their descriptions of scientific experiments.

4. There were few differences in the lists of statements which teachers with 0-2 years of experience and those with over 2 years of experience included in their descriptions of scientific experiments. This is true of the teachers as a group and the teachers belonging to each of the two educational background levels.
5. The findings of the current study support the argument presented in Chapter II to the effect that differences in conceptualizations of aspects of the nature of science by different groups of teachers may be detected if the analyses are based on responses to individual items on the questionnaire. In this study, when the teachers' responses were examined with respect to the independent variables, the resulting difference in responses to some individual statements dispute the "no difference" findings of past studies where conclusions were based on responses to a combination of several and sometimes unrelated items.
6. The teachers clearly made distinctions in the use of terms describing the role of experiments in science, terms such as "confirmation," "discovery," "falsification," "prove/disprove," "verification," or "formulation" of "scientific hypotheses," "scientific laws" and "scientific theories."

This observation is true for the teachers as a group and according to the selected variables studied. The teachers accepted the ideas of Hempel, Carnap and Kemeny that experiments are performed to "confirm" or "verify" scientific hypotheses and laws. They rejected the idea of "falsification" as argued by Popper and Fiebleman. However, since no definitions of these terms were provided on the questionnaire, this observation does not mean that all the teachers conceptualized each of these terms in the same way.

Recommendations

The potential usefulness of a descriptive study of this nature lies in curriculum evaluation. If as currently conceived, high premium is placed on student knowledge about the nature of scientific experimentation, then the descriptions of scientific experiments posited by science teachers should be compared to its representation in science curriculum materials. If marked differences are found between teachers' conceptions of the nature of scientific experiment and their representation in curriculum materials, it would suggest the need to effect changes in inservice and preservice training programs dealing with aspects of scientific experiments. For example, while many of the

curriculum materials of the last two to three decades adopted an "inductive approach" to student laboratory "experimentation", the group of teachers studied rejected the idea that experiments involve induction alone; they accepted the idea that experiments involve both inductive and deductive processes. There is no doubt that this finding will have implications about how they represent science to their students.

Further research is needed to ascertain if biological and physical science department in advanced teacher training colleges and universities where the NCE and degree teachers are trained, respectively, emphasize different aspects of scientific experiments and if so, is such emphasis desirable? This is particularly true with reference to the subject areas within each educational background level.

The findings of the current study are a first step toward obtaining an idea of the differing conceptualizations of the various terms that are subsumed under "the nature of science" concept which Niger State post-primary school science teachers hold. As an example, a large proportion of the teachers seem to have discriminated among the philosophical use of terms like "confirmation," "falsification," "verification," etc., and "scientific law," "scientific

theory," "scientific hypothesis," etc. Additional research studies are needed to determine if the conceptualizations which the teachers hold of these terms are consistent with their use in philosophical discourse. If the teachers' conceptions of these terms are philosophically consistent, it would suggest that the teachers do not misrepresent these aspects of the nature of science to their pupils. If the teachers' conceptions of these terms are confused and philosophically inconsistent, it would suggest the need to effect changes in the preservice and inservice programs to correct these misconceptions.

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APPENDIX I

1930-1980
50 YEARS
UNIVERSITY OF WISCONSIN-MADISON THE SCHOOL OF EDUCATION

Department of Curriculum and Instruction
Teacher Education Building
225 North Mills Street
Madison, Wisconsin 53706
608-263-4600

November 30th, 1978

Dear Sir/Madam,

I am a doctoral student in the above named institution specializing in Science Education. As a part of the requirements for the degree, I am undertaking a study related to the nature of science. The title of the investigation is: "Descriptions of the term 'Scientific Experiment' Held by Niger State Post-primary School Science Teachers."

Over the past several decades, educators, scientists, philosophers and other groups have stressed the importance of the understanding of the 'experimental nature of science' as a major objective of science teaching at both elementary and secondary school levels. While this objective is supposed to have permeated the science curriculum materials of the past two to three decades, no investigations have been undertaken to determine what understandings of the concept of experimentation in science the teachers, students, and other groups hold. This is most critical in the case of teachers who serve as the mediators between the various disciplines of science, and the using of instructional materials and the students.

