THE EFFECTS OF INSTRUCTION ON THE INTEREST AND COGNITIVE STYLE PROFILES OF PREDEGREE, PHYSICS STUDENTS IN MINNA, NIGERIA

BY

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D E P A R T M E N T OF EDU CATION
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DECLARATION

I hereby declare that this thesis has been written by me and that it is a record of my own research work. It has not been presented in any previous application for a higher degree. All quotations are indicated by quotation marks or indentation and the sources of information are specifically acknowledged by means of references.

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21.1.92
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CERTIFICATION

This thesis, entitled "The Effects of Instruction on the Interest and Cognitive Style Profiles of Predegree Physics Students in Minna, Nigeria" by Nnofuechi Andrew Oyedum meets the regulations governing the award of the degree of Doctor of Philosophy (Ph.D.) in Science Education of Ahmadu Bello University, and is approved for its contribution to knowledge and literary presentation.

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DEDICATION

This work is affectionately
dedicated to

1. My beloved late father,
   Chukwudulue Dominic Oyedum ("Mmayienwata"),
   for the visionary premium which so very
   early in the day he placed on education.

2. Nwachi Grace Oyedum,
   Mmayie's earthly companion. A faithful
   wife and loving mother. She gave me suck.

3. Elizabeth (Nkechinyere) Mgboyibo.
   The veritable "Mummy" and my priceless
   earthly companion. The beauty and
   majesty of our household!

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"Hoc erat in votis"!

ABSTRACT

The purposes of this study were to (i) identify the patterns of distribution of cognitive style profiles and interest orientations of a sample of predegree physics students, (ii) find out if and how cognitive style and interest are related to gender, age and career aspirations of the students, (iii) ascertain the relationship (if any) between students'" cognitive styles and their physics interests, and (iv) determine the effect of the teacher-directed discussion (TDD) mode of instruction on the cognitive styles, and physics interests of respondents.

Heath's (1964) 4-mode dimension of cognitive style (Recall (R), Principles (P), Application (A) and Questioning (Q))and interest conceptualized as a 3-dimensional character (Topic (T), Activity (.A') and Motive (M))as originally proposed by Gardner (1985) and recently employed by Haussler (1987), Gardner and Toon (1988) and Gardner and Tamir (1989) were used in this investigation$_0$

Seven major hypotheses were formulated and tested in the study. Non-parametric statistics, the Mann-Whitney U test and the Kruskal-Wallis one-way ANOVA, and the parametric Pearson product-moment correlation (r) were employed in analysing the data within 0.05 level of significance. In the experimental part of the study the Solomon 4-way (pretest, posttest, control group) design was used with a total of 326 predegree physics students of the Federal University of Technology (FUT), Minna who participated fully in the study to the end.

The results showed that:

1. The patterns of distribution of cognitive style profiles and interest orientations were respectively P-R-A-Q and T-A'-M showing that P and R were the dominant cognitive styles while T was the most dominant interest mode among the subjects. The students were thus more of principlcrs and recallers than appliers and critical questioners and their interest level was highest in the area of physics subject matter. The patterns of cognitive style and interest were found to be invariant with gender, age and career aspirations of the students.
2. Male and female students differed significantly in their physics interests but not in their cognitive stylos. Males consistently showed greater interest than females in all three modes of physics interest explored.
3. There were no age differences in cognitive style among the students. With respect to physics interest, significant differences were obtained only in the Motive (M) dimension. Students between 19 and 21 years of age showed the highest motivation for studying physics followed by those between 22 and 24 years. The youngest group of students between 16 and 18 years were the least motivated to learn physics. There was also evidence that in general students' interests in pliysics declined steadily from age 21 as students became older.
4. Cognitive style profiles and interest orientations of the pliysics students seemed unrelated to their future career expectations.

5. Instructive statistically significant correlations were revealed between cognitive style profiles and interest orientations of the physics students thus raising hopes that learners' physics interests could be predicted or nurtured through knowledge or nurture of their cognitive styles. The study showed that "non-recallers" and "appliers" in OPTICS and "non-principlcrs" and "appliers" in MAGNETISM would tend to demonstrate high levels of (physics) interest in the Topic (T) and Activity (A') dimensions. It was also revealed that "non-principlors" and "appliers" in physics generally and MECHANICS in particular would tend to have high interest in motives for studying phys." generally and specifically in studying physics because of prospects of taking up physics-related careers.

6. It was possible to modify the physics cognitive styles of the predegree students through the teacher-directed discussion mode of instruction (the experimaital treatment). Specifically, it was possible to shift cognitive styles from predominantly P, R, to A, Q and more specifically from P to Q.

7. The TDD mode of instruction was effective in raising the levels of physics interest in all three dimensions of interest-examined but could not effect a shift from one interest mode to another.

Based on these results some recommendations and suggestions were made for the improvement (in Nigeria) of science education in general and physics education in particular.

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ABBREVIATIONS

A.B.U.	Ahmadu Bello University, Zaria, Nigeria
A.M.I.	Activities Motives Inventory
A.S.E.P.	Australian Science Education Project
A.T.B.S.	Attitude Towards Biology Study
B.S.C.S.	Biological Sciences Curriculum Study
B.C.P.T.	Biology Cognitive Preference Test
C.B.A.	Chemical Bond Approach
C.E.S.A.C.	Comparative Education Study and Adaptation Centre
C_1, C_2, E_1, E_2	Control Group 1, Control Group 2, Experimental Group 1, Experimental Group 2 - the four groups in the Solomon 4-way quasi-experimental design employed in the present study.
C.O.I.	Career Orientation Inventory
C.P.E. II	Cognitive Preference Examination II
C.S.E.	Certificate in Secondary Education
D.I.D.	Defining Issue Discussion
D.I.T.	Defining Issue Test
F.U.T.	Federal University of Technology, Minna, Nigeria
G.C.E.	General Certificate of Education
I.P.I.	Interest in Physics Inventory
I.S.A.	Interest in Science Activities
I.S.A.S.	Interest in School Aspects of Science
I.S.T.	Interest in Science Topics
J.A.M.B.	Joint Admissions Matriculation Board
L.M.P.	Learning Mode Preference
N.I.S.T.E.P.	Nigerian Integrated Science Teacher Education Project
N.T.I.	National Teachers' Institute

P.C.S.T.	Physics Cognitive Style Test
P.S.S.C.	Physical Sciences Study Committee
R, P, A, Q	Recall, Principles, Application, Questioning - Heath's (1964) four-mode dimension of cognitive style employed in the present study.
S.B.S.	School of Basic Studies
S.B.S./A.B.U.	School of Basic Studies/Ahmadu Bello University, Zaria, Nigeria.
S.C.I.S.	Science Curriculum Improvement Study
S.P.O.T.S.	Student Perception of Teacher Style
S.S.C.	Senior Secondary Certificate
T.D.D.	Teacher-Directed Discussion
T, A', M	Topic, Activity, Motive - three dimensions of the interest character originally proposed by Gardner (1985) and recently employed by Hausler (1987), Gardner and Toon (1988) and Gardner and Tamir (1989) in their investigations of learners' science interests. The 3-dimensional model was used in the present study.
U.S.A.	United States of America
W.A.E.C.	West African Examinations Council

DEFINITION OF TERMS

INSTRUCTION

The art of teaching or training an individual or of imparting knowledge to a learner.

INSTRUCTIONAL MODE

A method of teaching or training a person or an approach used in imparting knowledge to a learner. Common examples are: lecture/expository, inquiry-discovery, teacher-directed discussion, problem-solving, project, laboratory, process approach, and lecture-demonstration modes of instruction. Other terms used synonymously with "instructional mode" include "instructional strategy", "instructional approach", "teaching mode" or "method of instruction".

INTEREST

A predisposition or state of an individual which enables him/her to attend to a particular object, organism, event, phenomenon or activity in preference to others.

COGNITIVE STYLE

The characteristic mode in which a person deals with or attends to a problem, situation, information or task presented to him/her. It is the "demonstrable manifestation of a cognitive preference" (Shuaibu and Ogunsola, 1983) and has been identified and operationally defined in various dimensions or types by

different researchers. Some of these dimensions or types include: Heath's (1964) four-mode model (Recall, Principles, Application and Questioning) employed in the present study, field-dependence versus independence (Witkin, 1950), conceptual versus perceptual - motor dominance (Broverman, 1960), analytical versus non-analytical (Kagan et al, 1963), reflective versus impulsive (Kagan, 1965), divergence versus convergence (Hudson, 1966), serialists versus holists (Pask, 1969) and introversion versus extroversion (Eysenck, 1970).

COGNITIVE PREFERENCE

The unseen internal mode or disposition of an individual which influences the overt manifestation of a cognitive style. It is the underlying unobservable factor in the exhibition of a cognitive style (Ohuaibu and Ogunsola, 1983; Ogunsola-Bandele, 1987).

SCIENCE AFFECT

A behavioural and attitudinal attribute exhibited by an individual through which the person expresses his/her predisposition, emotions or feelings towards science or science education. Examples include interest, enjoyment, satisfaction, value, liking, preference, choice, appreciation, approval or motivation.

LEARNING STYLES OR LEARNING STRATEGIES

Terms used synonymously with "cognitive styles" and commonly preferred by British authors. Learning strategies was defined by Rigney (1978) as "those operations or procedures that the students may use to acquire, retain and retrieve different kinds of knowledge and performance". Other synonyms of cognitive styles common in the literature are: "cognitive system principles", "cognitive control", and "thinking or intellectual styles".

MOTIVE

Something (a consideration, emotion or feeling) which excites one to action e.g. interest, value, appreciation or any other affect.

PREDICTOR VARIABLE

A variable whose values are used to predict or estimate the values on a criterion variable or measure (Twaite and Monroe, 1979). Four general types of predictors were identified by Dunkin and Biddle (1974), namely:

1. Presage Variable

   This refers to a teacher variable such as gender, age, teaching experience, qualification or motivation.

2. Context Variable

   A context variable could be a student variable (e.g. gender, age, ability, prelearning attitude), a school

variable (e.g. school type, location, size), or a classroom variable (e.g. size, climate, number of periods per week, availability of laboratory equipment).

3. Process Variable

A process variable refers to teacher or learner classroom behaviour or to observable changes in learner behaviour. Examples are teacher warmth, student participation and student enthusiasm.

4. Product Variable

This refers to an outcome variable in form of immediate or long-term pupil effect such as meaningful learning of subject matter, postlearning attitude, adult personality and professional or occupational skills.

TEACHER CHARACTERISTICS

A teacher's personal qualities or personality traits, his/her behavioural attributes or distinctive predilections which are overtly manifested before learners or influence the teacher's performance during the process of instruction. Teacher characteristics encompass both presage and process variables. Examples include warmth, friendliness, motivation, stimulation, training, experience, qualification, value system, curricular bias, cognitive style and teaching style.

Chapter 1

THE PROBLEM

A major goal of educational research is to seek better and more effective means of maximising learning which is usually measured in terms of students' academic achievements. In pursuit of this objective, new directions of research on even familiar and widely investigated concepts in education are at times opened up and explored with the hope of obtaining the vital bit of knowledge that would help to improve the teaching-learning process and so enhance gains in learners' achievements. Two such concepts which are already well-researched in science education are "interest" and "cognitive style".

Interest, it is presumed, provides strong motivation to learn. An individual who is interested in an activity, be it play or work, will put forth more effort to learn or perform it than a person who is less interested or bored. If learning experiences are to tap the full resources of a student, they

must be designed and presented in such a way that they are interesting. One way of doing this effectively is to make them coincide (as much as possible) with students' interests. In such a situation the student is ready and willing to learn because he/she is interested in what learning will bring him/her by way of personal advantage. Shane (1957) explained that interest is "something with which the child identifies his personal well-being". If a person sees that something will benefit him/her, he/she becomes interested in it and this motivates learning. As long as the learning activity is satisfying, interest remains high. When satisfaction declines, interest also wanes.

According to Hurlock (1972) interests add the element of enjoyment to life. When a learner is interested in a given activity, his/her experience with the activity will be more enjoyable than if he/she is not. If he/she lacks interests, his/her achievement will fall far short of his/her capabilities. Hurlock (1972:402) has pointed out that: "One of the reasons for underachievement among bright children, for example, is that they have too little interest in a subject to work up to their capacities." The quality of work a child does in school is believed to depend largely on interest. An interested learner might not only do better work than his/her less interested mates but also better work than would normally be expected from a child of his/her abilities.

Thus it seems obvious that the identification, stimulation and development of learners' interests, including science interests, are of major importance. Welch (1969) outlined two main considerations from which the present-day concern for the development of students' interest in science has stemmed:

1. Education in science is a basic component of the general education needed by all individuals in today's world, where science plays a major role in influencing present societies and shaping future ones.

2. Manpower demands in technological development are such that science teaching should stimulate student interests and eventually direct as many students as possible to choose a career in science.

Results of research on interest permit one to conclude that interest in science seems related to age, gender, science achievement, attitudes towards science, reasoning abilities and practised hobbies (Bingham, 1967-68; Meyer, 1970; Neujahr and Hansen, 1970; Hurlock, 1972; Kempa and Dube, 1973a; Gardner, 1975 and Haussler, 1987). The emerging trends are that:

(i) interest in science declines as students get older;

(ii) girls are less interested in science (especially physics) than boys;

(iii) students with high interest in science also achieve highly in science subjects; and

(iv) high interest in science correlates positively with favourable attitude towards science among learners at various levels of education.

In his international overview of students' interests in science and technology, Gardner (1985) outlined three major weaknesses of researches on students' interests in science, namely:

1. Much of the research gives the impression of not having been guided by theory;
2. Interest is often treated as a unidimensional quantity;
3. What is being measured is not explicitly made clear.

These shortcomings are quite similar to those identified by Brown (1975) in her incisive criticism of cognitive preference tests.

Haussler (1987) took measures to avoid these inadequacies in a recent study to investigate the development and change of interest in physics among students aged between 11 and 16 in the Federal Republic of Germany. Haussler's work is important for the following reasons:

(i) It confirms some of the age-old trends found in many earlier studies, namely that the overall interest in physics decreases as students grow older and that boys are more interested in physics than girls.

(ii) The study shows that the three dimensions of interest proposed earlier by Gardner (1985) are plausible and that one of these dimensions (the 'context' dimension) is dominant, contributing about 60% of the overall interest of a student in physics.

(iii) The design and the instruments of the study suggest a close relationship between "interest" and "cognitive style".

The present study partly focusses on the third reason stated above, that is to investigate this suggested relationship between interest and cognitive style.

The phenomenon known as "cognitive style" has, over the last three decades, engaged the attention and interest of researchers in the fields of psychology and education. Cognitive style in general describes the distinctive manner in which an individual prefers to deal with the stimulus world (Williams, 1975). It is the characteristic way in which a person prefers to attend to a situation, information or task with which he is confronted. "Attending" to a situation, information or task implies perceiving, conceptualizing, thinking about, apprehending, organizing, storing, transforming, utilizing and remembering information (Kogan, 1971; Witkin, 1973; Williams, 1975; Kagan et al, 1975 and Messick, 1976). In science education the situation, information or task are those associated with the teaching and learning of science, such as the subject matter of

a course (Heath, 1964), modes of presenting or remembering information (Shuaibu and Ogunsola, 1983 and Ogunsola-Bandele, 1987) and type of curriculum materials used (Heath, 1964; Marks, 1967; Tamir, 1975, 1976).

Klopfer (1971) identified two major differences between traditional curricula and the emergent science curricula of the '60's:

1. The new science curricula emphasize process skill development and inquiry learning (in addition to structure and unity of science) while the traditional science courses concentrate on the acquisition of the knowledge content of science - scientific facts, concepts, principles, generalizations, laws, theories and technological applications.
2. The new science courses are taught by inquiry and discovery approaches whereas the traditional programmes are taught primarily through the method of direct exposition/lecture and recitation.

As the need to evaluate the effectiveness of the new programmes (in comparison with that of the traditional courses) became more and more pressing, it equally became clear that conventional achievement tests would not be able to measure the differences between the new and traditional programmes in terms of learners' attainments. The arguments of the designers of the new science courses that the objectives of the new science curricula were quite different from those of the traditional courses and that

traditional achievement tests were systematically biased in favour of traditional courses were both understandable and plausible.

Motivated by this need to assess the progress of students towards the distinctive goals of the new curricula, Heath (1964) proposed four modes of cognitive style which he called "cognitive preferences" or "differing modes of attending to the subject matter of a course". Based on the cognitive style construct, Heath developed a Cognitive Preference Test (CPT) which he used to evaluate the achievement goals of the (then) new Physical Science Study Committee (PSSC) curriculum. This model has been widely and successfully employed in a large number of research studies in the various areas of science education.

The cognitive style modes as originally given by Heath (1964) and later illuminated by Van de Berg et al (1978), Jungwirth (1980), Tamir (1981), Tamir et al (1982) and McNaught (1982) are: Recall (R) or Memory (M), Principles (P), Application (A) and Questioning (Q). A brief explanation of each of the four cognitive style modes is presented below.

Recall (R) or Memory (M)

This mode refers to the recall or memorization of the knowledge items of science such as specific facts or terms. It indicates preference for or acceptance of factual scientific information for its own sake without consideration of its implications, applications or limitations.

Learners whose dominant preference is recall would tend to learn and to remember names, numbers, definitions, formulae, observations, terms, specific facts and the like.

Teachers who are recallers or who employ recall oriented teaching styles would be expected to lay emphases along the same directions in their science teaching.

Principles (P)

This mode refers to the identification of a fundamental principle underlying a scientific information. It indicates preference for or acceptance of a scientific information because it illuminates or exemplifies a basic scientific principle, concept or relationship.

A learner whose cognitive style is P would tend (to learn) to identify relationships between variables, rules that can be applied to groups of objects, organisms, phenomena or variables, or to explain phenomena or draw conclusions based on the underlying principle.

A teacher whose dominant preference is P or who uses a "principle" teaching style would (in his/her teaching) tend to emphasize the identification of fundamental principles, that is, identification of relationships between variables, rules that can be applied to classes of objects or explanation of phenomena.

Application (A)

This mode refers to practical application of scientific information. It indicates preference for or interest in scientific information because of its usefulness and application in a general, social or scientific context.

Learners whose prevalent cognitive style is application would tend (to learn) to identify practical applications related to the scientific information presented to them.

Teachers whose preference is predominantly application or who employ application-oriented methods of teaching would (in their teaching) tend to emphasize the use of scientific information to solve problems in everyday life.

Questioning (Q)

This mode refers to critical questioning of information. It shows a predilection to critically question or challenge a scientific information with respect to its completeness, generalizability and limitations.

A learner whose preference is for questioning would tend (to learn) to challenge, critically analyse or critically comment on the general validity of the science information. She/he would be inclined to generate suggestions and hypotheses for further investigations or to recognise a limitation or extension to the information.

A teacher whose dominant cognitive style is questioning or who uses a teaching style that is essentially geared towards questioning would (in lessons) tend to stress critical questioning of information, challenging of the general validity of the information and the need to be on the lookout for flaws, weaknesses, inadequacies and contradictions in a scientific information.

Heath's work represents a landmark in cognitive style research because through his model he introduced a method of measuring cognitive styles within the same context as that to which the measurement would be applied. This is probably one of the major reasons why the model has found popular acceptance and application in science education which is a multidisciplined field of knowledge.

Another likely reason is the immense potentials and considerable promise which (unlike the other so-called cognitive style dimensions) the model holds out as a pointer to possible ways of enhancing students' achievement gains in science by improving the teaching-learning process. Heath used the model to demonstrate differences in cognitive style between a sample of students using the PSSC curriculum and another sample of students following a conventional physics programme. He was thus able to show that his model was potentially useful for evaluating the success of the new science curricula as against those of the more traditional courses and for identifying curriculum-related differences in cognitive styles of learners (and their teachers). Both of these potentials of the cognitive preference test have been extensively explored during the last two decades by scholars and researchers in science education in a series of investigations which Heath's work had inspired. The reports of these investigations which are more directly germane to the present study are reviewed in detail in the next chapter.

In general the major focus of these studies have been on the identification of cognitive style as the sole criterion measure and the examination of the relationships between cognitive styles and a wide variety of predictors, comprising mainly of presage, context, process, and product variables associated with learners, curriculum materials and (to a lesser extent) teachers. A presage variable is a teacher variable (e.g. sex, age, teaching experience, qualification, motivation). A context variable could be a student variable (e.g. sex, age, ability, prelearning attitude), a school variable (e.g. school type, location, size), or a classroom variable (size, climate, number of periods per week, availability of laboratory support personnel). Process variables refer to teacher or pupil classroom behaviours or to observable changes in pupil behaviour (e.g. teacher warmth, student participation, student enthusiasm) while product variables refer to outcome variables in form of immediate or long-term pupil effects (e.g. meaningful learning of subject matter, post learning attitude, adult personality, professional or occupational skills) (Dunkin and Biddle, 1974). A greater proportion of published reports is on the cognitive styles of learners and on this, quite a substantial amount of work has been done (Tamir, 1981; Tamir et al, 1982; McNaught, 1982; Shuaibu and Ogunsola, 1983; Joe, 1983; Okebukola, 1984/85; Omoifo, 1986; Okebukola and Jegede, 1988 and Abah, 1988).

Although some useful examplars have emerged from these investigations, the findings have been largely conflicting and inconclusive. Nevertheless, there is indication that cognitive styles of learners may be influenced by their teachers, the curriculum materials they use and the modes of instruction used in teaching them. If these factors affect cognitive styles, the exact nature of their influences remains uncertain and has to be established through empirical research. For example, it is not clear whether it is the cognitive style of the teacher, his/her personal characteristics, his/her classroom behaviours, the instructional mode(s) he/she employs, the cognitive styles implicit in the curriculum materials used or a combination of some or all of these factors which actually affect the learners' cognitive styles and how.

One point in which most researchers are agreed is that the variety in the cognitive styles of students, identified through numerous studies, indicates that students prefer to learn in different ways. Hunt (1970) showed that students learn most effectively if they are taught with teaching methods which are consonant with their learning styles. Based on this empirical evidence and on the assumption that teachers influence the cognitive styles of their students, Hunt proposed a matching model in which he suggested that if the cognitive styles of the teachers and students are known, it may be possible to maximise learning outcomes by matching teachers with a particular style to students having that same style.

One implication of all these considerations is that differing modes of instruction corresponding to the identified cognitive (learning) styles of students should be employed in science classrooms. Thus there is need to identify, through empirical research, the modes of instruction which have the most generative effects on particular cognitive styles.

More importantly, what people usually prefer is not always what is best or most desirable for them. There is no guarantee that a learner's cognitive style would be educationally desirable. Therefore, by shifting a learner's cognitive style from a particular orientation to a more desirable one (using, for example, the goal of the educational programme - which is usually derived from the societal goal - as a criterion) he may be expected to learn more effectively.

Employing the defining issue-discussion (DID) method of teaching which is questioning-oriented, Shuaibu and Ogunsola-Bandele (1988) have demonstrated that the cognitive styles of students can be shifted from predominantly recall to questioning through teaching. This attempt appears to lend support to the notion that cognitive style is a learnable (rather than a fixed) trait which can be modified through training and maturation. Specifically the study has suggested that it is possible to move learners from a predominantly recall style to a questioning style if a suitable method of teaching is used.

It may be pointed out that the defining issue - discussion method of teaching employed by Shuaibu and Ogunsola-Bandele is just one out of a number of possible methods of teaching, and one that is rather uncommon. There is, therefore, a need to ascertain the (shifting) effects of other teaching methods, especially the known and more familiar modes of instruction such as teacher-led discussion. There is also the need to find out the instructional mode which is most appropriate for evolving not only the questioning style but also other cognitive styles. In recognition of these needs, Shuaibu and Ogunsola-Bandele averred that:

> It will be necessary to try out other teaching strategies in order to determine the most effective one that would enhance the development of a questioning cognitive style. Indeed the need to identify instructional strategies which may be matched to specific styles recommends itself.

In addition, it would equally be instructive to find out, through empirical research, the effect of different modes of teaching on the interest orientations of science learners. Most researchers agree that interest is a learned and learnable motive (Woodruff, 1962; Callahan, 1966; Hurlock, 1972; Hasan, 1975 and Shrigley, 1988). According to Hurlock (1972; 403) no child is born with ready-made interests. Instead interests are an outgrowth of learning experience. On the influence of learning on attitude, Baron et al (1977:105) have also written as follows:

> No one would seriously suggest . . . that children spring from the womb with all the complex attitudes they will later show as adults firmly in place. Rather, there is virtually universal agreement that they acquire these reactions in precisely the same manner that they acquire other forms of behaviour - largely through a prolonged period of learning.

Interest is considered a specific type of attitude, a sub-concept of the broader attitude concept (Gardner, 1975; Gardner and Toon, 1988). Nevertheless the true nature of the influence (on interests) of some instructional variables like methods of teaching is yet unknown.

The primary purpose of this study is two-fold: Firstly, the relationship between the interest orientations and cognitive style profiles of physics students is examined. Secondly, the effect of a specified method of teaching, the teacher-directed discussion method, on both the cognitive style and interest orientations of the physics students is investigated.

1.2 Statement of the Problem

The pioneering research study on cognitive preferences in science was carried out by Heath (1964) in the area of physics. Heath's work sparked off a flurry of other research studies on cognitive preferences in science. Interestingly and surprisingly most of these researchers who worked after Heath shied away from the discipline of physics and concentrated mainly on biology and chemistry in their probe of the cognitive preference attribute.

Thus the number of research studies on cognitive preferences in biology and/or chemistry is quite large. Although no overall consensus has emerged from the said studies, science educators, researchers and curriculists have been obliged with a few useful hints about the cognitive styles of biology and chemistry students and (in some cases) their teachers.

In the area of physics the situation is quite different. Very few researchers seem to have paid attention to the study of cognitive styles in physics. Both in Nigeria and elsewhere published reports of researches on the cognitive styles of physics students are sparse. Most of the cognitive style studies seem to be in the areas of chemistry and biology. However, a recent study by Abah (1988) examined the patterns of cognitive style (Heath's model) among science students offering physics, chemistry and biology in postprimary and tertiary institutions in Zaria area of Kaduna State, Nigeria. One of the objects of the study was to compare the cognitive styles of the subjects across the three disciplines of physics, chemistry and biology. The results showed that there were significant differences in cognitive style across physics, chemistry and biology thus suggesting the dependence of cognitive style on the nature of the subject matter or information presented to the learner.

More cognitive style studies of Abah's type are required in Nigeria in the physics area in order to verify the findings of research works already carried out and to ascertain the

relationships between students' physics cognitive styles and some common educational predictor variables. Part of the secondary purposes of the present study is to verify Abah's findings with respect to (i) the pattern of distribution of the cognitive styles, and (ii) the relationship between the cognitive styles and career aspirations of predegree physics students.

With regard to the science interests of learners, some definite trends have been established through research studies on interest. However, little progress has been made towards securing needed and valid answers to questions dealing with the development of science interests (Tyler, 1967; Ramsey and Howe, 1969). Two such unanswered questions identified by Hasan (1975) are:

1. What instructional procedures and classroom activities are most effective in fostering interest in science?
2. What variables (teacher-student, home, socio-economic, instructional, psychological, etc) influence the development of science interests?

The present study addresses itself to the above questions. It has been inspired by two recent studies carried out by Haussler (1987) and Ogunsola-Bandele (1987).

Haussler measured the interest in physics of students aged 11-16 years attending three different types of school in the Federal Republic of Germany. The design and instrumentation of

the study suggest a strong relationship between interest and cognitive style, thus lending additional support to the growing conception of cognitive style as an affective attribute (Payette, 1967; Ogunsola-Bandele, 1987 and Shuaibu and Ogunsola-Bandele, 1988).

Ogunsola-Bandele (1987) in her study examined the effects of two modes of teaching on the stability of the cognitive styles of a group of chemistry students in Nigeria. In the study she presumed cognitive style to be an affective characteristic and treated it as such. Specifically she explored the possibility of shifting the cognitive styles of the chemistry students from recall (R) to questioning (Q). Ogunsola-Bandele's major findings are:

1. It is possible to move students' cognitive styles in a desired direction using an appropriate teaching strategy. In this case the direction was from R to Q and the instructional approach was the defining issue-discussion method.
2. The Defining Issue Test (DIT) originally used by Rest (1974) to enhance the development of moral judgement provides an alternative means of measuring cognitive styles.

3. *Cognitive styles of learners can be indirectly and dependably measured by using teachers' perception of their students' cognitive styles.* The researcher, however, expressed due reservation about this particular finding because of the relatively small number of teachers that participated in the study (Ogunsola-Bandele, 1987: 159).

The first finding (concerning the modifiability of students' cognitive styles through teaching) is considered by this researcher as a significant contribution of the study and is the one that is directly germane to the present research. The present study has two primary purposes, namely:

(i) to investigate the relationship between the physics interests and cognitive styles of a group of physics students; and

(ii) to ascertain the effects of the teacher-directed discussion method of instruction on both the interest and cognitive style orientations of the physics students.

As its secondary objectives and in order to reverify and perhaps reconfirm some of the findings of similar earlier studies such as Meyer (1970), Shuaibu and Ogunsola (1983), Gardner (1985), Haussler (1987) and Abah (1988), the study also attempts to

(i) find out the nature or patterns of the cognitive style and interest profiles of the group of physics students; and

(ii) determine the differences in students' interest and cognitive style orientations due to such variables as gender, age and career aspiration.

The study specifically attempts to answer the following questions:

1. What is the pattern of the distribution of cognitive styles among the subjects?
2. What are the orientations of the subjects' interests in physics, interest being treated as a multidimensional entity?
3. Are there measurable differences in cognitive styles between
   (i) male and female students;
   (ii) students of different ages;
   (iii) students who aspire to different careers in science and technology?
4. Are there measurable differences in physics interest between
   (i) male and female students;
   (ii) students of different ages;
   (iii) students who aspire to different careers;
   using the 3-dimensional model of interest proposed by Gardner (1985)?
5. Are there any relationships between cognitive style profiles and interest orientations among the physics students?

6. Are cognitive style and interest profiles of physics students modifiable through the teaching method (the treatment) employed?

1.3 Need for the Study

The paucity of the number of cognitive style studies reported in the area of physics is a matter for genuine worry to science educators in general and physics educators in particular, especially those interested in cognitive style research. The problems which cohibit researchers from delving into the discipline of physics are probably those associated with the perennial, global issues of poor student enrolment in the subject and the general dearth of physics teachers. Accordingly any research in the area of physics involving a fair population of physics students or teachers as subjects is bound from the outset to be more painstaking, cost-intensive and time consuming than the same study carried out in other school subject areas. There is, nevertheless, a real need for cognitive style researchers to pay more attention than hitherto to the area of physics, the associated odds and problems notwithstanding. The present study is in the area of physics. It attempts to examine the effects of instruction on the cognitive style and interest profiles of physics students and the relationship between the two attributes (interest and cognitive style).

There is enough evidence leading one to infer that students' interests and cognitive styles in science may be fostered through instruction but little is known about the influence of some instructional variables (including modes of teaching) on the development of these attributes. The present study seeks to ascertain the effects of the teacher-directed discussion (TDD) mode of instruction on the cognitive styles and interests of physics learners.

It could be educationally valuable especially for science teacher education and science classroom practices if the TDD mode or instruction produces changes in some or all of the learners' cognitive styles and interest modes and if such changes prove to be consistent over time and location.

Reports of research on cognitive styles indicate that useful paradigms have emerged alright but the bulk of the findings remain inconclusive and conflicting. Again little is yet known regarding how knowledge about cognitive styles can be used to influence teacher education programmes and science classroom practices so as to enhance learning outcomes. While more research is needed to resolve the existing inconclusive and conflicting findings, there is also need to explore new directions that would show how knowledge about cognitive style profiles can help to raise the quality of science education and so increase students' academic achievements in science. This point has been underscored by Shuaibu and Ogunsola-Bandele (1988) when they

posited that: "These efforts at classification (of cognitive styles), however, have limited educational value unless and until they can be integrated with the teacher education programme to improve the teaching-learning processes." It is hoped that the results of the present study would contribute significantly to the realization of these needs.

For instance, the existence of a relationship between cognitive style and interest would have useful educational implications. The dependence of interest on cognitive style, for example, would imply that a modification of cognitive style through instruction could produce a corresponding change in the interest orientation of the individual(s) concerned. Non-dependence or nonrelationship would mean that the teaching approach could influence one attribute without necessarily affecting the other. Therefore, the investigation of the influence of the teacher-directed discussion method of instruction on interest and cognitive style profiles provides an alternative means of reverifying the possibility of a relationship between the two attributes.

A relationship between interest and cognitive style could also help to close the gap between interest which is an affective attribute and cognitive style, essentially a cognitive characteristic . Such a link may provide a good basis for a better understanding of the interrelatedness and functioning of other affective and cognitive variables which enter into educational practices.

Furthermore, confirmation of the affective nature of cognitive styles and the establishment of a relationship between cognitive style and modes of teaching might help not only to improve teaching and learning generally but also to facilitate the teaching of science affects, a task that has remained intractably difficult.

1.4 Basic Assumptions

The following assumptions underlie the study:

1. Subjects would understand each item in both research instruments, the Physics Cognitive Style Test (PCST) and the Interest in Physics Inventory (IPI) and would, therefore, make dependable responses to the items.

2. Science curriculum materials used at the secondary school level in Nigeria (the CESAC and WAEC science curricula) are more favourably disposed to the nurture of the Recall (R) and Principles (P) cognitive styles. This assumption is intended to control the influence of curriculum materials as extraneous variables on the experimental part of the study. Omoifo (1986) found that the patterns of cognitive styles for CESAC and non-CESAC chemistry and biology students were similar with R and P being more dominant than A and Q. In addition Omoifo found that the patterns of cognitive

styles implicit in the curriculum materials were R - P - A = Q and R - P - Q - A for chemistry and biology texts respectively. For both textual materials R and P were more dominant than A and Q. The cognitive style patterns were congruent with the cognitive style patterns obtained for the students who used the texts. This suggests that both the CESAC and non-CESAC curricula were more oriented towards R and P than towards A and Q and that both curricula influenced learners' cognitive styles accordingly. Omoifo's contention that the students' cognitive style pattern (with recall as the most dominant) was probably caused by the influence of "the nature of the subject matter . . . and not of the effect of the curriculum material used" and her subsequent conclusion that science curriculum materials in the Nigerian context have minimal effects on the cognitive styles of the students have been criticized in the present study (See 2.4.3; pp. 69 - 72).

3. A recall-oriented cognitive style is associated with the direct exposition/lecture mode of teaching. Evidence from research studies show that the expository method of instruction is predominantly employed in Nigerian (science) classrooms (Agwari, 1978; Shuaibu, 1979). The reported dominance of the recall cognitive style among science learners in Nigeria (Shuaibu and Ogunsola, 1983; Joe, 1983; Okebukola, 1984/85 and Omoifo, 1986) suggests a generative relationship between the teacher lecturing mode of instruction and the recall cognitive style.

4. A relationship between cognitive style and interest might throw more light into the affective nature of cognitive styles which was originally suggested by Payette (1967) and confirmed recently by Ogunsola-Bandele (1987) and Shuaibu (1988).
5. If cognitive style is related to interest, then mode of instruction might have an effect on interest if it has an effect on cognitive style.
6. A major prospect of cognitive style classification lies in its potential and promise to assist in:
   (i) the improvement of the quality of science teachers prepared through teacher education programmes, and
   (ii) raising the quality of teaching and learning in science classrooms. This potential, if it is real, can be tapped through empirical investigations of the type of the present study.
7. "Cognitive style" and "interest" are learned and learnable attributes rather than fixed characters and are, therefore, nurturable and modifiable through teaching.

1.5 Hypotheses

In attempt to seek answers to the research questions of the present study, the following hypotheses were tested:

Hypothesis 1

1(a) There is no significant difference in the cognitive styles of the four groups of physics students in the experimental design using Heath's (1964) four-mode dimension (Recall, Principles, Application and Questioning) of cognitive style.

1(b) There is no significant difference in the physics interests of the four groups of students in the experimental design using the three-dimensional model (Topic, Activity and Motive) of interest proposed by Gardner (1985) and recently employed by Haussler (1987) and Gardner and Tamir (1989).

Hypothesis 2

2(a) There are no significant differences in cognitive styles between male and female students who participated in the study.

2(b) There are no significant differences in physics interests between male and female students who participated in the study.

Hypothesis 3

3(a) There are no significant differences in cognitive style between students of different ages who participated in the study.

3(b) There are no significant differences in physics interests between students of different ages who participated in the study.

Hypothesis 4

4(a) Students in the four groups of the experimental design who aspire to different careers in science and technology do not exhibit significantly different cognitive styles.

4(b) Students in the four groups of the experimental design who aspire to different careers in science and technology do not exhibit significantly different physics interests.

Hypothesis 5

There is no significant relationship between students' physics cognitive styles as measured by the PCST and their physics interests as measured by the IPI.

Hypothesis 6

The teacher-directed discussion method of teaching (the experimental treatment) has no significant effect on the cognitive style distribution of the subjects.

Hypothesis 7

The teacher-directed discussion method of teaching (the experimental treatment) has no significant effects on the interest profiles of the subjects.

Chapter 2

REVIEW OF RELATED LITERATURE

2.1 Introduction

The present study is intended to examine the relationship between cognitive style and interest profiles of physics students and the effect of a selected method of teaching (the teacher-directed discussion method) on the two types of profiles. A considerable amount of research has been carried out world-wide on students' interests and cognitive styles in science. This is evidenced by the amount of published reports available in the literature in science education. In spite of this global picture, only a limited number of research studies in these two areas has been reported in Nigeria in the field of science education. The specific area of physics has generally received the least attention on a global basis.

Reports located outside Nigeria (notably the United States, Europe and Australia) are rather scanty when compared with what is available in the same places in other science subject areas.

In this chapter the literature related to the present study is reviewed. The literature review has been organised under the following headings:

1. The concepts of interests, cognitive style and cognitive preference (meanings and significances);
2. The multidimensionality of interest and cognitive style;
3. The relationship of interest and cognitive style with some educational variables;

4. The effect of instruction on interest and cognitive style;
5. Methods or procedures used by other researchers in studying interests and cognitive styles in science;
6. The teacher-directed discussion method of teaching.

2.2 Meanings and Significances of Interest, Cognitive Style and Cognitive Preference

2.2.1 Interest Concept

Interest is an affective attribute and a subconcept of that family of affective characteristics called attitude. Some of the definitions of interest given by Chambers (1972) in the Chambers Twentieth Century Dictionary include: advantage, benefit, concern, importance; a state of engaged attention and curiosity or a disposition towards such a state. Thus interest implies some element of gain, favour, regard, value, excitement or delight in something. It describes a predilection to attend to an object organism or event or to engage in some particular activities in preference to others.

Gardner and Tamir (1989) have stated that:

> The term "interest" usually refers to a preference to engage in some types of activities rather than others. An interest may be regarded as a highly specific type of attitude: When we are interested in a particular phenomenon or activity, we are favourably inclined to attend to it and give time to it.

Interest provides a strong motivation to learn especially when the individual in question considers the interest object to be of benefit or advantage to him (Shane, 1957; Hurlock, 1972).

The close relationship between interest and motivation largely informed the efforts of educators in the past to cultivate students' interests (including science interests) and this was largely instigated by John Dewey (Super, 1960). As long as an individual finds an activity enjoyable or satisfying, his interest in it remains high.

Gardner and Khoo Siek Toon (1988) and Gardner and Tamir (1989) have, however, pointed out that attitudinal terms such as 'enjoyment' and 'satisfaction' are closely associated and often correlated with interest but are not necessarily synonymous with it. The authors further explain that a person may enjoy a meal without being interested in it, or may dislike a meal but still display sufficient interest in it by asking about the recipe. A person may also be interested in issues towards which he has a negative attitude (racism, corruption, child abuse, nuclear warfare). The person's interest in such a situation reflects a positive attitude towards learning about the issue even though he holds a negative attitude to the issue itself. Thus interest in something does not necessarily imply a liking for that thing. Indeed the person who asks for the recipe of a meal he dislikes may be merely driven by sheer curiousty to find out the ingredients which have been used in preparing such an 'unpleasant' meal. Interest could, therefore, be positive or negative or rather (to be more correct) interest could be generated by a positive or negative attitude towards something.

Gardner and Tamir have in addition pointed out that interest can be regarded as either a trait (predisposition) or a state (emotional feeling). When, for example, it is said that an individual is interested in physics, this is not meant to imply that the individual demonstrates this interest 24 hours a day. A predisposition, behavioural intention or trait of the individual is merely implied. On the other hand if it is said that an individual is displaying an interest in physics, it implies that the student is currently doing something (i.e. engaged in an observable activity) in a manner which indicates the presence of a positive feeling. This is a description of current behaviour or state.

Krathwohl et al (1960) conceptualised the term "interest in science" as denoting a range of meanings that extends from positive feelings towards science to complete absorption in scientific enquiry. In this study interest is defined as a predisposition or state of an individual which enables him to attend to a particular object, event, phenomenon or activity in preference to others.

2.2.2 Cognitive Style Concept

Cognitive style is an aspect of individual or personality difference. It is both a psychological and an educational character which is useful for classifying or differentiating between individuals with respect to the kind of approach they

adopt to problems and learning tasks. The investigation of the concept of cognitive style originally started with attempts to explain individual differences as personality variables (Williams, 1975:62).

Cognitive styles have been conceptualised and defined in various ways. According to Field and Cropley (1969) cognitive styles are "the ways in which an individual's cognitive functioning and organisation appear to be characterised by idiosyncratic consistencies". Kogan (1971) defined cognitive style as "individual variation in modes of perceiving, remembering and thinking, or as distinctive ways of apprehending, storing, transforming and utilising information". Kempa and Dube (1973b) see cognitive styles as "characteristic modes in which individuals can attend to information or tasks presented to them". This suggests that cognitive styles are learning styles.

Witkin (1973) perceived cognitive styles as characteristic modes of functioning which people show throughout their perceptual and intellectual activities in a highly consistent and pervasive way. Williams (1975) who also viewed cognitive styles as "preferences" defined them as "the characteristic way in which persons prefer to conceptualize and organise the stimulus world". Pringle and Morgan (1978) in their own definition stated that "cognitive style reflects a characteristic and consistent mode of cognitive functioning exhibited by the learner in accommodating intellectual and perceptual experiences".

From the aforestated definitions it would appear that there is hardly any disagreement among researchers with regard to the way in which cognitive style is conceptualised. Clearly there is a general assumption that individuals differ in the ways in which they deal with or attend to a problem, a situation, learning task or information which is presented to them. The way a person deals with or attends to such a problem, situation or task is a function of his "cognitive style". Dealing with or attending to the situation, information or task involves such activities as thinking, perceiving, conceptualizing, learning, remembering, apprehending, storing, organizing, utilizing, presenting, teaching and so on. Cognitive style is, therefore, a concept that entails a wide range of perceptual and intellectual activities.

This probably explains the reasoning behind a few unique definitions that have also appeared in the literature. For example, Broverman (1964) stated that "cognitive styles have been conceptualized as relationships between abilities within individuals" while Shuaibu and Ogunsola (1983) defined cognitive style in science as "the mode of presentation of science information which an individual student would find it easiest to remember". Kagan, Moss and Sigel (1963) also defined cognitive styles as "stable individual preferences in mode of perceptual organization and conceptual categorization of the external environment".

Broverman's definition when viewed against that of Kagan et al raises the question whether cognitive styles are "preferences" or "abilities". Gardner (1963) claims that the distinction between cognitive style as preference and cognitive style as ability may be largely artificial although his own writings are more consistent with the preference interpretation. Williams (1975:61) has, however, argued that:" since numbers of writers have recognised the presence of cognitive styles in many different forms of behaviour, it seems more meaningful to conceptualize cognitive styles as stable preferences which manifest themselves in and affect abilities, rather than as abilities themselves." The definition by Kagan and his associates also introduces the idea of "stability" into the cognitive style concept. There is research evidence which tends to support the view that cognitive style is a stable phenomenon. On the other hand some evidence exists also which lends support to the suggestion that cognitive styles are unstable. The question of the stability of cognitive styles is discussed in greater detail in section 2.4 of this report.

Shuaibu and Ogunsola's definition is strictly operational with particular reference to their study. In it, however, the authors have implicitly asserted the equivalence of cognitive styles and learning styles and also restated the presumed close relationship between learning modes and teaching modes. Most researchers are agreed that cognitive styles and learning styles

are synonymous and assume that there is a close relation between learning styles and teaching styles. Learning style has been defined as an individual's preferred mode of problem-solving, thinking or learning (Adeyanju, 1985).

In science education, interest in the identification, classification and measurement of cognitive styles centres on their potential value for educational practice. Kempa and Dube (1973) identified two such values as:

> First, the knowledge of such styles may provide a basis for adjusting instructional strategies to the learning characteristics of individuals. Second, cognitive styles may be seen as parameters additional to the conventional cognitive and affective measures, to be considered in the assessment of an individual's intellectual performance or in the evaluation of educational process.

Messick (1970) had earlier suggested that cognitive styles "promise to provide a more complete and effective characterisation of the student than could be obtained from intellectual tests alone". Other prospects of cognitive styles and cognitive style research such as the possibility of "cognitive matching", provision of new bases for formulating objectives for new science courses and the establishment of clear relationships with other variables have been recognised and outlined (Hunt, 1970; Oyedum,1982).