The following questionnaire consists of statements related to the nature of 'scientific experiments'. As stated in the directions for completing the questionnaire, there is nothing like a 'true' or 'false' view of experiment since there are several diverging view points. I would appreciate it if you could spare a few minutes of your time and respond to the questionnaire.

Thanks in advance for your contribution to the success of this investigation.

Yours sincerely,

MOHAMMED ABDULRAHMAN

Please respond to the following questions:-

1) Which science subject(s) do you teach? _____

2) For how many years have you been teaching at post-primary school level? _____

3) Which of the following qualifications do you possess? (please tick the one(s) which apply to you).

a) NCE
b) Bachelor's Degree
c) Others (please specify)

_____

QUESTIONNAIRE

Scientific experiments have been described in a variety of ways by science educators, philosophers of science, and scientists. The following is a list of statements often included as parts of descriptions of the characteristics and functions of scientific experiments.

If you would include a particular statement as a part of your description of the characteristics or functions of scientific experiments, circle the word "Yes" immediately following the particular statement. If, on the other hand, you would not include the statement as a part of your description of scientific experiments, circle the word "No" immediately following the particular statement.

Please note that: -

1. It is not the aim of the study to establish the truth or falsity of the statements in any way.
2. You can respond to a particular statement by circling "Yes" or "No" but not both.
3. You are to consider all the statements on the instrument as independent of each other.
4. Your response to all the statements on the instrument is required.
5. Once you have responded to a particular statement, you are not to refer back to it.

STATEMENTS ABOUT SCIENTIFIC EXPERIMENTS

Please respond to the following statements:-

1. The outcome of a scientific experiment depends on technique of measurement employed. Yes No

2. A single scientific experiment could be crucial in any decision of accept or reject one of two conflicting scientific hypotheses. Yes No

3. No scientific experiment can conclusively prove or disprove a scientific law. Yes No

4. Scientific experiments are always based on theoretical principles. Yes NO

5. Statements expressing the results of any given scientific experiment can refer only to that particular experiment. Yes No

6. Scientific experiments involve only the proceed of induction. Yes No

7. Scientific experiments are performed to confirm scientific hypotheses. Yes No

8. One primary pre-requisite for the conduct of a scientific experiment, is the formulation of the problem to be investigated. Yes No

9. All observations made during the conduct of scientific experiments are always planned before hand. Yes No

10. The results of scientific experiments are the only basis for the formulation of scientific concepts. Yes No

11. A single scientific experiment could be crucial in any decision to accept or reject one of two conflicting scientific laws. Yes No

12. Scientific experiments involve only the process of deduction. Yes No

13. The results of a particular scientific experiment can have several possible interpretations. Yes No

14. Scientific experiments are performed to falsify hypotheses. Yes No

15. The results of scientific experiments are interpreted only on the basis of present knowledge. Yes No

16. Scientists working with similar experimental material may obtain conflicting results. Yes No

17. Scientific experiments are performed to falsify scientific theories. Yes No

18. The results of scientific experiments do not, on their own, lead to new knowledge. Yes No

19. All but one of the factors involved in a scientific experiment are always held constant. Yes No

20. Scientific experiments are performed to discover scientific hypotheses. Yes No

21. Scientific experiments are performed to formulate scientific theories. Yes No

22. A decision to accept or reject one of two conflicting sets of experimental results is solely dependent on the one which is able to withstand the severest test. Yes No

23. Experimentation in science involves the separation of complex phenomena into simple ones. Yes No

24. All the conditions that could affect the outcome of a scientific experiment can not be completely controlled. Yes No

25. Results of scientific experiments usually pose more questions than answers. Yes No

26. Only the results of scientific experiments which agree with prediction are useful. Yes No

27. There are no universally accepted steps of procedure that are followed in the conduct of all scientific experiments. Yes No

28. A scientific experiment consists of making an event occur under known conditions. Yes No

29. Scientific experiments involve both inductive and deductive processes. Yes No

30. The results of scientific experiment are useful only if they are repeatable or reproducible. Yes No

31. It is impossible to completely determine all the factors that could affect the outcome of a scientific experiment. Yes No

32. Scientific experiments are performed to discover scientific laws. Yes No

33. Scientific experiments are special forms of observation. Yes No

34. Statements expressing the results of scientific experiments can be applied to any of several related experiments. Yes No