It should be pointed out that the use of the term "cognitive style" is not uniform. Other terms which are also used synonymously to cognitive styles include "cognitive system

principles" (Holzman and Klein, 1954), "cognitive variables" (Pettigrew, 1958), "cognitive control" (Gardner, 1959 and 1960), "thinking or intellectual styles" (Heath, 1964; Wallach, 1965), "learning styles" (Hudson, 1966; Cropley, 1967; Keefe, 1979) and "learning strategies" (Brunner et al, 1965; Pask, 1976). Differences may exist in the nature and number of specific constructs identified by proponents under each of these labels but the constructs described by each term are different types of cognitive style.

2.2.3 Cognitive Preference Concept

The term "cognitive preferences" with its associated construct and test instruments was created by Heath (1964) in attempt to measure not "whether the student can identify correct or incorrect information, but rather what he is likely to do with information intellectually". Since then numerous research studies based on cognitive preferences in science have been conducted in different contexts using the so called Cognitive Preference Test (CPT). From the reports of these studies, two major views of cognitive preferences have emerged in the literature.

One school of thought, notable among whom is Pinchas Tamir of the Hebrew University, Jerusalem, perceives cognitive preference as a type or class of cognitive style (Tamir, 1975, 1981, 1982, 1983, 1985; Tamir and Kempa, 1977; Tamir et al, 1982;

McNaught, 1982; Okebukola, 1984/85 and Okebukola and Jegede, 1988). Some of these authors in their writings frequently use the expression "cognitive preference styles" in place of "cognitive preferences". To them cognitive preferences represent a subset of the universal set of cognitive styles; i.e. a class of cognitive styles.

A second school of thought among whom are Heath (1964), Kempa and Dube (1973), Ogunsola (1981), Shuaibu and Ogunsola (1983), Ogunsola-Bandele (1987), Shuaibu (1988) and Shuaibu and Ogunsola-Bandele (1988) conceptualise cognitive preference as an internal unseen factor which influences the overt exhibition of cognitive style. Ogunsola (1981, 1987) accepted Kogan's (1971) definition of cognitive style as "individual variation in modes of perceiving, remembering, and thinking, or as distinctive ways of apprehending, storing, transforming and utilizing information" but defined cognitive preference as the internal unseen mode of an individual that leads to exhibiting the cognitive style which can be seen externally i.e. it is the underlying internal factor in the exhibition of a cognitive style". In the same vein Shuaibu and Ogunsola (1983:102) described cognitive style as "the demonstrable manifestation of a cognitive preference". This suggests that cognitive style may be considered to be an outward (external) manifestation of an inward (internal) disposition called cognitive preference.

Interestingly most authors from within and outside both schools of thought apparently assume the equivalence of cognitive styles and cognitive preferences and in their writings tend to

use the two terminologies interchangeably. They also accept the use of Cognitive Preference Tests, originally designed by Heath (1964) for measuring this cognitive style. This may not be surprising but rather suggests that the two views described above complement rather than oppose each other. For how else should the apparent consensus among researchers about the equivalence of cognitive styles and cognitive preferences be logically explained?

However, a careful consideration of the issues involved seems to indicate that the situation is far from being satisfactory and a clarification of conceptions seems to recommend itself. Some of the questions which are raised in this regard are:

(i) Is the term "cognitive preferences" suitable for describing "modes of attending to the subject matter of a course"?

(ii) Are "cognitive styles" and "cognitive preferences" really equivalent?

(iii) What does a Cognitive Preference Test actually measure?

With respect to the first question, it would appear that the term "cognitive preferences" used by Heath to describe "modes of attending to the subject matter of a course" is a misnomer! If cognitive preference is a type of cognitive style, then it is merely a smaller class of a larger family. Furthermore, its manifestation must be influenced by an internal unseen factor known as "cognitive preference". It, therefore, sounds not only

tautological but also superfluous to employ the term "cognitive preferences" in describing a class of cognitive styles. Indeed quite a few types or dimensions of cognitive style are already known: field-dependence versus field-independence, levelling versus sharpening, reflectivity versus impulsivity, serialists versus holists, focussers versus scanners, and breadth of categorization among others. It would seem that each of these known cognitive style types is associated with an underlying internal factor (cognitive preference) in its overt manifestation. If this is the case, it would then seem illogical to use the term "cognitive preference" to describe a dimension of cognitive style, and then subsequently to talk of a "cognitive preference style".

It would seem that the concept of cognitive preference stands <u>beside</u> but not necessarily <u>within</u> the cognitive style concept. The two concepts are closely related but probably not identical. It is the view of this researcher that Heath's "modes of attending to the subject matter of a course" constitute a class of cognitive styles and may be called Heath's cognitive styles or Heath's cognitive style model. Using the expression "cognitive preferences" to describe this dimension of cognitive style appears inappropriate and has apparently created conceptual problems with regard to cognitive styles and cognitive preferences. In particular it has inhibited the nurture of a holistic view of each of these two concepts especially the

cognitive preference concept. As Brown (1975) has already pointed out, more studies are needed to facilitate the understanding of the true nature of cognitive preferences but this time not merely with respect to Heath's "modes of attending to the subject matter of a course" specifically but in relation to the concept of cognitive styles in general.

However, it could also be argued that the term "information processing mode" is equally not unique and suitable for describing Heath's modes of attending to the subject matter of a course. The argument would be that almost every cognitive style is in reality a mode of processing information. Such a contention would be right. In fact, Kempa and Dube (1973) defined cognitive style as "characteristic modes in which individuals can attend to information or tasks presented to them". The field-dependence-independence cognitive style has been described as "two contrasting modes of information processing" (Babalola, 1979).

This perhaps makes one appreciate Heath's problem in choosing a suitable label or terminology for his cognitive style dimension. It also means that finding such a suitable label, which is necessary in order to clarify the cognitive style and cognitive preference concepts, is a problem which researchers and theorists interested in this field will have to solve. Perhaps, and until such a label is found, it might be more appropriate to refer to these modes of attending to the subject matter of a course (recall, principles, application and

critical questioning) simply as Heath's cognitive style model, Heath's cognitive style dimension or Heath's information processing modes rather than as "cognitive preferences".

If the contention of wrong use of nomenclature to describe modes of attending to the subject matter of a course is acceptable, then the remaining two questions are easily answered. Concerning the equivalence of cognitive styles and cognitive preferences it may be argued that since cognitive preferences have been interpreted as the "internal factors in the exhibition of cognitive styles", they cannot be equivalent to cognitive styles. The two concepts would seem to stand beside each other, closely related but not necessarily identical.

However, what Heath (1964) erroneously described as "cognitive preferences" but which in reality are demonstrable modes of attending to information or modes of processing information actually constitute a class of cognitive styles. This, therefore, implies that these information processing modes or information processing styles are equivalent to cognitive styles but only in the sense and to the extent that the part may be equivalent to the whole. In other words, Heath's four information processing modes (recall, principles, application and critical questioning) are no more equivalent to cognitive styles than "mangoes are equivalent to fruits" or "cows equivalent to mammals"!

The third and last question concerns what a Cognitive Preference Test (CPT) actually measures. Following the aforestated arguments, it may be further submitted that what

has until now been known as Cognitive Preference Test should in reality be called Cognitive Style Test (to use a rather general term) or Heath's Cognitive Style Test (to use a more specific term). The former is in recognition of the fact that the instrument is measuring cognitive styles while the latter merely specifies the type of cognitive styles the instrument is measuring, namely, Heath's model of cognitive styles. The thesis in this study is that Heath's type of instrument measures what are overtly expressed (cognitive styles) and not necessarily what lurks underneath (cognitive preferences) whose true nature is probably not yet grasped. In fact some researchers seem to have recognised this truism: Ogunsola (1981, 1987) and Shuaibu and Ogunsola (1983) used Heath's type of instrument to study the cognitive styles of chemistry students. The authors called the 40-item chemistry instrument Ogunsola Cognitive Style Test (OCST) and throughout the bodies of the three reports made it clear that they were measuring cognitive styles and not cognitive preferences.

In the present study cognitive preferences are conceptualised as unseen internal modes which influence the overt manifestations of cognitive styles. Heath's (1964) famous four modes of attending to the subject matter of a course, on the other hand, are perceived as a distinct model or dimension of cognitive styles.

2.3 Multidimensionality of Interest and Cognitive Style

2.3.1 Multidimensionality of Interest

Early attempts at measuring interest in a science subject (such as physics) treated the interest construct as if it was a unidimensional entity and subsequently employed a single measure of interest as the independent variable. For example, the Strong Vocational Interest Blank (Strong, 1943; Blake, 1969), the Kuder Preference Record used by Mallinson and Van Dragt (1952) and the Academic Interest Measure (Halpern, 1965) all contain scales measuring science interest. However, no attempt was made at this stage to investigate the structure of interest within any science subject area.

Later investigations indicated that interest in a subject could reflect various topic-based dimensions. Factor analysis of Cooley and Reed's (1961) Science Activity Inventory by Walberg (1967) revealed that interest in nature study was quite distinct from interest in applied biology. Thereafter (and until recently) little attempt to study the science interests of students beyond the topic component seems to have been made. The tendency has been to regard 'interest in science', as synonymous with 'interest in its subject matter', at best with distinct patterns of interest being reflected for different topics. Gardner (1984) warned against this tendency and argued that:" Although it is certainly possible that many students

find some or most of the subject matter of some science discipline intrinsically interesting, it is conceivable that science subject matter may be instrumentally interesting, serving as a means of expressing other kinds of interest." As examples, he observed that some students may be interested in science because it gives them the opportunity "to make things and tinker with equipment". Some may appreciate practical work because they can work in small groups with their friends, or because they prefer to do independent work rather than listen to "streams of teacher-talk". Some students may yet feel bonds of friendship with their teacher and respond by displaying deep involvement in classroom learning. Other students may be interested in science as a means to an end, for example career aspirations, social status, parental approval or personal satisfaction. For such students the subject matter of the science subject may be somewhat incidental.

The author further argued that there may be a variety of reasons extrinsic to the subject matter itself which may be responsible for a particular task being interesting to a particular student. Gardner (1984:26), therefore, suggested that in studying the interests of students in science subjects "we need to examine the characteristics of students: what motivates them, what kinds of activities and social situations they prefer, in order to understand why certain kinds of learning tasks are (or are not) interesting".

In an international overview of students' interest in science and technology, Gardner (1965) again criticised the practice by which researchers treat 'interest' as if it was unidimensional. He contended that argument could be put forward for at least three distinct dimensions (or components) of interest, namely,

* subject matter (or topic) dimension,
* extent of commitment dimension,
* purpose dimension.

The three proposed dimensions can be easily defended. With respect to the topic dimension, it is possible that a science student may have very high interest in mathematics but low interest in biology. More importantly, a student who is interested in physics may have high interest in electricity and optics but little interest in mechanics.

With respect to the 'extent of commitment' dimension, it is possible that given two students who are genuinely interested in biology, one is contented with what he joyfully learns at school while the other back at home collects sample specimens to examine them more closely, visits ecological locations and reads books on evolution. These two students surely show different degrees of commitment to the study of biology. Finally, concerning the purposes dimension, it seems reasonable to suggest that students' interest in a science subject may differ because of the way in which they intend to use the knowledge gained in that subject.

Gardner (1985:24) acknowledged the influence of Yager's (1982) goal model on the analysis that yielded his three dimensions of interest. Yager identified a set of four goals which science teaching should be concerned with:

* personal needs,
* societal issues,
* academic preparations,
* career education/awareness.

According to Gardner, Yager's list of four goals led him to ask the following questions:

(i) To what extent are students <u>interested</u> in using science to meet personal needs?

(ii) To what extent do science students <u>want</u> to learn about environmental and energy issues which affect society at large?

(iii) How strongly are science students <u>motivated</u> by the possibility of pursuing academic work in science?

(iv) How many students are <u>willing</u> to consider the possibility of scientific or technological career?

These questions (or rather the answers to them) together with the list of goals that generated them, provided the basis for the derivation of Gardner's three interest dimensions.

Yager's list of goals apart, it would also seem that a careful consideration of 'science' as an enterprise (its description and definition) could also lead one towards the

three dimensions of interest proposed by Gardner. A description of science would reveal at least three major components:

(i) science as a product of inquiry - which reflects the 'topic' dimension of interest;

(ii) science as a process of inquiry - which is related to the 'extent of commitment' dimension of interest;

(iii) science as a human and social enterprise - which points to the 'purpose' dimension of interest.

An individual's interest in science may be an aggregate of the fascination held for him by a combination of aspects of these major components of the enterprise.

Inspired by Gardner's (1984, 1985) works, Haussler (1987) derived three similar dimensions of the construct 'interest in physics'. In doing this Haussler used a curricular model of physics education earlier developed by the author and his other associates (Haussler et al, 1982) in their study on desirable physics education in the Federal Republic of Germany. Haussler's dimensions for students interest in physics are:

(i) 'Topic' dimension: This refers to interest in a particular subject matter or topic of physics.

(ii) 'Context' dimension: This refers to interest in a particular context, motive or situation in which the topic is presented.

(iii) 'Activity' dimension: This refers to interest in the particular activity one is allowed to engage in, in conjunction with that particular topic.

Haussler's dimensions are clearly similar to Gardner's and are also related to Yager's (1982) four concerns of science education already referred to. For each of these interest dimensions Haussler further identified several sub-dimensions of interest in physics which he describe as 'categories' of the main dimensions. The author used these dimensions and their categories to design an instrument with which he studied the interest in physics of students between 11 and 16 years in the Federal Republic of Germany. A major finding of the study was that the context dimension was by far the most dominant of the three dimensions, making the greatest contribution to a student's overall interest in physics.

Two recent studies (Gardner and Khoo Siek Toon, 1988 and Gardner and Tamir, 1989 a & b) employing the three interest dimensions proposed by Gardner have also been reported. The first study dealt with the design and validation of an instrument for measuring interest in mathematics conceptualised as having the three dimensions: topics, activities and motives. Factor analysis was used to established distinct sub-dimensions for each of the three main dimensions. In both studies, however, the authors used the terms 'components' for the three dimensions and 'dimensions' for the sub-categories within the components.

The second study in which the authors investigated students' interest in biology (also conceptualised in terms of three components: topics, activities and motives) is in two parts. The first part deals with the construction of the instrument for measuring interest. Seven instruments in all were developed and administered to grade - 10 students in Isreal. Factor analysis was used to confirm the conceptualization on which the development of the instrument was based. In the second part of the study, the developed instrument was used to investigate the relationship between students' interest in biology and their grade - 11 enrolment intentions.

In view of this current thinking of interest as a multidimensional variable and the fact that it appears to be gaining credibility, it may be expected that future researchers would adopt this approach in probing the interest attribute. In the present study interest in physics is also conceptualised along the three dimensions employed by Haussler and Gardner and his associates, namely: topics, activities and motives. An interest in physics inventory is used to ascertain the relationship between interest in physics and cognitive style in physics.

2.3.2 Multidimensionality of Cognitive Style

Researchers agree that cognitive style is a multidimensional variable. However, the picture does not seem to be as clear and tidy as in the case of the interest construct, even though

multidimensionality of interest is a recent proposition. Various types of cognitive style (at least not less than 30 distinct labels have been located) originally proposed at different times by different researchers are identifiable in the literature. The preponderance of cognitive style types in the literature is probably due to the multidimensionality of the cognitive functioning of individuals which is also duly recognised and accepted (Field and Cropley, 1969; Messick, 1970; Kempa and Dube, 1973a and Williams, 1975).

It is, however, doubtful if every construct that has been proposed as a distinct 'dimension' of cognitive style actually qualifies to be so. Among what have been put forward in the literature as possible dimensions of cognitive style, some measure of overlap, similarity or relatedness is noticeable in certain cases. For example, the analytical versus non-analytical cognitive styles (Kagan et al, 1963) are similar to the field-dependence versus field-independence cognitive styles proposed by Witkin (1950). The field-dependent person is global and less analytical while the field-independent individual is more articulate and more analytical. The similarity between the two categories of cognitive style (field-dependence and analytical styles) has been acknowledged by Kagan and his associates (Williams, 1975:62). In the same vein the introversion - extroversion styles suggested by Eysenck (1970) have so much in common with Kagan's (1965) reflective - impulsive styles that one is tempted to suggest that Eysenck

merely proposed new labels for the cognitive styles which Kagan had identified earlier.

Hills (1982) has even suggested that some of the proposed dimensions of cognitive style may be mere factors "which appear to have an influence on cognitive style". He cites as an example, Bruner's (1956) 'learning strategies' which are claimed to be used by children in concept formation. Another example is the set of 'cognitive styles' investigated by Field and Cropley (1969), namely: mental operations, originality and flexibility. 'Mental operations' refers to the last Piagetian stage of mental development which starts at about age 11 and extends into adulthood. It seems more reasonable to consider this as a 'factor' which could influence cognitive style rather than as a cognitive style itself. Both 'originality' and 'flexibility' are among four distinct factors affecting creativity which were delineated by Guilford (1950) using factor analysis technique. All these observations, however, are views not substantiated by empirical evidence and so can neither be accepted as being correct nor be dismissed as untrue. More research is needed in the area of cognitive styles before definite conclusions could be made.

The aforestated problem concerning the dimensionality of cognitive style (i.e. the lack of clarity concerning the status of the various dimensions) is partly caused by the lack of consensus among researchers and theorists in the choice of nomenclature for describing major groups and their sub-groups.

The problem is a general one. For example in the case of interest measurement, Gardner employs the terms 'components' and 'dimensions' to describe the main dimensions and the sub-dimensions (of interest) respectively whereas Haussler uses the tags 'dimensions' and 'categories' respectively to describe same. Researchers in psychology and education may talk of 'global' and 'articulated' cognitive styles on the one hand or about 'recall' and 'application' cognitive styles on the other. Only the initiated, however, would recognise the former of these styles as the sub-dimensions of the field dependence versus field-independence dimension and the latter as two sub-dimensions of the dimension of cognitive style which Heath (1964) described as 'cognitive preferences'. Since, however, neither educational nor psychological research is intended to be esoteric, the need for researchers and theorists to adopt a generally accepted convention for this type of classification cannot be over-emphasized.

With respect to the dimensionality of cognitive styles, a careful study of the various identifiable cognitive styles aimed at classifying them into major dimensions and sub-dimensions would not only be appropriate but also quite useful. Such a taxonomy is, however, not part of the object of the present study. Owing to space constraints it is not possible to present here even brief descriptions of the major cognitive style dimensions or cognitive style types identified in the literature. For these descriptions the reader is referred to the works of Messick (1970:329-341), Ogunsola (1981:3-6) and Abah (1988:20-37).

A common feature of many of the identified styles needs to be pointed out: Many of these cognitive styles are each a continuum defined at the poles by either of a pair of opposite dyads. With such cognitive styles, it is assumed that individuals can be placed somewhere upon the continuum which extends between the extremes of the pair of alternatives.

2.4 Relationship of Interest and Cognitive Style with Selected Variables

In this section literature which deals with the relationship of interest and cognitive style with some selected variables is reviewed. Five variables are selected for the review: gender, academic achievement, curriculum effect, teacher effect (i.e. teacher characteristics) and teaching method. Each variable has been chosen on the basis that it is relevant to the present study and is a potential contributor to the interest and cognitive style profile of a physics student.

2.4.1 How Interest and Cognitive Style are Related to Gender

2.4.1.1 Interest and Gender

Gender is probably the variable that has been probed most by those who study the science interests of students. Results of many of these studies have revealed definite sex-related differences in the interest profiles of learners (Gardner, 1974;

Hasan, 1975; Gardner, 1985 and Haussler, 1987). In his international overview of students' interests in science and technology, Gardner (1985) has outlined the distinct differences observed in the patterns of science interests of males and females. A summary of the generalizations which emerge from the review provides a dependable picture of the prevalent situation and is presented below:

(i) Males show greater interest in science at the upper primary and lower secondary levels; they are more likely to enrol in science subjects at the upper secondary and tertiary levels of education; they are more likely to proceed to postgraduate work in the sciences.

(ii) Males are more likely to aspire to a science-based career; they are more likely to study science with a career in mind; engineering and technology careers are almost exclusively the preserve of males in most countries.

(iii) Males are more likely to be interested in physics and technology, in understanding how things work and in learning practical skills.

(iv) Females are more likely to be interested in biology (particularly human biology), in social science topics, in social implications of science and in learning science for its intrinsic value rather than for career purposes.

(v) Females tend to perceive science as more difficult and are less likely to feel confident about their ability to study science.

(vi) Males are more likely to hold negative stereotypes about females who study science with the result that females who enrol into the sciences are likely to be confronted with male disapproval.

(vii) Females are less likely to receive favourable advice about enrolling in science subjects.

(viii) Co-education appears to encourage the separation of male and female students into the physical and biological sciences.

These generalizations portray the global trends in gender-related differences in the interest orientations of learners and are supported by empirical observations in many countries. For example in Western Australia, Jennings and Zadnik (1980) found that the ratio of male/female enrolments in physics at tertiary level was 4.6:1 at the physics major level and 11.6:1 at postgraduate level. Also Dillon (1983) found that out of 31,000 members of the Australian Institute of Engineers only 90 of them are women. The scientific and technological advancement of any nation surely rests with her men rather than with the women.

In Nigeria this truism gives disturbing signals for the future of science and technology in the country. In states like Anambra there are indications of a recent general apathy, not to science education but to schooling generally on the part of male

children. The need for all those concerned with the education of children (parents, guardians, teachers, educators and those in government) to take firm positive measures to arrest this bad situation (in the interest of the future scientific and technological growth of the country) cannot be over-stressed.

2.4.1.2 Cognitive Style and Gender

Most of the studies which investigated the relationship between cognitive styles (Heath's model) and gender were carried out by Tamir and his associates. One of the studies (Tamir, 1975) used a sample of 989 Israeli 12th grade biology students out of which 468 were males and 521 were females. The results showed that males had higher preference for Q and A while the females had higher preference for P. The study also revealed significant interactions between sex and the type of curriculum studied. Females studying the new Biological Sciences Curriculum Studies (BSCS) course displayed the lowest preference for R while the non-BSCS display the highest preference for R.

An earlier comparison done by lumping all males and females together (irrespective of curriculum studied) had concealed this latter significant sex difference with respect to R. This result suggests that the type of curriculum studied affects female students' cognitive styles more than that of the males.

Tamir and Kempa (1977) investigated the cognitive preferences of first year college students in Israel and Canada and their relationship with sex (among other variables). The

sample was made up of 225 males and 74 females. No significant differences were found in the cognitive preferences of the two groups.

In another study (Tamir and Kempa, 1978) in which the cognitive styles across three science disciplines were examined, the authors also investigated the influence of gender on the cognitive styles. The subjects were a stratified random sample of 10th grade Israeli students (N = 599). The proportion of males and females in the sample were not stated. Analysis of data showed that boys had a higher R score in physics while girls had higher P score in chemistry. These two differences were significant at 0.05 level. In all other comparisons, no significant differences were obtained. The difference found was rather small considering that three science disciplines were involved. It is also significant that no sex differences were found in biology. It would seem that among the 10th grade science students, gender did not significantly affect cognitive styles. Tamir and Lunetta (1978) also found no significant sex differences in the cognitive styles of a group of talented high school students studying biology.

Two studies in Nigeria investigated gender-related differences in the cognitive styles of learners: Shuaibu and Ogunsola (1983) examined the cognitive style orientations of chemistry students in the School of Basic Studies (SBS), Ahmadu Bello University (ABU), Zaria. They found that males did not differ significantly from the females in their cognitive style profiles.

In the second study Joe (1983) investigated the cognitive preferences of another group of Nigerian students studying biology. Again he found no significant differences among the subjects in all four cognitive preference areas: R, P, A and Q.

Of all the studies reviewed, only among Israeli 12th grade biology students were any meaningful sex differences in cognitive styles observed. Weak differences were found among Israeli 10th graders in all three main science subjects: Physics, chemistry and biology. It does appear that gender does not exert much influence on cognitive styles. To find out what the picture is like in the Nigerian context, gender differences in the cognitive styles of physics students were examined in the present study.

2.4.2 How Interest and Cognitive Style are Related to Achievement

2.4.2.1 Interest and Achievement

General expectation and belief among educators and teachers is that a strong relationship exists between interest and achievement. However, available research evidence suggests that the relationship is fairly weak (Gardner, 1975, 1985; Schibeci, 1984). A number of Australian studies have reported correlations generally in the range 0 to 0.25 (Lewis, 1976; Power, 1981; Shannon et al, 1982), thus collaborating the weak relationship.

Nuttal (1971) obtained six values of correlations of science interest with examination grades in three science subjects at each of GCE and CSE 5th-form level. The values lie

between 0.32 and 0.49 and are considerably higher than values obtained in similar studies by many researchers before and after him. Gardner (1975:18) has suggested that the rather high values might have been due to the contribution of some unsuitable items identified in the instrument used for the study. The inclusion of such item was capable of raising the value of the correlation between interest and achievement.

Gatta (1973) found no differences in attitudes to chemistry between more and less able students. In a recent study, Schibeci and Riley (1983) reported the results of the analysis of data collected as part of the 1976-77 National Assessment of Educational Progress (NAEP) in the U.S.A. The results showed that attitudes influence achievement. An earlier finding by Eisenhardt (1977) had suggested that achievement influenced attitudes among 71,701 students in grades six to eleven in schools in Western Virginia, U.S.A. The two results, however, need not be seen as contradictory since there is the possibility that a two-way (rather than a one-way) relationship exists between interest (attitude) and achievement. This possibility has been duly acknowledged by Schibeci (1984:30).

Among those who take science in schools the relationship between interest and achievement has been found to be consistently weak. Gardner (1985) puts the mean range of correlation at between 0 and 0.4. Fraser (1982) has suggested on this account that if teachers want to improve achievement, they would be well advised to concentrate on achievement per se instead of trying

to improve achievement by improving attitude. On a second look, it may be clear that Fraser's advice may not yield much dividend at the end of the day. It has been rightly pointed out (Schibeci, 1984:31) that even if the results which led to the articulation of this view are valid (which is only a supposition), there is still much to be gained in teaching science lessons in such a way that they are interesting, enjoyable and satisfying to the learners.

Viewed from another perspective, if the relationship between interest and achievement at the individual student level is truly weak, then that would be welcome news to those who want science to be taught to all students. A low correlation implies that it is possible for students of low ability to be interested in studying science.

2.4.2.2 Cognitive Style And Achievement

There is evidence in the literature that a stronger relationship exists between cognitive style and achievement than between interest and achievement. Barnett (1974) found that higher achievers among a group of 10th grade American biology students showed a strong preference for application (A) while low achievers showed a strong preference for recall (R). The result indicates that academic achievement is related to cogntive style. And although one would have expected higher achievers also to have high Q scores, it is note-worthy that the differences shown are in the desired directions.

Tamir (1976) reported a strong dependence of cognitive style on achievement among 12th grade biology students in Israel. High achievers exhibited strong preference for questioning (Q), a weak preference for principles (P) and a strong dissatisfaction for recall (R). No significant difference was revealed between high and low achievers on application (A). Subsequent analysis also indicated that the relationship between cognitive preference and achievement depends, to some extent, on the type of subject matter content of the cognitive preference test employed.

Using a sample of talented Israeli high school students who mostly scored grades "A" or "B" in high school biology, Tamir and Lunetta (1978) found only one statistical difference in principles (P): "A" students had higher preference for P than "B" students. In his study of the relationship between cognitive preference and achievement of a sample of Australian 12th grade chemistry students, McNaught (1982) found that students who develop the cognitive preferences consistent with those implied by the curriculum studied tended to achieve more highly than students whose cognitive preferences were not consistent with the implied preferences. In addition the study revealed that a high score in a particular cognitive preference was positively correlated with performance on the types of cognitive tasks implied by that preference. These findings lend considerable support to the notion that cognitive style is a relevant variable in consideration of achievement in school science courses.

Joe (1983) studied the cognitive styles of a sample of Nigerian students studying biology in Rivers State. His examination of the cognitive style - achievement relationship revealed that low achievers scored highly on R and Q while high achievers exhibited strong preference for P and A. The result with respect to R and A are in agreement with an earlier finding by Barnett (1974) while the result in respect of P agrees with what was obtained by Tamir (1976, 1981). The evidence in respect of Q is significant and in contrast with what would have been expected. In discussing the results, Joe attributed the cause to the probable effect of the expository method of teaching which was mainly in use among biology teachers. An additional cause might be curriculum effect. The students studied the WAEC School Certificate Biology course which the researcher considered to be "modern" and so inquiry oriented. The course is, however, traditional and hence more favourably disposed towards R. Thus the speculative explanation given by the author that the "domineering role" of biology teachers in Nigeria who mostly employed the lecture method of teaching must have suppressed the questioning zeal of high achievers and compelled them to condition themselves accordingly seems plausible.

Okebukola (1984/85) examined the relationships between cognitive preference orientations and performance in biology of students on the traditional and the Comparative Education Study and Adaptation Centre (CESAC) biology syllabuses. The results show that the four

cognitive preferences correlated significantly with achievement in biology. Students with P and R cognitive styles achieve significantly better than those with A and Q on the traditional curriculum. On the CESAC curriculum (which is more modern) students with preference for A and Q achieved significantly better than those with P and R. A negative correlation between Q and biology achievement was again revealed in this study for the traditional curriculum. This confirms Joe's (1983) finding and lends support to the view that the trend is a feature of the Nigerian traditional biology course, the WAEC (non - CESAC) *School Certificate Biology Course.*

The findings of the studies reviewed point to the existence of a meaningful relationship between cognitive preferences and achievement in science. It appears that students with certain cognitive preferences might learn better on some curriculum programmes. One implication for curriculum designers and teachers is that if learning materials or scientific knowledge is not presented to the student in a manner which is congruent with his preferred mode of processing information, optimal learning might be hindered.

The relationships of achievement with cognitive style and insterest were not explored in the present study. However, a review and discussion of the interest - achievement and cognitive style - achievement relationships were considered appropriate because "academic achievement" is central to a proper understanding and appreciation of the roles of interest and cognitive style in science education.

2.4.3 How Interest and Cognitive Style are Influenced by Type of Curriculum

2.4.3.1 Interest and Type of Curriculum

Reported research on the influence of curriculum on students' science interests is sparse in the literature. Most studies have focussed on the broader and more general construct of attitude which encompasses interest and other affective variables such as enjoyment, satisfaction, appreciation and value. Some of these studies have compared the attitudes of students taking two different curricula with some "innovative" curriculum (e.g. PSSC, SCIS, BSCS, ASEP, Project Physics) pitted against some traditional alternative.

Mackay (1971) reported that a new locally produced physics course in Southern Australia was rated as more enjoyable than its traditional competitor and that a pilot run of the PSSC physics course was associated with worse declines in enjoyment than its traditional counterpart. Fraser (1975) found that Grade 7 ASEP students rated their satisfaction with classroom climate and their enjoyment of science more highly but there was no difference in the ratings of their interest in science when compared with those of students following a traditional course. Rennie (1978) compared the attitudes of students taking the Project Physics course with those of students offering traditional physics in Western Australia and found no significant difference between the two groups. There is also evidence

(though scanty) which suggests that locally produced, flexible curricula that allow for individual rates of learning are more likely to enhance students' interests in science (Allen, 1972; Milson, 1973; Gardner, 1973).

In their separate reviews of attitudes to science Gardner (1975) concluded that the effects of curriculum on students' attitude to science are relatively small while Schibeci (1984) is of the view that the findings of the studies reviewed do not permit a definite statement to be made on the strength of the influence of curriculum on learners' attitudes. Both authors are, however, agreed that the nature of the curriculum studies by students does influence their attitudes to science. Similarly, it is presumed that the science interests of learners are influenced by the type of curriculum they study. However, sufficient empirical evidence is not yet available for a proper understanding of the true nature and extent of such influences.

2.4.3.2 Cognitive Style and Type of Curriculum

With respect to curriculum effects on cognitive styles, the numerous studies reported indicate that the cognitive styles of students may be dependent on the type of curriculum they study.

In formulating the cognitive preference construct Heath (1964) was motivated by the need for an alternative means (outside the conventional achievement tests) of evaluating the new science curricula whose features are markedly different from those of traditional courses. Heath reasoned that these

distinguishing features of the new curricula reflected different cognitive preferences of the designers and hence that different curricula would imply different cognitive preferences. In his maiden study Heath found that PSSC students demonstrated stronger preference for P and Q than the non PSSC while the non-PSSC showed stronger preference for R than the PSSC students. The two groups did not differ significantly on application (A). The findings were in line with the predicted outcome with respect to R and Q. Similar results were obtained by Marks (1967) who compared the cognitive preferences of chemistry students following the modern CBA course and a traditional chemistry course. CBA students scored higher than non-CBA on P and Q but lower on R. No difference was found between the two groups on A.

Tamir (1975) examined the effects of the BSCS curriculum and a traditional (non-BSCS) course on the cognitive styles of a sample of Israeli 12th grade biology students. He found that regardless of their achievement level, BSCS students showed a higher preference for Q and a lower preference for R than their non-BSCS counterparts. No differences were observed between the two groups on P and A. This is in agreement with earlier findings in respect of Q and R (Heath, 1964; Marks, 1967).

Tamir and Lunetta (1978) explored the curriculum related differences in the cognitive styles of 177 American students who studied biology. Two different curricula were used: the BSCS Blue, Yellow and Green versions and the traditional "modern Biology" course. Students who used the Blue and Yellow versions

had identical cognitive preference scores while those who used the Green version had scores that were different. Accordingly the cognitive preference scores of students who used the Blue and Yellow versions were combined so as "to increase the power of the statistical test". The analysis showed that Blue and Yellow version PSCS students had significantly higher Q scores than the students on the traditional course while the students on the traditional course had significantly higher scores for R. The sample of the Green version students was too small for any definite conclusions about the effect of the Green version to be made. Again the higher Q and lower R cognitive preference orientation for students following an inquiry-oriented curriculum was consistent with earlier results already mentioned.

Okebukola (1984/85) examined the cognitive preferences of Nigerian students who used the GESAC and the traditional WAEC biology syllabuses. The results showed that students who used the traditional WAEC syllabus preferred R most (46%) and Q least (8%). On the other hand students who used the GESAC biology syllabus preferred A most (40%) and Q least (10%). This aspect of the data was not subjected to statistical tests of significance; only percentages as indicated were reported.

However, the orders of cognitive preference distribution for the two groups were: R - P - A - Q in the ratio 5.9 : 4.7 : 1.2 : 1.0 for the non-GESAC students and A - R - P - Q in the the ratio 4.0 : 3.8 : 1.2 : 1.0 for the GESAC students. The higher preference for A and lower preference for Q shown by

The SBS offered a one-year pre-degree programme for students who had completed the secondary school course and had passed the qualifying WAEC School Certificate or GCE O level examination.

The results showed that the order of the distribution of cognitive styles for non-CESAC students was R ≥ P ≥ A ≥ Q in the ratio 1.4 : 1.3 : 1.1 : 1.0 while the order for CESAC students (chemistry and biology combined) was R ≥ P ≥ A = Q in the ratio 1.5 : 1.3 : 1.0 : 1.0. The patterns and the ratios for the two groups were approximately the same. CESAC students did not appear to differ from non-CESAC students in their cognitive style patterns. In the chemistry sub-test the pattern for CESAC students' cognitive styles was R ≥ P ≥ Q ≥ A while in the biology sub-test the pattern was R ≥ P ≥ A ≥ Q. The pattern for the CESAC biology students is consistent with the overall cognitive style pattern for all respondents but at variance with an earlier one obtained for a different sample of Nigerian high school biology students (Okebukola, 1984/85).

Another important finding in the study is the lack of congruence between the cognitive styles implicit in the CESAC curriculum materials (both chemistry and biology) and the cognitive styles of the students who actually used the materials. A chi-square statistical test was used to assess the extent of dependence of the CESAC students' cognitive styles on the cognitive styles implicit in the CESAC curriculum texts. The results showed that the cognitive styles of the students were

probably not dependent on the styles implicit in the textual materials thus leading Omoifo to conclude that the influence of CESAC curriculum materials on students' cognitive styles is minimal.

However, another look at the data, that is the patterns of cognitive styles obtained for both the students and the curriculum materials prompts some scepticism about the researcher's conclusion and the statistical analysis that led to it, thus suggesting an alternative interpretation. The patterns of cognitive styles implicit in the textual materials were R - P - A = Q (4:3:2:2) and R - P - Q - A (3:3:2:1) for chemistry and biology texts respectively. For both materials R and P are the most dominant implicit styles while A and Q are the least implied. The patterns are clearly in consonance with those identified for the cognitive styles of the students who used the materials. It would therefore seem that the CESAC materials are achieving the objectives of the designers (i.e. teaching rote learning skills and fundamental principles) judging from the revealed implicit styles. It does not seem reasonable for one to expect a curriculum thus oriented towards recall to turn round and help its users to become inquirers. In discussing her results, Omoifo (1986:93) affirmed that: "For the pattern of styles implicit in the CESAC textbooks, there was evidence to suggest that recall was the most preferred style." But she went on to suggest that students' cognitive style pattern (with recall also as the most preferred style) was probably

caused by the influence of "the nature of the subject matter... and not of the effect of curriculum material used".

A more plausible interpretation would seem to be that the designers of the CESAC curriculum materials intended them to be inquiry-oriented (judging from the stated philosophy and approach that guided their work) but only succeeded in designing them to be recall - oriented. Thus Omoifo's finding that "CESAC materials were relatively more favourably disposed to A and Q the dominance of R notwithstanding" appears self-contradictory and hence doubtful. One might wish to ask if the emphases on A and Q in the CESAC textual materials are sufficient to make any appreciable impact when compared with the emphases on R and P. Omoifo's facts do not seem to support such an optimism. On the contrary there might be need to rewrite the CESAC texts in order to orientate them more towards A and Q particularly towards Q.

In the present study, therefore, it is assumed that curriculum materials used in the Nigerian context (that is the traditional WAEC and the CESAC curricula) would be more favourably oriented towards (i) the Recall (R) and the Principles (P) cognitive styles, and (ii) interest in science topics (T).

2.4.4 How Interest And Cognitive Styles Are Influenced by The Teacher

The role of the teacher in the teaching-learning process is crucial and decisive. There are numerous possible ways in which a teacher can influence the interest or cognitive style profiles of learners. These ways include the teaching method he employs, his

attitudes (general and specific), his personal characteristics or personality traits (e.g. cognitive style, warmth, friendliness), his training, his experience and his value system. Some of those teacher variables could exert greater effects than others. For example, there is evidence that students' interests in science are probably more strongly influenced by teachers' personalities and value systems than their training, teaching experience and background (Rothman et al, 1969).

In this section literature pertaining to the dependence of interest and cognitive styles on teacher variables is reviewed. Although, as already stated, "teaching method" may rightly be considered as a teacher variable, its influence on interest and cognitive style orientations of science students is reviewed separately in the next section.

2.4.4.1 Interest and Teacher Variables

In her recent book, Perrott (1982) has summarised several research reviews (Ryan, 1960; Flanders, 1972; Rosenshine and Furst, 1973) which identified some of the observable characteristics of effective teachers i.e. teachers who are able to foster gains in achievement and stimulate positive attitudes to learning. Perrott's summary reproduced from Gardner (1985: 21) is shown in Box 1. Many investigators of teachers' effects on students' science interests (or attitudes) have focussed on various aspects of these indicators of effective classroom teaching.

Box 1: Observable indicators of Effective Classroom Teaching

Ryan's Factors

1. Teacher is warm and understanding versus cold and aloof
2. Teacher is organised and business like versus unplanned and slipshod.
3. Teacher is stimulating and imaginative versus dull and routine.

Flander's Indicators of Indirect Teaching Style

1. Teacher asks questions
2. Teacher accepts pupils' feelings
3. Teacher acknowledges pupils' ideas
4. Teacher praises and encourages pupils.

Rosenshine and Furst's Correlates

1. Teacher is enthusiatic
2. Teacher is businesslike and task oriented
3. Teacher is clear when presenting instructional content
4. Teacher uses a variety of instructional materials and procedures
5. Teacher provides opportunities for pupils to learn the instructional content.

Source: Gardner, P. L. (1985:21)

Bohardt (1975) investigated the relationship between years of teaching experience of teachers and the science interests of their students. He used a sample of science learners in grades 4 through 8. No significant relationship was found in the study beween the two variables. On the other hand Breen (1979) correlated the attitudes of students with the interest of their teachers in four subject matter areas of elementary science curriculum. Slight but significant correlations were found between the teachers' science interests and the pupils' attitudes to science.

There is evidence that students' attitudes are influenced by a number of teacher cognitive style variables such as achievement - pressure and cognitive organisation. At senior high school level, physics teachers who pressed their students to achieve tended to be associated with higher pupil enjoyment of science (Gardner, 1972). At the primary level, however, such pressure may be counter-productive: Power (1981) found a significant negative correlation between achievement-pressure and primary pupils' attitudes to science.

Teachers who are cognitively well-organised, with good understanding of the subject matter and a capacity for effective planning appear to foster students interest in science at all levels. In senior high school physics, Gardner (1972) found a positive relationship between teachers' cognitive organisation and pupils' enjoyment of science. These findings suggest that

teachers who engage in structuring behaviour (e.g. providing overviews of topics, reviewing ideas, organising class discussion) enhanced pupils' attitude to science.

Students' science interests also seem to be influenced by the emotional climate of the science classroom which reflects the prevalent interpersonal relations between the teacher and his students. Gardner (1982) evaluated fifteen classes taking a course in refrigeration theory and found that two classes expressing low level of satisfaction with their course both rated their teachers as low on "warmth" and "stimulation".

Different behaviours or treatments meted by teachers to different students may accentuate differences in interest already existing among learners. For example, Power (1973) found that pupils who were initially sophisticated and who expected to succeed in science were chosen more frequently for classroom interaction by the teacher and have received positive reinforcement more often.

The forms of language that science teachers use during teacher-pupil interactions in the classroom is another factor which may affect the teacher-pupil rapport and consequently students' interest in science. The remark by Gardner (1984) concerning this is pertinent:

> Some science teachers adopt an inquisitional style probing, correcting, criticising - rather than a conversational style. A social situation in which a student learns to perceive himself as ignorant and subject to disapproval for offering wrong answers is hardly conducive to the enhancement of interest in the topic under discussion.

From the studies reviewed, it would seem that in general positive behaviour of the teacher (based on sound psychological classroom practices) are congruent with positive attitude or high interest of students in science while negative teacher behaviours are counter-productive.

2.4.4.2 Cognitive Style and Teacher Variables

Several researchers have explored the influence of a number of teacher variables on the cognitive styles of students. Schmedemann and La Shier (1967) investigated the cognitive preferences of PSSC physics students and selected characteristics of their teachers. The study aimed to detect the relationship between the students' cognitive preferences (the dependent variable) and each of four teacher variables (independent variables): teachers' cognitive preferences, teacher warmth, teacher demand and teacher motivation. A 20-item Cognitive Preference Test was used to measure the cognitive preferences of both teachers and students - both responded to the same instrument. Data in respect of the three remaining independent variables (warmth, demand and motivation of the teachers) were collected by means of a 12-item Student Inventory responded to by the students. Each item in the Student Inventory which was adapted from an original instrument used by Reed (1962) described a teacher behaviour which corresponded to one of the three variables. An example of one of the "warmth" items is as follows:

Our teachers show a sense of humour in class . . .

A. almost never

B. few times

C. sometimes

D. often

E. very often

Each item was scored as follows: A, 1 point; B, 2 points; C, 3 points; D, 4 points; and E, 5 points. In this way a high score indicated that the characteristic being measured was strong while a low score indicated that the characteristic was weak.

Some 31 PSSC teachers and their classes participated in the study. The exact total number of students was not specified but this was hardly necessary since class means were used in all computations. The following hypotheses were tested:

1. There is no relationship between cognitive preferences of teachers and the cognitive preferences of the students.
2. There is no relationship between teacher warmth and the cognitive preferences of the students.
3. There is no relationship between teacher demand and the cognitive preferences of the students.
4. There is no relationship between teacher use of motivation and the cognitive preferences of students.

The results of data analysis did not permit the rejection of any of the four hypotheses. Students' cognitive preferences were

apparently not influenced by either the teachers' cognitive styles or the teachers' classroom behaviours.

The cognitive preference criterion measure failed to discriminate within each group despite the early hopes raised by Heath's (1964) results. Neither the validity nor the reliability of any of the two instruments used was reported. Apparently suspecting that the instruments were faulty, the authors suggested the use of a longer Cognitive Preference Test (i.e. containing more than 20 items) and an indirect way of identifying the cognitive styles of the teachers (e.g. through the students).

Tamir (1975, 1976) examined the effect of teacher's curriculum bias (i.e. the attitude of a teacher towards the curriculum in use) and the cognitive preferences of 989 Israeli 12th grade biology students. The first report (Tamir, 1975) concerned the effect of teachers' curricular bias on the cognitive preferences of students while the second report (Tamir, 1976) focussed on the influence of teachers' curricular bias on the students' cognitive preference - achievement complex. Some of the students offered the innovative BSCS biology course while the others studied a traditional (non-BSCS) biology course. The cognitive preferences of the students were measured by means of the 40-item BCPT designed and validated by the author. The teachers(N=50) responded to an attitude inventory and were classified on the basis of this as BSCS supporters (N = 24) and BSCS non-supporters (N = 26).