35. Scientific experiments can be used to check cause and effect relationships. Yes No

36. No scientific experiment can, on its own, lead to a decision to accept or reject one of two conflicting scientific theories. Yes No

37. Scientific experiments always involve qualitative observations. Yes No

38. The results of scientific experiments always lead to new knowledge. Yes No

39. Statements expressing the results of scientific experiments always include ideas for testing the implications of such results. Yes No

40. Scientific experiments are performed to confirm scientific laws. Yes No

41. Scientific experiments can never reveal all the possible differences between two contrasting phenomena. Yes No

42. Scientific experiments canpnot be used to check cause and effect relationships. Yes No

43. Scientific experiments are performed to establish scientific theories. Yes No

44. Scientific experiments are performed to formulate scientific laws. Yes No

45. No scientific experiment can conclusively prove or disprove a scientific hypothesis. Yes No

46. The results of all scientific experiments are in one way or another, useful. Yes No

47. Scientific experiments are performed to verify scientific theories. Yes No

48. The results of scientific experiment are accepted only after several trials agree with prediction. Yes No

49. It is not possible to vary only one factor at a time in a scientific experiment. Yes No

50. Scientific experiments are performed to verify scientific hypotheses. Yes No

51. The products of scientific experiments are facts. Yes No

52. The results of scientific experiments are probabilities. Yes No

53. Scientific experiments are performed to falsify scientific laws. Yes No

54. Scientific experiments can not be used to prove scientific theories as true or false. Yes No

55. Scientific experiments are performed to predict scientific laws. Yes No

56. The results of a particular scientific experiment can have only one possible interpretation. Yes No

57. Scientific experiments involve only quantitative observations. Yes No

58. Scientific experiments can be performed to test the fundamental assumptions of nature. Yes No

59. Scientific experiments can be used to confirm scientific theories only by the indirect confirmation of the consequences of the theories. Yes No

60. The results of scientific experiments are valid only under the precise set of conditions in which the experiment was conducted. Yes No

61. There are universally accepted steps of procedure which are following in the conduct of all scientific experiments. Yes No

62. The results of simple scientific experiments are preferred over those of complex ones. Yes No

APPENDIX II

REFERENCE CITATIONS FOR STATEMENTS ABOUT SCIENTIFIC EXPERIMENTS.

Statement number	References
1.	Popper, p. 124; Hanson, p. 67.
2.	None.
3.	Frank, p. 22.
4.	Hanson, p. 157; Nash, pp. 167, 207; Hempel, p. 36; Popper, p. 107; Kemeny, pp. 97, 115; Fiebleman, pp. 117-118; Toulmin, p. 45.
5.	Popper, p. 28.
6.	Frank, pp. 297-300.
7.	Frank, p. 16; Popper, p. 27; Beveridge, p. 18; Fiebleman, pp. 114, 116, 117, 159; Hempel, p. 20.
8.	Nash, p. 152.
9.	Fiebleman, pp. 119, 129, 131.
10.	Nash, p. 152.
11.	None.
12.	None.
13.	Fiebleman, p. 153; Frank, pp. 43, 225.
14.	Fiebleman, p. 121.
15.	Beveridge, p. 27; Frank, p. 45.
16.	Beveridge, p. 34; Nash, 140.
17.	Popper, p. 80.
18.	Popper, p. 268.
19.	Fiebleman, p. 149.
20.	Fiebleman, p. 121; Hempel, p. 20.

Statement number	References
21.	Nash, p. 373.
22.	Popper, p. 109.
23.	Nash, p. 207.
24.	Nash, p. 162.
25.	Fiebleman, p. 130; Hanson, p. 67.
26.	None.
27.	Hanson, pp. 67, 129; Toulmin, p. 74.
28.	Beveridge, p. 20.
29.	Fiebleman, p. 121; Hempel, p. 20.
30.	Beveridge, p. 23; Popper, pp. 45, 99; Fiebleman, p. 129.
31.	Nash, p. 163.
32.	None.
33.	Fiebleman, p. 114.
34.	None.
35.	Carnap, p. 227.
36.	Hempel, p. 28.
37.	None.
38.	Frank, p. 45.
39.	Popper, p. 99.
40.	Carnap, pp. 42, 46.
41.	Nash, p. 129.
42.	Frank, p. 17.