Results of the analyses showed that regardless of the achievement level or the curriculum actually studied, the students of BSCS supporters had higher scores for A and Q and lower scores for R. An interesting revelation was that initially there was no difference between BSCS and non-BSCS in their preference for A but after partialling out the effect of teachers' curricular bias, it was found that the BSCS approach was more related to a higher preference for A.

When achievement level was taken into consideration, curricular bias of teachers was found to have a strong effect on the 'cognitive preference-achievement' association. The summary of the results is as follows: Regardless of curriculum studied, high achieving students of strong supporting teachers had high Q high P, low R while high achievers of non-supporting teachers had low R, low A. Low achievers of BSCS supporters had high R, low Q low P while low achievers of non-supporters had very low R, very low Q. When the curriculum studied was considered, certain trends emerged more clearly. Thus it was revealed that the highest R score belonged to low achievers of BSCS non-supporters while the lowest R preference belonged to high achievers of BSCS supporters. The data suggest that with respect to R, the dominant or determining factor is the teacher's curricular bias rather than the nature of the curriculum. For A, however, the dominant factor appears to be the curriculum, while a combined effect of the two factors is apparent for Q for which the lowest score

belongs to the *non-BSCS non-supporters*. The findings suggest that teachers' attitude to the curriculum being used influences not only the cognitive preferences of students but also their cognitive preference-achievement profiles.

The influence of teachers' cognitive styles on the cognitive styles of their students was explored by Tamir (1977) in a study which was an outgrowth of the two just reviewed above (Tamir, 1975, 1976). In her criticism of cognitive preference testing, Brown (1975) had suggested that it was possible that in responding to a cognitive preference test, a student is merely exhibiting a conscious or subconscious conforming behaviour rather than a personal valuing behaviour. She argued that in exhibiting such a conforming behaviour, the student may actually come to adopt the attitude of his teacher in order to maintain a favourable relationship. Through such a process of "identification" the student might believe in the views he adopts but they are of course tied to and dependent on the teachers opinion and, therefore, not part of his own personal value system.

One implication of Brown's argument is that the teacher may by his own value system influence students' value systems. More specifically the cognitive preferences of students may be affected by their teachers' cognitive preferences. The educational advantages of such a state of affairs have already been pointed out (Hunt, 1970). Considerable indirect evidence against the possible influence of the teacher on the cognitive styles of learners is available (Barnett, 1974; Williams, 1975)

but the Schmedemann and La Shier (1967) study provides a more direct evidence against Brown's identification theory. They found no significant relationship between teachers' cognitive styles and the styles of the students or between cognitive preferences of students and any of the other three teacher characteristics (Warmth, demand and motivation) tested in the study.

In order to examine the relationship between the cognitive preference patterns of teachers and those of their students (in the study under review), Tamir tested the following hypotheses:

1. Significant differences will be found between the teachers and their students in their cognitive preference scores.
2. The cognitive preferences of the teachers will not correspond to those of their students.
3. In spite of the hypothesized differences in the levels of cognitive preference scores between the teachers and their students, similar interrelationships among the four cognitive preference areas will exist for both groups.

To test these hypotheses the biology teachers (N=46) of the students (N=989) who participated in the two earlier studies were asked to respond to the 40-item BCPT. 37 teachers responded by means of the graded rating system by which a rank of 1 is assigned to the option least preferred and a rank of 4 to the option most preferred. Analyses of the data yielded the following results:

1. Both the teachers and their classes possessed a very high preference for P, and they did not differ in their preference for P or P-A (the "utility" scale - see Kempa and Dube, 1973b; Tamir and Kempa, 1977). High preference for P had been found to be a characteristic of Israeli science students (Rogel, 1974; Tamir, 1975; Tamir and Kempa, 1978) and seems to be applicable to teachers as well. It was found that whereas teachers had a very high preference for Q and a very low preference for R, their students manifested on the average the same levels of preference for R, Q and A. These revelations suggested that the teachers and their students differed in their cognitive preferences. Thus the first hypothesis of the study was accepted.

2. No correlations were found between the cognitive preferences of the teachers and their classes; hence the second hypothesis was accepted. However, when correlations were compared for teachers and classes in each of the three types of school which featured in the study (city schools, agricultural schools and Kibbutz schools) significant correlations were found between the cognitive preferences of teachers and students only in the Kibbutz schools. The congruence appeared only with respect to P and P-A and was not considered sufficient for the rejection of the second hypothesis (i.e. the no identification hypothesis). Therefore, Tamir concluded that the responses of the students

was a manifestation of their own personal information processing mode and not a conforming behaviour to please their teachers.

3. Interrelationships among the four cognitive preference areas for the teachers and students yielded results which supported the third hypothesis only partially.

It is noteworthy that the main finding of this study, namely that the cognitive preferences of teachers do not corresponds to those of their students, agrees with Schmedemann and La Shier's (1967) results and provides additional evidence against Brown's hypothesis that in responding to a cognitive preference test students might be merely depicting conforming behaviour to please their teachers. More research would be necessary to confirm this evidence and also to explore other ways in which the teacher could influence his students' cognitive styles. One of the objects of the present study is to examine the influence of the teacher-directed discussion method of teaching on the cognitive style and interest patterns of physics stuents.

2.4.5 How Interest and Cognitive Styles are Influenced by Instructional Method

2.4.5.1 Interest and Methods of Teaching

Gardner, Gray and Taylor (1981) studied the effect of teacher transmissiveness (directiveness) on students' interest in science at grade - 10 level. A strong negative relationship was revealed

by the data analysis. The results suggest that students who are allowed to progress at their own rate (i.e. those who are taught through individualised approach) may display greater interest in science. Tuckman and Waheed (1981) found that the use of individualised approach with undergraduate students resulted in more favourable attitude compared with the group not exposed to the method. Presumably teachers who employ teacher-dominated (expository) forms of instruction are less likely to be engaged in guiding individual students at their own rates.

Fraser (1975) compared junior high school students taking the individualised ASEP course with non-ASEP students and found that ASEP students rated their classes as higher on scales measuring individual attention and satisfaction. On the other hand, Cullen (1981) investigated the attitude of first year primary teacher education students and compared an experimental group taking an individualised physical science unit with a control group which was conventionally taught. It was found that the experimental group was able to recognise some of the educational advantages of the Physical Science unit (e.g. greater clarity of objectives, greater access to the lecturer, greater self-responsibility) but they rated the unit as slightly less enjoyable than did the control group.

Associated with the notion of learners' progress through individualisation of instruction is the idea of freedom of choice over the topics within the curriculum. While it is possible for a student to become interested in a topic which someone else (e.g. the teacher) has selected, it can be argued that the

fullest expression of a student's interests is likely to occur under conditions of personal autonomy or freedom of choice. In fact, the failure of Cullen's (1981) study to show that individualised instruction was more enjoyable has been attributed to the possibility that the students in the experimental group had no control over the learning task in terms of either amount or subject matter (Gardner, 1984).

Another teaching approach which research has reasonably shown to be fairly consistent in fostering positive attitude is the activity-oriented approach. Krammer (1979) found that the attitudes of a sample of student teachers taught with this approach were positive when compared with the group taught with a different method. Dawson and Bennett (1981) asked Grade 8 students to rate their liking of 17 teaching methods. Methods involving student participation (doing experiments, making models), or visual stimuli (visit the zoo, watch film or slides) were most popular while listening to the teacher talk and copying notes were unpopular. In an evaluation of Project Physics in North South Western Australia, Quinlan (1981) used a scale called "Emphasis on Experiments". He found that stronger emphasis on experiments tended to be associated with higher class mean interest.

Many other studies have investigated the effects of specific teaching methods on the more general attitude construct. The results are diverse. Those methods which have been claimed to result in positive attitudes (compared with a group not exposed

to the approach) include: lecture-laboratory compared with lecture only (Saunders and Dickson, 1979); use of literature (Fisher, 1980); structured films (Simmons, 1980); computer-assisted-learning (Alesandrini and Rigney, 1981) and unstructured museum tours (Stronck, 1983). The following methods have been reported not to result in more positive attitudes (compared with a group not exposed to the strategy): field-based laboratory work (Samuel and Kempa, 1976); emphasis on process skills (Gabel et al, 1977; Riley, 1979); comparison of expository, modular and gaming approaches (Hess and Shrigley, 1981) and laboratory work (Garrett and Roberts, 1982; Friend and Gaifa, 1983). The diversity of the approaches investigated and the findings obtained hardly permit any generalizations, at least not for now. In his update of the review of attitudes to science, Schibeci (1984:42) has rightly observed that "curriculum and instructional variables influence attitudes, but the strength of this influence is difficult to determine from the studies reviewed".

2.4.5.2 Cognitive Style and Methods of Teaching

Although in recent years there has been a growing awareness of the need to teach individuals to "learn how to learn" (Rigney, 1978; Bransford et al, 1981; Perry and Downs, 1985) researchers have not explored the potentialities of cognitive styles towards meeting this need. The few studies that have

probed the relationship between method of instruction and cognitive styles have mostly focussed on the field-dependence-independence dimension of cognitive style (Pringle and Morgan, 1978; Shymansky and Yore, 1980; Ritchey and La Shier Jr., 1981). Only the reports of two studies (Barnett, 1974; Shuaibu and Ogunsola-Bandele, 1988) that investigated the effects of instruction on Heath's four-mode cognitive style dimension (R, P, A, Q) were available to the researcher. These two studies are reviewed below.

Barnett (1974) investigated the relationships among biology achievement, teaching method and cognitive preferences using a population of high school biology students. He reasoned that the concept of cognitive preferences would seem to be related to inquiry teaching because students with a strong preference for Q and A could be expected to learn more effectively using inquiry processes than students who show a strong preference for R. In additiona, he further argued, if student inquiry is to be promoted through science teaching, a suitable teaching method must be employed.

The study was not experimental in design; no teaching method was used as a "treatment" in the study. Rather "teacher style" as perceived by the students was the variable tested. This variable was measured using a modified version of Tuckman's (1968) instrument, the "Student Perception of Teacher Style (SPOTS)". Tuckman had proposed two broad categories of teaching styles, the "directive" and "non-directive" teaching styles and developed

the student rating scale SPOTS for classifying teaching approaches into these two categories. The modified form of SPOTS used in this study required students to rate the intensity of specific teacher behaviour on a 9-point scale and so provided a measure of teacher directiveness. A non-directive teaching style could be expected to promote achievement in an inquiry-oriented classroom because it provides an informal atmosphere where student planning and questioning are encouraged.

The cognitive preferences of students were measured by means of Atwood's (1971) Cognitive Preference Examination II (CPE-II). CPE-II was designed after Heath's (1964) instrument except that CPE-II contained only three instead of four scales: R, A and Q. The scale for P was not included. Williams (1975) used a similar Cognitive Preference Test in which the Q scale was eliminated. Achievement in biology was measured with Form E of the Nelson Biology Test originally developed by Nelson (1965). Both the CPE-II and the Nelson Biology Test were administered in a pretest-posttest design. The modified version of SPOTS was administered during the posttest period only, i.e. at the end of one semester of instruction.

The subjects were 1477 tenth grade biology students drawn from high schools located in three major metropolitan areas in Kenturky: Louisville, Lexington and Convington. Of the four hypotheses tested in the study only two are relevant to the discussion here. These are:

1. After a semester of instruction there will be no significant difference in the mean cognitive preference scores on memory, application and questioning among groups of tenth-grade biology students who are classified on the basis of their perception of the directiveness of their biology instructor's teaching style.

2. There will be no significant difference in mean achievement scores among groups of tenth-grade biology students classified on the basis of their perception of the directiveness of their biology instructors' teaching style.

The data analysis revealed significant differences in the students' mean cognitive preference scores for A and R. Students who perceived their teachers as using a non-directive style of teaching scored more on A than their counterparts who saw their teachers to be using the directive teaching method. On the other hand, students whose teachers used the directive teaching style scored more on R than students whose teachers used the non-directive style. Students of non-directive teachers actually scored more on Q than students of directive teachers but the difference was not significant. The results thus permitted the rejection of the first hypothesis (i.e. hypothesis 1 above).

The results further indicated significant difference in student biology achievement scores. Students of non-directive teachers were higher achievers. The second hypothesis was also rejected. Comparison of pairs of means indicated that biology

students who demonstrated a strong preference for either A or Q tend to be higher achievers than students who prefer R.

These findings of Barnett's study clearly suggest that certain teaching modes could be more favourable to certain cognitive preferences. Although the data do not permit any definite conclusions regarding the cognitive style - teaching mode relationship, they certainly inspire further research in this direction.

In a recent study, Shuaibu and Ogunsola-Bandele (1988) explored the effects of the defining - issue - discussion method of teaching on the cognitive preference profiles of a group of A-level chemistry students. The specific purpose of the study was to ascertain the possibility of using the defining-issue-discussion approach to shift cognitive styles of the students from predominantly recall (R) to questioning (Q). The subjects were 69 pre-degree students from a College of Agriculture who took an A-level course in chemistry as part of their training. The potency of the defining-issue-discussion method as an approach to changing the affective behaviour of individuals has been well demonstrated and employed in several countries (Williams, 1975; Rest, 1974; Okatahi, 1984).

The following hypotheses were tested in the study:

1. That the distributions of control and experimental subjects on the Heath's 4-mode cognitive style model were not significantly different;

2. That these distributions were not significantly different from those of the SBS - ABU students of comparable academic standing; and
3. That the experimental treatment had no significant effect on the subjects' subsequent distribution on the cognitive style test (CST).

The background of the subject was similar to that of students admitted into the School of Basic Studies (SBS), Ahmadu Bello University (ABU), Zaria.

The Solomon 4-way (pretest-posttest control group) design was adopted yielding two control (C_1,C_2) and two experimental groups (E_1, E_2), one each of which was pretested. Subjects were randomly assigned to the four groups. All groups were posttested after the experimental groups had received treatment for three weeks. The criterion measure was a 20-item chemistry Cognitive Style Test adapted from Tamir and Kempa (1978). The reliability of the instrument was estimated at 0.86 using the split half (odd-even) method while the Cronbach alpha internal consistency coefficient for each style was calculated to be R - 0.84, P - 0.63, A - 0.54 and Q - 0.52. Owing to acute distortions from normal distribution shown by the data, the non-parametric chi-square statistic and the Man-Whitney U-test were employed for the analyses.

The results of the analyses revealed no significant differences in the cognitive preference of the students as represented by the pretested groups (C_1, E_1), hence the first

hypotheses could not be rejected. The order of the distribution of the cognitive styles was R - P - Q - A in the ratio: 1.57 : 1.37 : 1.02 : 1.00. A comparison of this with the distribution obtained by administering the same test to chemistry students of SBS/ABU, Zaria (R - P - A - Q in the ratio: 1.56 : 1.39 : 1.05 : 1.00) indicated no statistical difference, hence the second hypothesis could not also be rejected.

With respect to the effect of the treatment, noticeable gains in Q were shown in three out of the five possible sub-tests. The increase was, however, statistically significant in only one of these three sub-tests and this was in respect of the groups (C_2, E_2) which did not have any pretest. Only one other sub-test showed that the experimental group with both the pretest and posttest was the only group in which the shift was in the desired direction (as predicted by the researchers' alternative hypothesis) although the changes - loss in R and gain in P, A, Q - were not statistically significant. The results also showed evidence of the orthogonal relationship between R-Q and P-A, the "curiosity" and "utility" scales which had been identified in earlier studies (Kempa and Dube, 1973b; Rogel, 1974; Tamir, 1975; Tamir and Kempa, 1977, 1978) and so reconfirms the rational for shifting cognitive styles from predominantly R to Q using a suitable teaching strategy.

In the discussion of the results the authors suggested that the lack of consistency in the results could be due to a number of possibilities: The pretest seemed to have had a negative and

counter-productive effect. Treatment appeared to have been more effective on the group which did not have the pretest. The need to replicate the study and also to consider using a posttest only control group design were pointed out. The authors have also pointed out (for the benefit of future related studies) other possible limitations to their study. For example, time of exposure to the treatment was only three weeks. It would be instructive to investigate the influence of a longer period of exposure. Again the choice of the defining-issue-discussion approach as the treatment was rather "a chance event". There is need to explore the influences of other teaching methods and perhaps identify the one that has the most favourable effect for the development of the questioning cognitive style.

The present study attempts to investigate the effects of the teacher-directed discussion approach on the cognitive style and interest orientations of a group of physics students. The researcher intends to take into consideration most of these points which the authors have raised.

2.4.6 Stability of Interest and Cognitive Styles

Closely related to the influence of different variables on the interest and cognitive style profiles of learners is the question of stability of these two characteristics. The knowledge of whether interest or cognitive style is a fixed trait or one that can be acquired through training and life experiences (and therefore

learnable and teachable) is of importance to education and educational practice. The educator or teacher is not necessarily bothered about which way the "scale tilts" i.e. whether interest or cognitive style is a stable or unstable entity. What is of concern to him is to know what the true position is so that he/she can tap the implicated advantages. For there is surely some advantages to be gained educationally from the stability or otherwise of interest or cognitive styles. This point has been succintly expressed by Tamir (1982):

> If, in fact, cognitive preference is a fixed characteristic then it may be a useful tool in teacher education and selection. More likely, however, is that cognitive preference is a learned trait which can be changed by maturity, interactions and experience. Cognitive preference tests do show, in a most convincing manner, that not all people prefer to learn in the same way. If we can assume that they learn best in their preferred way, we have some rather overwhelming evidence for the logic of offering alternative modes of instruction and learning in a classroom.

As has already been pointed out, a lot of research has been conducted to explore the possibility of changing students' interest (or attitude) through teaching. Although results have been diverse and largely inconclusive some exemplars have come to light. For example individualisation and activity-oriented approaches to teaching have been found to foster high level interest and positive attitudes to science. While this reflects some measure of progress it is still inadequate. Educators would certainly wish to know further if and how (through teaching) a learner's interest in a particular (science) subjects, science topic or science learning

activity may be shifted from a low level to a higher level, and perhaps even from one topic or learning activity to another.

With respect to the stability of cognitive styles, much is yet to be learnt through research. The idea of the stability of cognitive styles was first suggested by Kagan, Moss and Sigel (1963) when they defined cognitive style as "stable individual differences in mode of perceptual organization and conceptual categorization of the external environment". This notion of the stability of cognitive styles may have been prompted by the way in which the nature of the attribute was perceived since there was no indication that the authors were guided in their definition by any empirical evidence.

Researches by Witkin et al (1967) and Schimek (1968) indicated that persons attain stability in cognitive styles during adolescence. Witkin and his co-workers have posited that if cognitive styles are to play any role in the development of educational practices that take individual differences into consideration, then they must be presumed to be comparatively stable over time and, to a large extent independent of the nature of the information presented to the learner. Glaser (1970) disagreed with this view and argued that since it is the teacher who directs and guides the thought processes of learners, he should also influence their cognitive styles.

Both arguments seem plausible but it may be pointed out that their points of emphases are different, whereas the view of Witkin and his colleagues stresses "nature of information presented

to the learner", Glaser emphasises "teacher effect". Information presented to the student may refer to the nature of the discipline or subject matter (e.g. inquiry-based, concept-oriented, expository). On the other hand the teacher may influence the cognitive styles of his students in a variety of ways: teachers cognitive styles, teachers characteristics (of which there is a host of possibilities), teachers' attitude (towards the curriculum in use or towards the subject), and the teaching style employed by the teacher.

Some of the literature related to the influence of some of these variables have been reviewed. The results of the research findings do not permit any definite conclusions or generalizations to be made. It is, therefore, necessary to build up "better" evidence through more research. The recent work of Shuaibu and Ogunsola-Bandele (1988) points to one important direction in which future research on cognitive preferences needs to be directed. In the present study the relationship between cognitive styles and interests of physics students and the possible effects of a teacher-directed discussion approach on the two attributes (interests and cognitive styles) are examined.

2.5 Collection and Treatment of Data on Interest and Cognitive Style

Data collection is not an indiscriminate, aimless exercise. In research, every bit of the data to be collected must be directly related to the problem being investigated, the hypotheses

of the study and more specifically the variable(s) being examined. Experienced researchers are aware of the attraction which irrelevant data frequently hold for investigators and know better than to pay any heed to them.

The way in which the data collected in research are organised and treated, whether or not to use statistical tests and the appropriate type of statistics to use similarly depend on the type(s) of hypotheses being tested, the variables being examined, the nature of the research design and the kind of data collected.

2.5.1 Collection and Treatment of Interest Data

Interest data are usually collected by means of interest inventories the earliest forms of which typically contain a list of careers, topics or activities, the respondent being required to indicate those in which he is interested. Interest inventories employed in science education research falls into two broad categories; general interest inventories and specific interest inventories. General interest inventories yield interest profiles in a variety of areas. An example is the Study of Values Test (Allport, Vernon and Lindzey, 1960) which yields scores on six scales (theoretical, aesthetic, economic, social, political and religious) and has been used in science education by Blankenship (1965), Rothman et al (1969) and Murphy (1970). The Academic Interest Measure (Halpern, 1965) and the Strong Vocational Interest Blank (Strong, 1943) each contains a physical science interest scale which had been used by other

researchers in measuring learners' science interests (Walberg, 1969; Blake, 1969). The Factorial Interest Blank (Sandal, 1960) is another examples of the general interest inventory. This instrument was employed by Hanrahan (1972) and although lesser known, it is a carefully designed interest inventory (Gardner, 1975).

Specific interest inventories are restricted purely to measures of science interest. Examples include the:

(i) Science Interest Questionnaire (Khan, 1950) with six scales reflecting interest in various science subjects;

(ii) Science Activity Inventory devised by Cooley and Reed (1961);

(iii) Pupil Activity Inventory used by Rothman (1969);

(iv) Clarke Science Interest Checklist (Clarke, 1972) which assesses students relative interest in biological science, earth-science and physical science topics; and

(v) Science Activity Checklist which had been prepared by Skinner and Barcikowski (1973).

Different techniques have been adopted in the construction of these interest scales. One common technique is to present the respondent with a list of scientific activities or topics and ask him to indicate which activities/topics he considers interesting. The number of such activities/topics so indicated are simply counted. The Science Activity Inventory is an example of such a scale.

A second technique, used by Khan (1950) and Muthulingam (1963) requires the respondent to indicate the intensity or level of his interest on, say, a five point scale. The responses are then treated as responses on a summated rating scale. The instruments used by Haussler (1987) and Gardner and Tamir (1989) in their recent works exemplify this technique.

A third technique is typified by the Clarke Science Interest Checklist in which each item presents three concepts reflecting a biological-science, an earth-science and a physical-science topic. Subjects are asked to choose the topic they most like to learn about and the concept they least like to learn about. This type of instrument is said to be ipsative or to yield ipsative data. For each respondent it yields a profile indicating his interests in the three areas but not his actual level of interest in any of them.

It may be appropriate to throw some more light on ipsative instruments and ipsative data which also feature often in the measurement of Heath's (1964) four-mode dimension of cognitive styles. In an ipsative instrument the respondent may be regarded as having a fixed total score which he distributes among the various scales within the instrument. Thus it is impossible to obtain an extremely high (or low) score on all scales. Ipsative measurements yield profiles for individuals. In other words, each score reflects the individual's strengths or weaknesses without necessarily showing how strong or how weak he is in relation to another person.

In an ipsative interest measurement the concern is to know which objects a person is most highly interested in (or those attitudes he holds most strongly). It would be possible for another person with identifical scores to have much higher level of interest (or to be much stronger in his attitudes). In an ipsative instrument respondents are required to 'rank' the options while in a normative (i.e. non-ipsative) scale they are asked to simply 'rate' the options. It is important to point out also that there is an inherent tendency for ipsative scales within an instrument to be negatively intercorrelated, since a high score on one scale must be associated with lower scores on the others.

A cognitive style test such as a Cognitive Preferance Test (CPT) may be ipsative or normative depending on whether the subjects have been asked to rank or to rate the response options. Cattell (1944) had defined normative, ipsative data and the need for researchers to be careful in using them so as to avoid (i) the use of unsuitable statistical techniques, and (ii) making inappropriate interpretations. Several studies have since shown that there is no need for special statistical treatment of ipsative data because relationships obtained with ipsative data have been found to be very similar to those obtained with normative data (Kempa and Dube, 1973; Kempa and Tamir, 1976; Tamir and Lunetta, 1977, 1978). This notwithstanding, Cattell's advice regarding the need for researchers to be careful in using ipsative data to avoid making improper interpretations remains valid.

According to Gardner's (1975) categorization, the process of constructing a valid and reliable interest inventory and then using it in a soundly conceived research project, may be regarded as consisting of five stages:

(i) defining the interest object(s) to be measured;

(ii) scale construction;

(iii) trial

(iv) appropriate utilization; and

(v) appropriate choice of research design and statistical analysis.

Defining the interest object(s) implies specifying the type of interest being measured (e.g. interest in different physics textbooks) and the theoretical construct underlying the scale. If an instrument is to be designed to measure different variables, such variables should be clearly spelt out in advance and the instrument should yield separate scores for each of these variables.

A meaningful scale should faithfully reflect the position of the respondent on some well-defined continuum. For this to be possible all the items within the scale must be related to a single interest object. A disperate collection of items, reflecting interest in a wide variety of objects, does not constitute a scale, and cannot yield a meaningful score. The Attitude to Science Course at Training College (Shah, 1962) and Harrison's (1971) science attitudes scale have been criticised

for having this shortcoming (Gardner, 1975). Other weaknesses which have been associated with some interest inventories include: confusion of various theoretical constructs, inclusion of defective items and inclusion of items that do not reflect the construct which the scale set out to measure. These weaknesses have been discussed in details, with illustrative typical examples in the review of attitude to science (Gardner, 1975:13-14).

The preliminary trial or pilot study is an important part of any research project. During the pilot study the instrument is administered to a sample which is approximately comparable to the target population for which the instrument is ultimately intended. Data collected from the pilot study is very useful for critically rechecking the properties of the instrument as a whole, properties of the scales within the instrument and properties of the individual items within the scale. Vital item and scale statistics are usually computed and used in checking these properties. For interest (or attitude) inventories of the Likert type, the most important properties normally checked are scale sensitivity, internal consistency, stability and factorial validity. Sensitivity refers to the ability of a scale to discriminate amongst respondents i.e. to spread the subjects along the available range of scores.

Internal consistency is the tendency of items to be correlated with one another and with the total scale scores. It is influenced by two major factors: the number of items in the scale

and the extent to which the items reflect a clearly defined unitary construct. The internal consistency of a scale can be estimated using the split-half (odd-even) correlation coefficient, or Cronbach's alpha coefficient. Stability (or reliability) refers to the tendency of a scale to yield similar scores when administered to the same respondents at different times and can be determined by calculating the test-retest correlation. The time interval between administrations should be long enough for the subjects to forget the wordings of and their responses to individual items, but short enought to prevent long-term factors from influencing their responses. In practice an interval of a few weeks (usually two or three) is considered adequate.

Factor analysis provides information as to whether items have been correctly assigned to scales and as to whether the scales are unique because different scales load on different factors. Factor analysis is necessary when a single instrument contains a number of separate scales.

The diverse, inconsistent and inconclusive nature of lots of research findings have been largely attributed to the failure of researchers to investigate these instrument properties and/or to investigate them properly. In concluding his recent update of the review of attitudes to science, Schibeci (1984) has lamented that "despite the very large body of literature, it is difficult to draw unequivocal conclusions regarding the influence of particular variables on student attitudes to science". Regarding

what the science education community can do to improve the prevalent situation, he suggested as follows:

> In general, a first step could be for journal editors to urge their reviewers to be more critical in their reading of attitude studies. There are a number of studies which have apparently been subjected to a blind reviewer system which should not have been published without modification. Studies which report no attempt to gain reliability and validity data about the attitude instrument form one category of studies which should be summarily rejected.

Appropriate utilization refers to the need for an underlying theory relating two variables between which some relationship is presumed to exist. If, for example, a treatment X is considered to be associated with outcome Y, there ought to be some basis for arguing that the treatment is connected with the outcome. Finally a suitable research design must be selected for the study and appropriate statistical procedures chosen for the data analyses. As already pointed out all this would depend on the nature of the research problem, the hypotheses tested, the variables being examined and the data collected.

Two recent studies on students' science interest (Haussler, 1987; Gardner and Tamir, 1989) are reviewed below in order to highlight current approaches to the collection and treatment of (science) interest data.

In his international overview of students' interest in science and technology, Gardner (1985) had criticised studies on students' interests in science, pointing out that most of them show one or more of the following weaknesses:

(i) Much of the research gives the impression of not having been guided by theory;

(ii) Interest is often treated as a unidimensional quantity; and

(iii) What is often measured is not explicitly made clear.

An instrument to be used in a longitudinal study to investigate the development and change of interest in physics was later developed in the Federal Republic of Germany (Hoffman et al, 1985) in such a way that the shortcomings identified by Gardner were avoided. To do this the following measures were taken:

(i) The unfolding of the construct 'interest in physics' was done on the basis of a curricular model of 'education in physics' yielding three curricular dimensions;

(ii) The construction of test items in these three dimensions followed the results of a (delphi) study on 'education in physics for today and tomorrow' (Haussler et al, 1982) which guided the selection of categories within each dimension; and

(iii) The test items were designed to measure the intrinsic motivation of students for engaging in physics-related activities irrespective of the particular setting in which this activity takes place.

The principles used in developing the interest in physics test and the results of a cross-sectional study carried out in West Germany using this test have been outlined in Haussler's (1987) work which has largely inspired the present study. Although

neither the problem(s) nor the hypotheses of the study were stated by Haussler, it seems clear that the purpose of the study was to identify the interest profiles of physics students and to determine how these profiles were related to age, sex, and school type in the Federal Republic of Germany.

The dimensions of the construct "interest in physics" were derived from a curricular model of physics education developed by Haussler et al (1982) in their study of desirable physics education for high school students in Germany. In the said model statements about physics education consisted of three elements, namely areas of physics with which familiarity is required for an understanding of the subject; situations, contexts or motives in or for which a particular area is meaningful; and the appropriate or desirable modality of an individual's disposition over or his dealing with physics education. These three elements were then used as dimensions of students' interest in physics on the assumption that interest in physics can be broken into interest in a particular

* subject matter or topic of physics;
* context or situation in which that topic is presented; and
* activity a person is allowed to engage in in conjunction with that topic.

The results of the delphi study on desirable physics education also guided the identification of categories or subdimensions for the three main dimensions. All together eight categories were

identified for the topic dimension, seven for the context dimension and four for the activity dimension.

The categories for the three dimensions as tabulated by Haussler (1987: 81) are presented below:

Table 1: Categorization of the dimension 'topic'

(T 1) Optics: How light can be influenced by lenses and mirrors and how optical instruments function.

(T 2) Acoustics: How sounds, tones and noises are produced and how they spread.

(T 3) Heat: How heat spreads and how it can be used to set an object in motion.

(T 4) Mechanics: How the motion of a vehicle can be described and how force can be saved with simple machines.

(T 5) Electricity and magnetism: What electricity and magnetism actually are and how they can be generated.

(T 6) Electronics: How electronics functions and how we can use it.

(T 7) Structure of matter: What basic components the whole world is built of.

(T 8) Radioactivity and nuclear power: How atoms disintegrate or split and how this process can be utilized.

Table 2: Categorization of the dimension 'context'

(C 1) Physics as a vehicle to enhance emotional experience

(C 2) Physics as a vehicle to understand technical objects in everyday life.

(C 3) Physics as a basis for vocations I (technical vocations, vocations related to research in physics)

(C 4) Physics as a basis for vocations II (medicine, art, counselling)

(C 5) Physics as an intellectually challenging scientific enterprise I (qualitative level)

(C 6) Physics as an intellectually challenging scientific enterprise II (quantitative level)

(C 7) Physics and its impact on society.

Table 3: Categories of the Activity Dimension of Interest in Physics

(A 1) Learning on a receptive level

(A 2) Learning by doing

(A 3) Engaging in higher cognitive operations

(A 4) Evaluating technical developments in conjunction with controversial issues

The three dimensions of interest derived in this study are similar to those proposed by Gardner (1985), namely subject matter, purpose and extent of commitment.

To incorporate the three dimensions of interest into an interest inventory, two possibilities were considered: either the test has three separate parts each measuring only one dimension or it will consist of test items, each of which contains all three dimensions. The latter option was chosen on the grounds that it would avoid doubts as to the validity of the test which a choice of the first option was likely to raise. Thus in each test item reference was made to one topic, one context and one activity, leading to 8 x 7 x 4 = 224 possible item configurations. Three examples of item configurations are shown in Table 4 (Haussler, 1987: 83).

Table 4: Examples of Item Configurations

1.	To get more information about A1		force saving T3	
	tools in a mechanic workshop C3			
2.	To plan experiments A3	suitable for	investigating the properties C5	
		of	electromagnets T5	
3.	To learn more about A1		how colours occur T1	
	in the sky (blue sky, rainbow, sunset) C1			

A1 refers to the first category of the activity dimension as in Table 3, T3 to the third category of the topic dimension and C3 to the third category of the context dimension.

For each item the student is asked to indicate his level of interest on a five-point Likert scale as follows:

My interest in this item is

very high	high	medium	low	very low
( )	( )	( )	( )	( )

Not all possible test configurations were included. For each topic, only eleven combinations with the other two dimensions were selected for the final version of the test, thus yielding a total of 88 items. Since the test was also administered to students who had not had any prior physics instruction, the problem arose that such students were required by the test to express interest in areas of which they had little knowledge. To deal with this difficulty, each student was given a one-page introductory text for every topic covered by the test so as to get the novice familiarized with some ideas and concepts characteristic of that topic. To adjust the test for older students who had varied experiences in physics classes, the following measures were taken: (i) the introductory texts were geared to a more sophisticated level, (ii) the items were formulated in terms of "learning more" about a particular area of physics; and (iii) examples were given in the introductory section of the test to show that there is always something more to learn on a higher level of understanding.

The 88-item instrument was administered to a sample of 4035 West German (physics) students in the age range 11 to 16 years attending three different types of schools: Gymnasuim, Realschule and Hauptschule.

The data collected were analysed using a variance analysis mathematical model according to which it was assumed that the compound or total interest in physics I (ijk) with respect to a particular interest item composed of topic (i), context (j) and

activity (k) can be written as a sum of terms representing a constant (or the grand mean), the main contributions of each of the three interest dimensions, the contributions of the interactions between the dimensions and the contribution of an error term, respectively.

$$I(ijk) = \text{Constant} + T(i) + C(j) + A(k) + TC(ij) + TA(ik) + CA(jk) + e(ijk)$$

where the term 'Constant' represents the overall interest in physics, T (i), C (j), A (k) represent the main contributions of the dimensions, e (ijk) an error term accounting for all sorts of deviations from the mathematical model while the rest represent the contributions of the interactions between the various dimensions.

The analysis revealed that the explained inter-item variances were typically of the order of 60% when only the main effects were considered. The contribution of the interaction terms was found to be a mere two or three percent. This was insignificant in comparison to the main effects, hence contribution of the interactions was neglected in the analysis. Since the contribution of the error term was also found to be minimal, it was suggested that the bulk of the unexplained 40% variances was not due to the individual differences in the interest profiles of the students but rather was caused by the individual features of the items such as systematic errors in the way in which individual items were

formulated. Of the 60% explained variance the topic and activity dimensions were found to contribute about one-fifth each while the remaining three-fifths was contributed by the context dimension of interest. "In other words, the response on an interest item is mainly influenced by the kind of context with which the item is associated and much less by the particular content or the particular activity involved" (Haussler, 1987:86).

The following results emerged from the analysis of the data:

(i) Neither the overall interest in physics profile, nor the interest profiles in the three distinct dimensions were influenced by the type of school attended by the students not even in the case of older students in the sample who had attended a certain type for as long as six years.

(ii) The overall interest in physics decreases as students grow older. This conforms with the general trend found in many other studies. The drop which is most pronounced between 12 and 13 years is, however, moderate and far from being alarming.

(iii) Sex differences in interest exist among the physics students. These differences are outlined in the discussions below. Differences in interest between the boys and the girls are not very large and the gap tends to get smaller as students get older, suggesting that physics teaching in Germany does not seem to decrease the interest of the girls relative to that of the boys. Girls tended to like

almost equally well or better than the boys, topics like light, heat or a acoustics, i.e. topics that can be grasped by the senses, but they were less inclined to all the other topics. Boys had higher interest for electronics and for radioactivity and nuclear power, both being rather remote to the senses. In the case of electronics the gap widened with age while for radio-activity and nuclear power the gap disappeared with age. Perhaps the females regarded electronics (which is technology oriented) as a male area which they would rather keep away from. In contrast, nuclear power, which is a sensitive and controversial issue in the society seemed to appeal to the girls more and more as they grew older. The context dimension showed that girls appeared uninterested in the quantitative mathematical aspects of physics and in physics as a basis for technical vocations. On the other hand the girls were equally well or even more interested than boys in physics as a vehicle to enhance emotional experience and in physics related to vocations like medicine, art or counselling. Finally, as girls grew older, they become more and more interested in the impact of physics on society. With respect to the activity dimension, it was found that in general younger children like "learning by doing" more than older persons while both young and old students like other activities equally well. The interest of the boys in all activities is higher than that of the girls(though the difference is not

much) but in the case of "evaluation of technical developments in conjunction with controversial issues", the interest of the girls rises above that of the boys from age 14 onwards.

(iv) No topic was outstandingly liked or disliked by the students - all topics fell between the 3-point (medium) and the 4-point (high) interest levels on the scale - neither was there any dramatic changes in the pattern of interest with increasing age.

One important generalization that emerged from the sex differences in students' physics interests is that to develop interest in physics girls seem to rely more than boys on opportunities to use their senses, to see relations to other areas of the social culture and to ask questions about the meaning of physics to human existence. This conclusion is in line with an earlier finding (Gilligan, 1982) that distinct solution patterns exist for boys and girls when they are confronted with dilemma situations. According to Carol Gilligan, the reasoning of the girls appeared to stem from "a world of relationships, a world that coheres through human relationships rather than through systems of rules". Haussler regretted that physics education in Germany did not particularly stress those topics, contexts and activities that were favoured by girls and suggested that "the gap in interest between boys and girls may be closed if physics is treated not solely as a scientific enterprise but also in its connection to the society as a whole, including controversial issues".

In their own study of students' interest in biology, Gardner and Tamir (1989) also conceptualized interest as a multidimensional construct comprising three components: topics, activities and motives each of which has several dimensions. A test battery comprised of seven instruments was developed and validated (Part I of the study) and then used to explore the relationship between interest and the enrolment intensions of Israeli senior high school biology students (Part II of the study).

In designing the test battery for students' interest in biology, Gardner and Tamir drew upon aspects of the earlier positions on the subject by Lind (1982), Gardner (1985) and Haussler (1987). Lind had conceptualized interest in physics in terms of various scientific activities (e.g. observing, calculating, theorizing). Gardner and Haussler on the other hand adopted the three-component model as a basis for investigating the structure of students' interest in science. The test battery is made up of seven instruments, each consisting of items scored on a five-point Likert type of scale.

For the topic dimension, a 45-item instrument, the Interest in Science Topics (IST) scale, covering a wide range of topics in high school biology, was designed. The instrument was divided into two parts, Form A (25 items) and form B (20 items) and then administered to different samples of the population in order to avoid making excessive demands on the students time. Sample items are:

How interested are you (or how interested do you think you would be) in the following topics?

(i) How new cells are formed

(ii) The process of digestion.

For the activity component, two instruments were constructed: the Learning Mode Preference (LMP) scale and the Interest in Science Activities (ISA) inventory. The items in the LMP reflected three categories conceptualised for this component, namely experiential learning, student autonomy and cognitive challenge. Sample items include:

(i) Attending a good teacher's lecture

(ii) Carrying out an investigation in the school laboratory

(iii) Carrying out an individual project

(iv) Copying summaries from the blackboard

(v) Studying in small groups.

The ISA contained items which reflected various cognitive processes that scientists engage in while pursuing scientific knowledge, e.g. observing, estimating, theorizing. Conceptualization of the categories for this scale was derived from the work of Lind (1982) who found factor analytic support for it in a study of students' interest in learning physics. Items for this instrument were written in the following four categories:

(i) Interest in theories - e.g. "examining theories on sugar production in leaves",

(ii) Interest in observation - e.g. "observing the root growth of a plant after it has been turned upside down",

(iii) Interest in mathematics - e.g. calculating the size of cells observed under a microscope",

(iv) Interest in practice activities - e.g. finding a way to prepare very thin plant tissue sections".

The motives component was assessed by means of three instruments: the Activities Motives Inventory (AMI), the Interest in Social Aspects of Science (ISAS) and the Career Orientation Inventory (COI). The AMI is a general inventory with items in which a wide variety of reasons were offered for being interested in a particular topic. Respondents were asked to indicate the importance of each reason to them. Sample items are:

(i) Better chance of success in examination

(ii) Spending time outdoors in nature

(iii) Related to my future career.

The ISAS and the COI each focussed on a specific reason for interest in more detail. ISAS was concerned with issues involving the interaction between biology and society. The following are sample items:

(i) Effect of chemical industries on the environment

(ii) Moral issues related to artificial fertilization.

THE OOI required students to rate their interest in various biology - based careers. Examples of items are:

(i) Computer specialist in a biological research institute

(ii) Physician

(iii) Hospital nurse

(iv) Caretaker of animals in a zoo.

An Attitude Towards Biology Study (ATBS) scale, an instrument designed to measure students' general attitudes to learning biology was also designed. Items in the instrument were either favourable or unfavourable attitude statements. Examples:

(i) Self-confidence in learning biology,

e.g. (a) "Studying biology is quite easy for me"

(b) "I often need the help of the biology teacher"

(ii) Enjoyment,

e.g. (a) "I enjoy studying biology"

(b) "Investigating natural phenomena which are already understood is a waste of time"

The set of items in this scale were intended to reflect an overall reaction to biology (rather than specific aspects of it) and a mixture of various affective reactions (enjoyment, usefulness, cognitive challenge versus boredom, pointlessness).

Finally, for the purpose of the second part of the study, an eighth instrument (Instrument Q) was devised. This was a set of questionnaire items which sought general and personal information from students e.g. gender, enrolment intention, past performance in science subjects, parental occupations.

The authors claim that all items in the test battery were original. Items for the topic dimension were prepared after careful analysis of the content of Israeli high school biology course. The content of the motive instrument were influenced by Yager's (1982) desirable science teaching objectives and by some interview data reported by Sjoberg (1983) on the factors affecting undergraduate students' interests in science and mathematics. Items assessing enjoyment of physics were taken from Gardner's (1972) earlier enjoyment of physics scale and modified appropriately. The instruments were administered by a team of student teachers to a sample of 878 grade-10 biology students located in 12 Jewish and 2 Arab schools, 10 out of which were situated in Jerusalem.

The instruments were subjected to factor analysis in order to examine the structure of students' interests as revealed by the patterns underlying their responses to the items in each scale. The results of the analyses provided support for the items and the categories within each interest component used in the final versions of the instruments. The reader is referred to the original report for details regarding the analyses and the results which informed the final selection of items. However, a few aspects of the results deserve brief mention:

1. For the activity component factor analysis yielded four distinct categories instead of the three initially conceptualized by the authors. These categories are:
   (i) Interest in experiential learning
   (ii) Interest in reception learning
   (iii) Interest in learning through writing and summarizing
   (iv) Interest in learning through group discussion.

2. Results of factor analysis demonstrated a total lack of support for the conceptualization which led to the construction of the ISA instrument that was derived from the work of Lind (1982). Although the analysis yielded four factors, they were not identifiable in terms of cognitive processes (observing, theorizing) in which scientists engage. Rather the factors shown reflected another set of "topic" measures and were subsequently used as such in the second part of the study.

3. Apart from the four dimensions for the "activity" component, the factor analyses also yielded a total of 9 dimensions for each of the "topic" and "motive" components.

For the second part of the study, the data were analysed using zero order correlations and multiple correlations. The aim was to explore relationships between the dependent variable (enrolment intentions) and the independent variables (science interests, ability, attitude). Following the information obtained from the general questionnaire (Q) on students' enrolment interests, students were classified into four groups:

H: Students intending to take high-level biology

L: Students intending to take low-level biology

P: Students intending to take one or both of the physical sciences

N: Students not intending to take any science.

In Israel students towards the end of grade-10 make specialist subject choices for grades 11 and 12. They must decide which subjects to take and at what level to take them. Biology may be taken at 2-,3-.4- or 5-point level. The points count as credit toward the final examination (the Bagrut) at the end of grade 12. The courses to be taken involve lower content coverage (2- or 3- point level) or higher content coverage (4- or 5- point level).

The four enrolment groups constitute the dependent variables. With respect to the independent variables, the set of categories of the three major interest components for which factor analytic support was obtained made up the interest variables; ability was assessed from the information about students' science grades in the three science subjects (physics, chemistry, biology) taken in grade 10 as indicated by the students in the general questionnaire (Q); while attitude (to biology study) was measured by four factors which emerged from the factor analysis of the responses to the ATBS instrument. Two factors obtained from the general instrument (Q) namely "perception of the Matriculation examination as fair" or as "interesting", were also added to the set of attitude variables.

The following findings emerged from the correlational analyses:

1. The independent variables (science interest, ability, attitudes) showed ability to distinguish high-level biology students from the others and non-science students from the others.