Statement number	References
43.	Toulmin, pp. 110,112.
44.	Nash, p. 373; Toulmin, pp. 52, 89.
45.	Fiebleman, p. 124.
46.	None.
47.	Kemeny, p. 87.
48.	Carnap, p. 42; Hempel, p. 20.
49.	Beveridge, p. 36.
50.	Kemeny, p. 187.
51.	None.
52.	Hempel, pp. 61-62; Fiebleman, pp. 154, 161, 189; Kemeny, p. 79.
53.	Popper, p. 80.
54.	Hempel, pp. 27-28; Frank, p. 22.
55.	Fiebleman, p. 197.
56.	None.
57.	None.
58.	None.
59.	Carnap, 49; Hempel, p. 87.
60.	Frank, p. 153; Beveridge, p. 35.
61.	Fiebleman, pp. 144-145.
62.	Hempel, p. 142.

APPENDIX III

NAMES OF POST-PRIMARY SCHOOLS SURVEYED

1. Government College, Bida
2. Government Secondary School Eyagi, Bida
3. Government Teachers' College, Bida
4. Federal Government Girls' College, Bida
5. Government Girls' Secondary School, Bida
6. Government Secondary School, Lemu
7. Government Secondary School, Kutigi
8. Government Teachers' College, Mokwa
9. Women Teachers' College, Kontagora
10. Government Secondary School, Kontagora
11. Government Secondary School, Kagara
12. Dendo Secondary School, Agaie
13. Government Secondary School, Abuja
14. Government Teachers' College, Abuja
15. Government Secondary School, Paiko
16. Government Teachers' College, Izom
17. Women Teachers' College, Minna
18. Government Secondary School, Minna
19. Government Teachers' College, Minna
20. Ahmadu Bahago Teachers' College, Minna
21. Government Girls' Secondary School, Minna
22. Government Teachers' College, Wushishi

APPENDIX IV

1930-1980
50 YEARS
UNIVERSITY OF WISCONSIN-MADISON THE SCHOOL OF EDUCATION

Department of Curriculum and Instruction
Teacher Education Building
225 North Mills Street
Madison, Wisconsin 53706
608-263-4600

August 19th, 1978

The Permanent Secretary
Ministry of Education
Niger State, MINNA
Nigeria

Dear Sir:

REQUEST FOR PERMISSION TO UNDERTAKE A STUDY IN NIGER STATE POST-PRIMARY SCHOOLS

I am a graduate student working towards a doctorate degree in Science Education in the above named institution.

As a part of the requirements for the degree, I am planning to undertake a study involving all post-primary school science teachers in Niger State.

Specifically, the study involves obtaining "descriptions of scientific experiments held by the state's post-primary school science teachers". The term "scientific experiment" is a part of the domain of the "nature of science". The understanding of the nature of science has been emphasized as a major objective of science teaching at post-primary school level. This study is an attempt to solicit the views of the teachers on this important aspect of science. Since science teachers serve as the mediators between the disciplines of science and their students, it is considered essential that we have information on the views of the teachers on this important topic.