2. Intention to enrol in high-level grade-11 biology correlated moderately ($r \geq 0.3$) but significantly with three variables: good achievement in grade-10 biology, enjoyment in learning biology and interest in reproduction. The correlation with "enjoyment in learning biology" suggests that while there may be theoretical arguments in favour of defining multidimensional interest constructs in fine detail and measuring them seperately, global general measures are still important. Correlation with "interest in reproduction" suggests that this topic plays a more important role than others in shaping a student's decision to continue with biology at a higher level.

3. Intention not to enrol in any science (N group) correlatedd negatively with an "interest in the microscope", "interest in plants", and "interest in problem solving". It is important to note that unlike in the H group (where achievement in biology was the best single predictor of future enrolment), in the N group interest variables generated the stronger correlations. It would thus, seem that interest is the key factor for deciding whether a subject would be taken at all or not. After taking that

decision, then personal competence (i.e. ability/ achievement) is then used to decide on the level at which the subject will be taken.

4. Other variables - gender, career orientation, problem-solving motives also have some influence on biology enrolment decisions. Those who are likely to avoid grade-11 science include the students with little interest in microscopic observations, little interest in plants, poorer grades in biology and chemistry and girls rather than boys. The finding that career motives are related to enrolment intentions is consistent with Sjoberg's (1983) finding of the importance of interest as a major factor affecting the career choices of Swedish students.

5. The study provides considerable support for the (construct) validity of the topics - activities - motives model of interest.

6. Biology is clearly the most popular of the three main science subjects in Israel, with two-thirds of the total sample expressing the intention to enrol in it at grade 11. Although chemistry was shown to be more popular than physics, it was less likely to be taken at high-level.

In discussing the implications of the findings, the authors proffered the following suggestions:

(i) Although there is evidence for the validity of the multidimensional construct of interest, further instrument-development is necessary in order to

amalgamate items which measure similar dimensions, to write new items to measure dimensions which for now contain only few items, and to remove items with low factor loadings.

(ii) Biology teachers and educators would no doubt wish to continue their effort to enhance the appeal of their subject by altering those variables over which they have some control. Areas to which they should pay attention include the teaching of cell division and reproduction and genetics since interest in these topics correlated positively and significantly with intention to enrol in high-level biology.

(iii) Further research is necessary to investigate the factors that make the physical sciences so markedly less popular.

(iv) Attempts to foster interest in the microscope, in plants and in problem solving might encourage some students who might otherwise drop science after grade 10 to continue with some science instead. Teaching methods which allow for some social mode of learning (e.g. group discussion) might also appeal to such students.

(v) School might try and provide grade-10 students with more information about the range of careers available to those with a biology background.

The authors concluded the report by counselling that the clear evidence of the multidimensional nature of interest "should be borne in mind by researchers seeking to evaluate the specific effects of instructional materials and teaching methods on students' interests". This advice is relevant to the present study in which the effect of the teacher-directed discussion mode of instruction on students' physics interests and physics cognitive styles are examined.

2.5.2 Collection and Treatment of Cognitive Style Data

Cognitive styles are measured by means of various approaches and instruments depending on the cognitive style dimension concerned. Heath's four-mode model which is employed in the present study is measured by the Cognitive Preference Test (CPT) originally designed and used by Heath (1964). A distinguishing feature of the CPT is that it provides a method of measuring cognitive styles within the same field as that to which the measurement is to be applied. Each item in the instrument begins with a stem (usually a factual scientific statement or diagram) followed by four extension statements or options. All the options are correct scientific statements each related to the stem and corresponding to one of the four cognitive style modes: recall or memorization (R), principles (P), application (A) and critical questioning (Q). Respondents are asked to rate or rank the options according to their own individual or personal preference thus

yielding respectively normative and ipsative data which have already been explained (see section 2.5.1). In the ranking or graded rating procedure, 4 points are allotted to the most preferred option, 3 points to the next, 2 points to the next and 1 point to the least preferred option.

Modifications of the original instrument have been introduced by some researchers. For example, Barnett (1974) used a CPT that has only three scales, namely R,A,Q. This instrument called Cognitive Preference Examination - II (CPE-II) was originally developed by Atwood (1971). The fundamental principles scale was not included. Williams (1975) also used a similar scale in which the critical questioning (Q) scale was eliminated. Atwood explained that interviews with students completing a preference test served as basis for reducing the number of options from four to three. The students interviewed expressed difficulty in keeping four options clearly in mind while making a choice. The fundamental principles (P) was chosen for elimination because it was judged to be generally "less distinct" than the other options. No reason was given by Williams for not including the Q cognitive style scale in his CPT. Tamir (1975) has pointed out that Atwood's decision to leave out 'Principles' in his cognitive preference test (CPE-II) may be rather unfortunate since evidence from several studies indicate that 'Principles'(P) appears to differentiate very well between students following new and traditional curricula.

In most studies employing cognitive preference tests the cognitive styles of respondents (usually students and teachers) have been measured directly from their responses. Attempts have, however, been made in some studies to identify cognitive styles of subjects by an indirect approach. The approach involves identifying the cognitive styles of students as perceived by their teachers or (perhaps) vice vera. The CPT format is beset with two problems: (i) scoring is cumbersome, and (ii) the stem is often suggestive of the keyed responses.

The indirect approach was used by Ogunsola-Bandele (1987) who identified chemistry teachers' perception of the cognitive styles of their students and compared the patterns obtained with those obtained more directly from the students' own responses. Bean and Hovart (1975), Shuaibu and Martins (1984) and Mahuta (1985) had suggested an indirect approach to classroom observation and measurement in order to reduce threats to external validity which is usually associated with more direct methods of measurement. Ogunsola-Bandele administered the same CPT to both the chemistry teachers and their students but with different instructions. Students were asked to rank the options by awarding 4 points to the most preferred and 1 point to the least preferred. On the other hand teachers were asked to indicate how the majority of their students were likely to react to each item (i.e. how the majority of their students would rank each item). Analysis of the data using the Mann - Whitney U test revealed no significant differences between the students' claims to preferred

cognitive styles and the teachers' perception. The results suggest the indirect method of estimating cognitive styles could be as dependable as the direct approach. In the present study the direct approach will be employed in assessing the interest and cognitive style profiles of physics students.

An alternative method of measuring cognitive styles using the Defining Issues Test (DIT) has been explored by Ehuaibu (1988). The DIT (Rest, 1974) consists of six hypothetical stories and respondents were required to evaluate a set of twelve issue - statements. The subjects rated how important each issue-statement was in deciding what ought to be done. Although this was a recognition task, it enabled the respondents to reason. In addition the subjects were required to rank four most important choices, thus making objective scoring possible. The test offers a means of measuring changes in moral judgment through the assessment of crucial moral issues in situations involving moral dilemmas.

In the DIT, each of the twelve issue-statements associated with a story was written to exemplify some characteristics of one of the stages of moral development. Okatahi (1984) used a model of the DIT in her study with Nigerian subjects in which she attempted to increase the moral judgement level, locus of control and self-concept of individuals. Her results were demonstrative of the potentiality of Rest's dilemma-issues approach in the Nigerian cultural context.

The DIT used in Shuaibu's (1988) study was a paper and pencil cognitive style test made up of 10 short passages. Each passage presented an issue in chemistry or chemistry context in which respondents were required to take a decision. The issue was presented in a stem followed by four response options, all related to the stem and each corresponding to one of Heath's cognitive style modes (R, P, Q, A). This instrument together with another 20-item CPT of Heath's type was administered to a sample of 69 chemistry students of a School of Agriculture in a pretest-posttest experimental design. The items and options of the DIT followed the format of Rayette (1967) and Rest (1974). In it a number of passages or situations relating to issues in chemistry (e.g. fractional distillation, Hardness of water, Atomic structure) which are to be found in the School Certificate O-level chemistry were presented. Subjects were asked to choose that response which suited their reaction best. A typical item in the DIT is as follows:

THE ALLOTROPES OF CARBON

It's getting to six O'clock this evening and some students decide to go for a stroll around the staff quarters. A few meters from where they started, Jide picked an engagement ring with a diamond stone. They all stopped and had a look at it in turn. Which of the four comments (a - d) is closest to the one you would have made?

"Diamond and graphite", said Yomi, "are the free states in which carbon occurs". Others replied:

(a) They are called the allotropes of carbon.

(b) They are the two different physical forms of carbon but with the same chemical properties.

(c) Diamond is attractive and in great demand for jewelry.

(d) There are other non-metals, such as sulphur, which exist in free states.

Selection of option (a) adds to a respondent's R score, while selection of option (b) adds to his P score. Option (c) corresponds to A and option (d) refers to Q.

The instrument was administered to the subjects in a pretest-posttest design and the data were analysed using the Mann-Whitney U test. A comparison of the DIT subtest with the Heath subtest showed that both tests were comparable although Heath's model was more consistent in demonstrating a shift from R to Q. The DIT more consistently showed a shift towards P. Thus the DIT which may be regarded as a popularisation of Payette's (1967) approach by Rest (1974) offers another possible means of reverifying the cognitive style construct (Heath's model).

In the present study subjects' interest in physics will be measured directly by means of an interest inventory adapted from those used recently by Haussler (1987), Gardner and Tamir (1988) and Gardner and Tamir (1989). The cognitive styles of the students will be similarly estimated directly through a GPT

designed according to Heath's (1964) and Kempa and Dube's (1973) formats.

2.6 The Teacher-Directed Discussion Method

Several research studies have shown that science students in Nigeria are predominantly recallers (Shuaibu and Ogunsola, 1983; Joe, 1983; Okebukola, 1984/85; Omoifo, 1986; Ogunsola-Bandele, 1987; Abah, 1988). Generally Nigerian students score highest in R, followed by P and usually have low A, Q scores. The general pattern of cognitive style distribution is R - P - A - Q or R - P - Q - A. This implies that the greatest difference in cognitive styles lies between R and Q. It has therefore been reasoned that the effect of an attempt to modify the cognitive styles of science learners in Nigeria should be felt most dramatically in the shift from R to Q, if such a treatment was effective (Ogunsola-Bandele, 1987).

Results of researches conducted elsewhere show that inquiry-oriented curricula are more favourably disposed towards the questioning cognitive style (Heath, 1964; Kempa and Dube, 1973b; Tamir, 1975; 1976; Tamir and Lunetta, 1978). It can, therefore, be presumed that a teaching approach suitable for moving (or attempting to move) students' cognitive styles from R to Q should be inquiry oriented. The choice by Shuaibu and Ogunsola-Bandele (1988) of the defining issues - discussion approach as an

appropriate instructional method for attempting a shift of chemistry students' cognitive styles from predominantly R to Q was probably informed by this reasoning. Although the results that emerged from their study were largely inconclusive, it is clear that both the experiment and the approach hold considerable promise for future research studies on the modifiability of cognitive styles.

Available evidence also indicates that individualised and activity-oriented methods of teaching foster higher interests in and more favourable attitudes to science on the part of students (Kramer, 1979; Tuckman and Jaheed, 1981; Dawson and Denneth, 1981; Gardner, 1984). It would, therefore, be expected that an inquiry-based, activity-oriented method of teaching, such as the teacher-directed discussion approach, should have the potential to (i) increase the levels of students' interests in physics or effect changes in students' interest profiles and (ii) produce changes (gains) in the cognitive styles of physics students or a shift from one style to another, particularly from R or P to Q.

Shuaibu and Ogunsola-Bandele recognised that their choice of the defining-issue- discussion approach was rather incidental and suggested that other methods be tried in order to find out not only their individual generative effects on cognitive styles but also the one that has the greatest generative (or modifying) effects on particular cognitive styles. In the present study the teacher-directed discussion approach is employed in a pretest-

posttest experimental design to explore the influence of instruction on the interest orientations and cognitive style profiles of physics students.

The teacher-directed discussion approach is a method of teaching in which the students actively and verbally interact with each other and (to a lesser extent) with the teacher in the consideration of a problem or topic under study. It is an overall step by step procedure for teaching a specific topic or course in order to attain definite instructional objectives. The approach is, therefore, a preplanned, organized and unique mode of teaching by itself and not just the incidental, informal type of discussion which may come up in the course of the use of another method of instruction. The role of the teacher during the discussion is that of a guide and moderator. In most cases he poses the problem and then directs its discussion and consideration.

Several authors have sharply contrasted the discussion method with the lecture/expository approach to teaching (Lund and Trowbridge, 1973; Abdullahi, 1982; Brown, Oke and Brown, 1982). Outlining the nature of the discussion method, Brown Oke and Brown (1983:4) stated that:

> This method covers classroom learning activities involving active and cooperative consideration of a problem or topic under study. It is characterised by increased involvement and active participation of members of the class. Unlike the lecture method or the expository method where the teacher is the dominant person, in the discussion the teacher stays very much in the background. She poses the problem initiates interaction, and allows students to pursue the discussion towards the attainment of the goal.

During a discussion the students actively consider the topic, project or problem; they weigh the points for and against, argue with each other, suggest possibilities and solutions, evaluate alternatives and draw conclusions or generalizations. The teacher leads the discussion and directs its course (i.e. in a teacher-guided type of discussion). A problem can be discussed by the whole class jointly (whole class discussion) or the class can break up into separate groups to consider the problem or different aspects of it (group discussion).

The discussion method that is used in the present study has the following distinguishing features:

(i) It is inquiry oriented

(ii) It is activity based

(iii) It is student centred

(iv) It taps richly from the questioning and cooperative learning techniques.

Sund and Trowbridge (1973) consider the discussion approach as an inquiry method of teaching and strongly assert that when properly employed the method is more likely (than not) to develop inquiry behaviour. The inquiry spirit is stimulated by the questioning technique employed by the teacher in directing the discussion. The importance of questioning in the discussion method was underlined by Sund and Trowbridge (p. 132) when they said that: "Any discussion leader interested in developing inquiring behaviour seldom gives answers but asks questions instead. Students in answering questions learn to evaluate, analyse and synthesize knowledge."

Five important purposes of questioning have been identified:

(i) for teaching (as in the so-called socratic method),

(ii) for drilling and practice;

(iii) for guidance or leading,

(iv) for stimulating or motivating, and

(v) for evaluating (Brown et al, 1982).

The purposes most relevant to the discussion approach are the use of questioning for "guidance or leading" and for "stimulating or motivating". Every discussion should stimulate reflective, critical and creative thinking. The teacher should spend time formulating and analysing the types of questions he would ask in a discussion to ensure that the learners are guided toward the desired goals. Through such questions students would also be helped to organise facts and materials, to interprete information and materials, to establish relations such as cause and effect and to provide reviews. The discussion leader's questions should, therefore, be "thought questions" requiring reflective and critical thinking or application rather than "factual questions" requiring mere recall of facts and information.

A major objective of modern science teaching is to use science process skills as a vehicle for getting scientific knowledge acros to the learners. Meaningful science teaching must involve students doing activities. This approach was adopted in the experimental treatment for this study i.e. the teacher-directed discussion method.

A discussion may serve as a useful preliminary to a learning activity (experiment) or as a follow up to such an activity. The students participate fully in the discussions and the activities. The teacher and leader is very much in the background initiating, guiding and steering the entire learning process. A major advantage of the method is that it wells up the interest of the students "because they are involved" (Sund and Trowbridge, 1973).

Since the method is rooted in the principle of students interacting with one another, it means that they would most of the time work in groups rather than individually. Recent studies in Nigeria have indicated the superiority of cooperative learning approaches (over individualistic strategies) in promoting meaningful learning and how these are influenced by students' preferred learning styles (Okebukola, 1985, 1986; Okebukola and Jegede, 1988).

Planning a discussion lesson and effectively leading the discussion itself during the lesson are arts which dedicated teachers learn and improve upon with experience. Several steps and guidelines to assist teachers in the use of the discussion approach have been suggested by Sund and Trowbridge (1973), Brown et al (1982), Abdullahi (1982) and Maduabum (1984).

2.7 Summary Of Related Literature

Related literature reviewed in this chapter shows that a consensus exists among science educators and researchers with respect to the meanings and importance of the concepts of "interest" and "cognitive style" in science education. Cognitive styles and cognitive preferences are considered equivalent by most scholars and, therefore, often used inter-changeably. However, a critical look at the different definitions of the "cognitive preference" concept available in the literature suggests a possible initial error in conceptualization on the part of Heath (1964).

Both interest and cognitive style are multidimensional characters which are considered useful for evaluating or predicting performance outcomes among learners and their teachers. Heath's 4-mode cognitive style model (Recall (R), Principles (P), Application (A) and Questioning (Q)) is only one out of many dimensions identified in the literature (not less than 30 different labels are available). In the case of interest, 3 distinct dimensions (Topic (T), Activity (A') and Motive (M)) have so far been empirically proposed (Haussler, 1987; Gardner and Toon, 1988; Gardner and Tamir, 1989). Heath's 4-mode cognitive style model and the 3-dimensional model of interest were employed in the present study.

Reports of various researches on interest reveal that conclusive generalizations have emerged which point to definite relationships between interest and some variables notably gender,

age, subject matter, career traits and learners' achievements. These trends have been summarised and presented. For cognitive styles no such definite trends have come to light. The findings have been largely inconclusive and at times even conflicting.

The relationship between modes of instruction and such predictors of learning as cognitive style and interest is of current interest to researchers. The focus of concern is on how knowledge about cognitive style or interest may be used to influence teacher education programmes and science classroom practices in order to enhance gains in learners' achievements.

Most researchers are of the view that cognitive styles and interests are not fixed traits but rather learnable and teachable characteristics (Glaser, 1970; Hassan, 1975; Tamir, 1982; Shrigley, 1988). The work of Shuaibu and Ogunsola-Bandele (1988) gives a ray of hope that cognitive styles may be modifiable through teaching. The need for other studies to verify this finding and to identify teaching modes which may be matched to specific cognitive styles is implied.

Furthermore, some relationship between cognitive style (a psychological attribute) and interest (an affective trait) was suggested by Haussler's (1987) study. Payette's (1967) earlier view of cognitive style as an affective entity was recently re-examined by Ogunsola-Bandele (1987) and Shuaibu (1988) with encouraging results. Therefore, an investigation of the relationship between cognitive style and interest (in a science subject) seemed not only proper but also promised to yield instructive results.

Chapter 3

DESIGN AND PROCEDURE OF THE STUDY

3.1 Introduction

The main object of the present study is two-fold: to investigate (i) the relationship between interest orientations and cognitive style profiles, and (ii) the effects of a teaching method, the teacher-directed discussion method, on the interest and cognitive style patterns of a group of predegree physics students.

In this section the theoretical models, the design and the procedure of the study are presented. Specifically the development of the instruments for the study, their validity and reliability data and the method of administering them are described. The subjects for the study, the nature of the experimental treatment and the modalities for the treatment are also discussed.

3.2 The Design

Three theoretical models provide the framework and guide for the present study. These are:

(i) Heath's (1964) 4-mode cognitive style model;

(ii) Gardner and Tamir's (1989) 3-dimensional model of interest in a science subject which is a slight modification of Haussler's (1987) model;

(iii) The Solomon 4-way quasi-experimental pretest-posttest design unique for its ability to separate effects of treatment from effects due to history or maturation such as the effects of pretest.

These models are useful in providing the basis not only for data collection but also for data analysis and interpretation of the results. The design of the present study is, therefore, in three parts:

(i) In the first part the cognitive styles of the subjects were assessed by means of a Physics Cognitive Style Test (PCST). The PCST is a 40-item multiple-choice instrument designed after the format of Heath's (1964) and Kempa and Dube's (1973). It is intended to measure the cognitive styles of physics students who have completed the senior secondary school physics course.

Each item in the PCST begins with a 'stem' which is an introductory statement or a diagram in physics. Each stem is followed by four response options labelled A, B, C, D. All the response options are **correct** and each option corresponds to one of Heath's four cognitive style modes, namely Recall (R), Principles (P), Application (A) and Questioning (Q). The content of the PCST covers most areas of the senior secondary physics course content. The test was administered to the students at the beginning and end of the experimental treatment.

(ii) The orientations of students' interests in physics were surveyed by means of an Interest in Physics Inventory (IPI). Current thinking is that interest is a multi-dimensional construct. So far three major dimensions (Topic (T), Activity (A') and Motive (M)) each with several categories or sub-dimensions have been empirically delineated (Gardner, 1985; Haussler, 1987; Gardner and Toon, 1988; Gardner and Tamir, 1989).

The IPI is a 105-item inventory in which there are 56 items in the topic dimension, 24 items in the activity dimension and 25 items in the motive dimension. The items were adapted from the inventories used by Haussler (1987) and by Gardner and Tamir (1989) in their recent studies of students' science interests. The interest inventory was also administered to the subjects in a pretest-posttest strategem.

(iii) A quasi-experimental arrangement was used to examine the effects of a teaching mode, the teacher-directed discussion method, on the physics interests and cognitive style profiles of the students. The approach used by Smith and Bramblett (1981) and recently employed by Shuaibu and Ogunsola-Bandele (1988) was adopted. They employed the Solomon 4-way design as described by Campbell and Stanley (1963). In this design model subjects are randomly assigned.to each of four groups of which two serve as the control (C) and two as the experimental (E) groups. Only one control and one experimental group are pretested while all four groups are subjected to the posttest.

The model may be summarised as follows:

Control Group I (C1):	Pretest	_____	Posttest
Control Group II (C2):	_____	_____	Posttest
Experimental Group I (E1):	Pretest	Treatment	Posttest
Experimental Group II (E2):	_____	Treatment	Posttest

The Solomon 4-way design is useful for the following reasons:

* controls instrument reactivity;
* facilitates comparison of subjects who differ only in that they received the pretest;
* assesses the degree of change that occurred between pretest and posttest for each treatment.
* employs other advantages of a factorial design.

The introduction of C2 and E2 within the control and experimental groups respectively is intended to separate the effects of the pretest from those of the treatment. The measure also serves to minimise other external threats to the validity of the data obtained in the study and hence makes the inferences arising from the study more dependable. Therefore, if the treatment was effective, it would be expected that the means of the posttest scores of the experimental sub-groups would be consistently and significantly greater than the means of the pretest scores, that is E1 posttest scores should be greater than E1 pretest scores and E2 posttest scores should be greater than C1 pretest scores. Similarly the means of the posttest scores for the experimental sub-groups would be expected to be significantly greater than the means of the posttest scores of the control sub-groups, i.e. E1 posttest scores $>$ C1 posttest scores, E2 posttest scores $>$ C2 posttest scores and E2 posttest scores $>$ C1 posttest scores.

In the present study students were randomly assigned to all the four groups. The experimental groups were taught by means of the teacher-directed discussion approach (the treatment) while the control groups were taught through lectures in an expository manner.