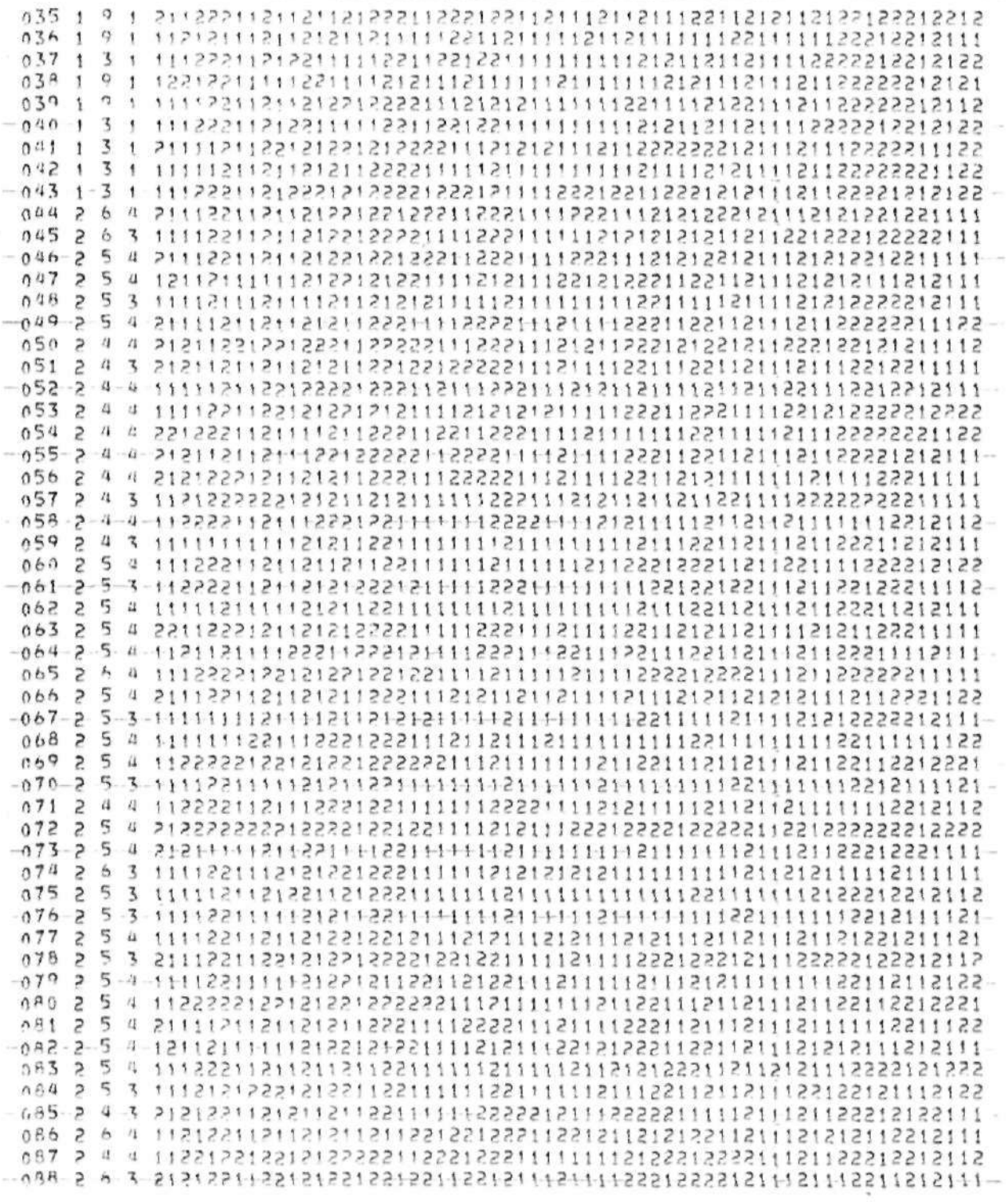
Your help in facilitating the success of this study will be highly appreciated.

Yours sincerely,

MOHAMMED ABDULRAHMAN

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                (4) BSC BIOSC (5) BSC PHYSC (6) BSC GENSC (9) NONE/
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*SELECT IF      (EDUCATION EQ 2 AND EXPERIENCE EQ 4)
*SELECT IF      (SUBJECT EQ 1 OR SUBJECT EQ 4)
*SELECT IF      (SUBJECT EQ 2 OR SUBJECT EQ 5)
*SELECT IF      (SUBJECT EQ 3 OR SUBJECT EQ 6 OR SUBJECT EQ 9)
*SELECT IF      (EXPERIENCE EQ 1 OR EXPERIENCE EQ 3)
*SELECT IF      (EXPERIENCE EQ 2 OR EXPERIENCE EQ 4)
FREQUENCIES     GENERAL=RESP1 TO RESP62
STATISTICS      ALL
OPTION          3,5
```

TITLE OF THESIS DESCRIPTIONS OF THE TERM "SCIENTIFIC EXPERIMENT" HELD BY NIGER STATE, NIGERIA, POST-PRIMARY SCHOOL SCIENCE TEACHERS.

Major Professor MILTON O. PELLA

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Membership in Learned or Honorary Societies

Publications ABDULRAHMAN, M. and SAMOILOFF, M. R; "Sex-specific Aging in the Nematode Panagrelus redivivus, Canadian Journal of Zoology, 53:651-656 (1975).

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