3.3 Instrumentation

3.3.1 The Physics Cognitive Style Test (PCST)

The four-mode cognitive style model suggested by Heath (1964) and later employed by Kempa and Dube (1973) and Tamir (1975, 1976) is used in the present study. The cognitive style instrument is a 40-item multiple-choice test covering seven out of the eight major content areas of the Nigerian Senior School Certificate (SSC) and the General Certificate of Education (GCE) O-level physics courses. The areas covered are: mechanics and properties of matter, heat, light (optics), electricity, magnetism, wave motion and sound. The area of atomic and nuclear physics was left out partly because of the need to have a manageable number of items and partly because of the difficulty experienced by the researcher in writing items (in this content area) which would be suitable and meaningful to students within the Nigerian context. Table 1 shows the distribution of the 40 items of the PCST over the seven listed content areas:

Table 1: Distribution of the PCST Items by Physics Content Area

Content Area	Items
Mechanics and Properties of Matter	1,7,13,19,25,30
Heat	2,8,15,20,26,31,37,39
Light (Optics)	5,11,17,23,29,35,38,40
Electricity	4,10,16,22,28,33
Magnetism	3,9,14,21,27,32
Waves	6,12
Sound	18,24,34,36

Each item in the PCST presents a stem which is an introductory statement or diagram in physics followed by four extension statements as response options. Both the stem and response options are factual physics statements (or diagrams) with each option corresponding to one of Heath's cognitive style modes R, P, A or Q. A typical item is presented below with the cognitive style implied by each option shown in brackets:

17. The ray of a beam of light incident on a concave mirror and parallel to its principal axis may be focussed at different points on the principal axis.

    A. The effect is described as spherical aberration (R)

    B. This happens only in concave mirrors with wide aperture (Q)

    C. All rays of light parallel and close to the principal axis converge at the principal focus after reflection in a concave mirror (P)

    D. Parabolic rather than spherical mirrors are used in searchlights and headlights of motor vehicles because spherical aberration does not occur in them (A).

The PCST was administered as both pretest and posttest. Steps were taken during the posttest to ensure that subjects were not cued to the responses as a result of the influence of the pretest. For example the sequence of the items and the options

were rearranged, the wordings of the instructions at the beginning were altered while retaining the original meaning and paper of different colour was used to print the posttest.

3.3.2 The Interest in Physics Inventory (IPI)

In recent studies interest in a science subject has been conceptualized as having three components or dimensions, namely topic (T), activity (A') and motive (M) dimensions. Each component in turn has several sub-dimensions or categories. The categories or sub-dimensions employed in the present research have been adopted from Haussler's (1987) and Gardner and Tamir's (1989) studies. The IPI covers all the three dimensions and their respective categories.

For the topic dimension seven categories corresponding to the seven topics (content areas) covered by the PCJT have been represented. These categories are: "mechanics and properties of matter", "heat", "light" (optics), "electricity", "magnetism", "waves" and "sound". Three categories, namely "reception learning", "learning by doing" and "engaging in higher cognitive operations" have been delineated for the activity dimension. For the motive component the following two sub-dimensions were adopted: "social aspects of physics" and "physics-related careers".

The first part of the IPI is the Interest in Physics Topics (IPI) sub-scale. It contains a total of 56 items written to reflect interest in each of the seven categories of the topic dimension. 24 items evenly distributed among the three sub-dimensions have been written for the activity dimension. This sub-scale is the second part of the IPI and is called Interest in Learning Activities (ILA) sub-test. The third and last part of the interest inventory is the Interest in Motives for Studying Physics (IMSP) sub-scale. This is further sub-divided into two parts: the Interest in Social Aspects of Physics (ISAP) which has 10 items and the Interest in Physics-related Careers (IPC) which comprises 15 items.

The items of the IPI are adapted from those in the instruments used by Haussler and by Gardner and Tamir by making modifications which are appropriate to physics and to the local (Nigerian) setting. Items within each dimension or sub-scale have been separately numbered. Table 2 shows the distribution of the 105 items of the IPI in their separate interest dimensions or sub-scales:

Table 2: Distribution of the IPI Items by Interest Dimension

Interest Dimensions	Items
(T1) Interest in Mechanics and Properties of Matter	1,2,3,4,5,33*,36,37,38,39,40
(T2) Interest in Heat	6,7,8,9,10,14,17,42,43,44
(T3) Interest in Light (Optics)	11,12,13,15,16,22,24,27,28*,45,46
(T4) Interest in Electricity	25,26,30,33*,34*,35*,50,51,55,56
(T5) Interest in Magnetism	31,32,34*35*,41,52,53,54
(T6) Interest in Waves	18,19,20,23,47,48
(T7) Interest in Sounds	21,28*,29,49
(A'1) Reception Learning	1,2,3,4,5,6,7
(A'2) Learning by Doing	8,9,10,11,12,13,14,15,16,17
(A'3) Engaging in Higher Cognitive Operations	18,19,20,21,22,23,24
(M1) Interest in Social Aspects of Physics	1,2,3,4,5,6,7,8,9,10
(M2) Interest in Physics-Related Careers	11,12,13,14,15,16,17,18,19,20, 21,22,23,24,25

* Item based on more than one topic,
e.g. Light and Sound (Item 28),
Electromagnetism (Items 34 and 35)

Students are asked to indicate the level of their interest in each item of IPI on a five-point Likert type scale as follows:

My interest in this item is:

Very high	high	moderate	low	very low
( )	( )	( )	( )	( )

Sample items are as follows:

Topic Dimension

Mechanics: "How different types of machine help us to do work more easily",

Heat: "Expansion and contraction of substances when they gain or lose heat",

Light: "Formation of shadows and eclipses",

Electricity: "How electricity is transmitted from the power house to the consumers",

Waves: "Illustrating different properties of waves using the ripple tank".

Activity Dimension

Reception learning: "Attending a classroom lecture by a good physics teacher",

Learning by doing: "Performing an experiment in the physics lab",

Engaging in higher cognitive operations: "Designing an experiment to test a hypothesis in physics".

Motive Dimension

Social aspects of physics: "Effect of hydroelectric dams or power stations on the environment",

Physics-related careers: "Geophysicist working with an oil company".

Like the PCST, the IPI was administered to the students before and immediately after the treatment.

3.3.3 The Pilot Study

The PCST and the IPI were administered in a pilot study to a sample of 48 physics students (41 boys and 7 girls) of the College of Advanced Studies (CAS), Zaria in November, 1969. The purposes served by the pilot study were to:

(i) determine the reliability estimates of the instruments;

(ii) explore the feasibility of the study through a trial run;

(iii) identify any problems or difficulties which respondents might encounter and the probable mistakes they might be inclined to make in completing the tests;

(iv) determine the approximate time duration which the subjects would need to respond to the tests properly;

(v) establish the dominant cognitive styles and physics interests of the students so as to note the likely direction in which the treatment could influence these traits if the treatment was effective;

(vi) obtain any other logistic hints which might facilitate the success of the main study.

The reliability data obtained from the pilot study together with data on validity of the instruments are reported in the next section of this chapter. The pilot study also showed that the CAS physics students (who may be classified as "post-secondary", "pre-university" or "pre-degree" students) scored highest in P and least in Q in the cognitive style test (PCST). The actual distribution pattern was P - R -A -Q in the ratio 1.6 : 1.4 : 1.2 :1.0 showing that the dominant cognitive styles among the respondents were P and R. This is in agreement with the pattern obtained earlier by Abah (1988) for different samples of pre-university physics students drawn from the same CAS, Zaria and from SBS/ABU, Zaria.

In the same way it was found that the level of physics interest of the students was highest in physics topics (T) and least in motives for learning physics (M). The actual distribution pattern obtained was T- A'- M in the ratio 2.3 : 1.2 : 1.0. Thus, assuming that the distribution patterns are valid, one would expect that if the treatment in the main study is effective in shifting cognitive styles and interests of the subjects, then cognitive styles would be moved from predominantly P and R to predominantly A and Q while interests would be moved from predominantly topic (T) oriented to predominantly motive (M) oriented.

In summary, the following decisions in respect of the main study were guided by the results of the pilot study:

(i) The PCST and IPI were appropriate and reliable for the purpose of the research study.

(ii) No time limit would be set for subjects to respond to the test items.

(iii) The plan to administer the instruments during students' normal lesson time was in order but a double-period lesson was preferrable.

(iv) The verbal instructions at the beginning of the tests and the general level of language employed in writing the test items seemed adequate.

(v) Respondents would be reminded (over and again) to ensure that all items are responded to and their personal data information duly supplied. This appeal notwithstanding, steps would be taken to quickly check the instruments as they are turned in by the subjects. The use of research assistants would, therefore, be necessary.

(vi) The plan to focus the treatment on moving the students' cognitive styles from R, P to A, Q was in order. Specifically a shift from P to Q (for cognitive styles) and T to M (for interests) would be targetted.

3.3.4 Validity and Reliability of the Instruments

An analysis of the subject matter content of the West African Examinations Council's Senior School Certificate and the General Certificate of Education (O-level) physics syllabuses

used in Nigeria was carried out to ensure that all the information incorporated in the PCST and the IPI fell within the cognitive framework of the students participating in the study. This is a necessary condition to the content validity of the two tests used in the study.

For the PCST a total of 88 items covering the seven selected content areas of the senior secondary school physics course were initially written in such a way that they would be intelligible to the respondents. The comments and suggestions of a team of five secondary school physics teachers who went through the items helped to improve the face validity of the test. The items were then submitted to a panel of ten judges made up of three senior lecturers in the Department of Physics, one professor of chemistry, one computer analyst and statistician and five science educators two of whom have physics background. All ten judges lecture at Ahmadu Bello University (A.B.U.), Zaria and each has a minimum of a master's degree and not less than eight years teaching experience in the university. The chemistry professor was chosen because of his familiarity with and experience in cognitive style testing.

In the first sifting of the items about 50 items reaching at least 70% agreement among the judges were selected. These items were re-written (where necessary) along the lines suggested by the judges and then resubmitted to their scrutiny From the subsequent keying of the experts the final pool of 40 items

distributed over the seven major areas of physics were selected (see Table 1, p.145). Only items reaching at least 80% agreement were included in the final instrument.

Face and content validities for the IPI were determined in the same manner as for the PCST. Content validation was done by a panel of five experts, three physicists and two science educators with physics background. These five experts were members of the panel of ten that validated the PCST. Following the reactions of the judges the items on which there was at least 80% consensus among the experts were selected for the final instrument. This resulted in pruning down the items of the IPI from 118 originally written to 105 then retained in the final test. A minimum of 80% consensus among the panel of judges was considered adequate to ensure the validity of both instruments.

Both the PCST and the IPI were administered to a random sample of physics students of the College of Advanced Studies (CAS), Zaria at the beginning of the 1989/90 academic session in a preliminary study. The internal consistencies (reliability coefficients) of the instruments were estimated from the responses of the students using the split-half (odd-even) method and the Spearman-Brown formula. The sums of the scores on the odd and even items of each test were calculated for each respondent. These scores were then correlated using Pearson product-moment correlation. The product moment correlation

thus obtained was then adjusted to give the reliability coefficient using the Spearman-Brown formula:

$$r = \frac{2r'}{1 + r'}$$

where r = reliability coefficient and r' = Pearson product-moment correlation coefficient obtained (Anatasi, 1976: 115-116).

For each instrument the reliability coefficient was calculated for the whole instrument and then separately for each of the different sub-scales within the test. The reliability of the PCST was estimated at 0.91 while that of the IPI was 0.99. Tables 3 and 4 show the reliability estimates obtained respectively for the cognitive style and the interest sub-scales.

Table 3: Split-half Reliability Estimates of the Physics Cognitive Style Test (PCST) Sub-Scales.

Cognitive Styles	r*
Recall (R)	0.848
Principles (P)	0.856
Application (A)	0.862
Questioning (Q)	0.856

* Odd-even correlations adjusted by Spearman-Brown formula.

Table 4: Split-half Reliability Estimates of the Interest in Physics Inventory (IPI) Sub-Scales.

Interest Dimensions	r*
Topic (T)	0.915
Activity (A')	0.916
Motive (M)	0.885

*Odd-even correlations adjusted by Spearman-Brown formula.

All the reliability coefficients obtained for the main scales and the sub-scales of the two instruments were tested for significance using the formula

$$t = r\sqrt{\frac{n-2}{1-r^2}}$$

where r = reliability coefficent, n = number of subjects (48 in this case) and the critical value of t is the critical value of the student's t statistic given by

$$t \text{ critical} = t\,(n-2,\ \alpha = 0.05)$$

(Siegel, 1956: 212)

For the present case, t critical = t (46, α = 0.05) = 2.021

All the reliability estimates were found to be statistically significant at 0.05 level of significance and were, therefore, considered suitable and satisfactory for the present study.

3.4 Subjects for the Study

The subjects for the study were all the 360 pre-degree students (277 males and 83 females) of the Federal University of Technology (FUT), Minna aged between 16 and 27 years and admitted for the 1990/91 academic session. The university offers one year pre-degree courses in physics, chemistry, biology, mathematics and English language to students who have completed their SSC or GCE O-level courses and wish to take degree courses in the university. The purpose of the courses is to solidify the foundations of the students in English language, mathematics and the sciences and so prepare them more adequately for the rigorous technology-based courses in the university.

The decision to use the post-secondary cadre of students was important for the present study. The items of both the PCST and the IPI were written on topics selected from seven out of eight major content areas of the relevant physics curriculum. Only the area of "nuclear and atomic physics" was left out. Accordingly, subjects for the study would necessarily be those students who have completed (or almost completed) their School Certificate or GCE O-level courses. Attempts by the researcher to use suitable institutions in Zaria (where the researcher was doing his course) for the study were aborted by institutional and logistic problems. In the end, after all due considerations, the FUT, Minna was chosen as the most convenient and feasible

alternative. The researcher lives and works in Minna and is quite close and familiar with the staff and facilities at the physics department of the university.

The pre-degree physics course in FUT, Minna is only slightly more advanced than the O-level physics course which the students have just completed in the secondary school. The simplest aspects of the O-level content are excluded while a few slightly more advanced topics are added. At the end of the one year pre-degree programme students take an internally moderated examination. Successful students proceed to the School of Foundation Studies where they spend two years (100 and 200 levels) doing advanced courses in physics, chemistry, biology, geography, geology and mathematics. At the end of the foundations course successful students move to their various preferred areas of specialization which are now biased towards specific technologies. Pre-degree physics students in each year usually number between 120 and 150. In the previous (1989/90) academic year a total of 140 students went through the programme.

However, owing to some political reasons, the university at the beginning of the 1990/91 academic session suddenly decided to change its admission policy in respect of the pre-degree programme. The new policy was in favour of admitting "as many qualified students as possible" into the programme. As a result

a total of about 360 students (277 males and 83 females) were eventually admitted for the course in the 1990/91 school year. Even one month after the university opened on 17th November, 1990 many new students were still registering for the programme. The university closed on 18th December, 1990 for a three week Christmas break and opened again on January 7th, 1991. It was only after then that the pre-degree students could be properly organised for meaningful academic work. The effects which the unexpected change in pre-degree admission policy had on the present study have been acknowledged and outlined under "limitations to the study".

The subjects were randomly divided into four groups; two experimental and two control groups. To do this the laboratory technician who handled the registration of the pre-degree students was instructed to allocate the students randomly to four groups A,B,C,D as they registered. He was given four sheets of paper (one sheet for each group) for putting down the names of the students in specific groups as they registered. The technician was clearly told to assign students randomly and simultaneously as the students turned up for registration. For example, if eight students turned up for registration at the same time, two students should at once be randomly assigned to each of the four groups. One experimental and one control group were pretested while all four groups were given the posttest after the treatment period. Table 5 shows the distribution by gender by group of the 326 students who fully participated in the study to the end.

Table 5: Distribution of Subjects by Gender by Group
(N = 326)

Groups	No. of Subjects		
	Male	Female	Totals
Control (C1)	65	15	80
Control (C2)	67	11	78
Experimental (E1)	63	19	82
Experimental (E2)	62	24	86
Totals	257	69	326

3.5 The Procedure

The Federal University of Technology (FUT), Minna whose pre-degree students were used for the study opened on 17 November, 1990 for the 1990/91 academic session. Pre-degree students were randomly assigned to four groups as they registered in the physics department. The first four weeks of the semester were mainly spent on registration, orientation and general organisation of the new students. The researcher used this period to meet with the students and got them properly organised for the work ahead.

Lectures started in earnest immediately the university resumed on 7th January, 1991 after a three week Christmas vacation. The pretest was administered during the third week of January, 1991 (14-19 January) to the Experimental Group E1 (N = 90) and the Control Group C1 (N = 88). The cognitive styles of the subjects were measured by means of the PCST while the IPI was used to identify their interest orientations. For the PCST the graded rating procedure was employed whereby respondents ranked the response options allotting 4 points to the most preferred, 3 points to the next, 2 points to the next and 1 point to the least preferred. Thus for each cognitive style mode the highest possible score is 160 and the lowest is 40. A full response to all the items yields a total score of 400.

For the IPI subjects were asked to rate their interests in each item on a five-point Likert type of scale. 5 points were awarded to the highest point on the scale corresponding to "very high" interest level while 1 point was allotted to the lowest point on the scale corresponding to "very low" level of interest. The mid-point of the scale ("moderate" or "average" interest level) received 3 points.

Students were given sufficient time to respond to all the items. In other words no time limit was set for subjects to respond to both tests. The tests were administered during students' normal lesson periods. In the personal data section

of the instruments, students were required to write their names and groups to facilitate the matching of their pretest and posttest responses.

During the administration of the instruments the researcher personally distributed the test materials with the help of some research assistants. Subjects were allowed to read through the instructions on how to respond to the test items. The instructions were then further explained verbally to the students. They were allowed to ask questions for further clarifications. The research assistants also helped to check each test material as they were turned in by the students after completion. This measure greatly helped to ensure that each student correctly responded to <u>all</u> the items in a test and supplied all the personal data information required.

After the pretest the students were taught for 8 weeks (January 21 - March 16), each group having lessons for three hours every week. All groups were taught by the researcher himself. The experimental groups were taught by the teacher-directed discussion method of instruction (the experimental treatment) while for the control groups instruction was expository using the lecture method. Owing to the large number of students involved, the two experimental groups E1, E2, were taught separately. This made it possible for the students to be organised into manageable smaller groups for learning activities. Each experimental group was divided into eleven such smaller working groups of 8 students each. All lesson

activities were carried out by the students in these small groups. The two control groups C1, C2 received all their lessons (none of which was activity-based) jointly. Both the experimental and the control groups had instruction on the same topics in physics. At the end of the treatment period all groups were given the posttest.

3.6 The Experimental Treatment

In this study the experimental groups were taught by the teacher-directed discussion method of instruction which was the experimental treatment while the control groups were taught by the traditional lecture approach. All lessons were taught on electricity during the eight weeks. The topics covered were: electric current; electric potential and potential difference; Ohm's law; resistances in series and parallel; types of resistors; measurement of resistance; resistivity; measurement of potential difference; electric cells; electric light, work, energy and power; electrolysis. The topics were part of the students normal physics course for the semester.

The teacher-directed discussion method of teaching is an instructional mode in which the students interact actively and verbally with each other and with the teacher in the consideration of a problem or topic under study. The teacher plays a guiding

and moderating role, posing the problem or topic to be discussed, initiating the interaction and tactfully steering the discussion towards the attainment of the objectives of the lesson. The learners on their part carefully consider the topic, react to it, argue with one another, suggest solutions, evaluate alternatives and draw conclusions or generalizations. Thus the students become creators rather than passive recipients of ideas (Brown et al, 1982).

A typical discussion lesson was in three parts:

1. A brief discussion as a preamble or introduction to the lesson topic, a learning activity or an experiment.
2. The learning activity or experiment through which learners would be guided to the knowledge content to be acquired in the lesson.
3. A more elaborate discussion aimed at achieving the following:
   (i) to articulate the main knowledge content learnt in the lesson (or several lessons);
   (ii) to outline the practical applications of the knowledge gained in everyday life and the possible weaknesses, limitations or criticisms of the knowledge acquired in the lesson(s).

Depending on the type of topic being treated (and other factors that might have prevailed) one of the parts listed above was skipped in any one lesson where necessary. For example, where

a topic did not lend itself to any meaningful learning activity or experiment, the knowledge content was learnt through questioning and discussion only.

The third part of the lesson stated above is by far the most germane to and the major focus of the experimental treatment in the present study. It would seem reasonable to argue that by presenting and explaining knowledge items in physics during a physics lesson, the recall (R) and principles (P) cognitive styles have been considerably taken care of, i.e. in terms of nurturing or attempting to nurture these styles through teaching. This is because the knowledge items embody the terms, concepts, specific facts, principles, laws, generalizations and theories which have the potential to influence recallers and those (students) who prefer principles in the usual manner but perhaps not appliers or critical questioners. Thus it seems that in so far as every method of science teaching aims to and actually does present scientific knowledge to the learners then every method could be said to be 'prima facie' favourably disposed to the nurture of R and P cognitive styles.

On the contrary not every method (or every teacher) deliberately emphasises practical applications or critical questioning of scientific knowledge presented in a lesson. It is reasoned that science learners cannot easily become "appliers" or "critical questioners" of scienfic knowledge unless they are taught or trained to be so through consciously and deliberately emphasising these cognitive processes in the course of instruction.

The present study emphasised practical application and critical questioning of physics knowledge through the use of the teacher-directed discussion mode of teaching. The purpose was to explore the possibility of shifting students' cognitive styles from predominantly R and P to A and Q and their interest orientations from topics (T) to activities (A') and motives (M). It is presumed that since this mode of instruction is inquiry oriented, employs the questioning technique and deliberately lays stress on application and critical questioning of information, it should have the potential to move learners' cognitive styles from R,P to A,Q and their physics interests from a topic-based orientation to one that is directed more towards physics learning activities and motivations for studying physics.

For the experimental group each lesson as much as possible began with a brief discussion followed by a learning activity or experiment and then ended with another discussion. At the end of a unit of instruction a general discussion was held to recapitulate the major knowledge items learnt and the practical uses or critical questions discussed in relation to them. A typical teacher-directed discussion lesson on "Electric Current and Potential Difference" is outlined below:

ELECTRIC CURRENT AND POTENTIAL DIFFERENCE

Stage I: Introductory Class Discussion

The teacher put on the electric lights and a ceiling fan in the classroom, drew the attention of the students to them and posed the following questions to the students:

1. What produces the light in the bulbs?
2. What makes the fan blades move?

Students were picked to give answers to the questions. Answers were briefly discussed as appropriate when they were supplied. Correct or near correct responses or responses whose further discussion would lead to a better understanding of the lesson and facilitate the attainment of the lesson objectives were put down on the blackboard by the teacher. The following responses were written on the blackboard:

(i) electric energy
(ii) light energy
(iii) electricity
(iv) mechanical energy
(v) current
(vi) electric charges
(vii) electric current
(viii) electricity is doing work

The suitability of each of these responses written on the chalkboard as answers to the two questions above was then discussed by the class. At the end of the discussion, it was agreed that although each of the responses had an element of correctness in it, the simplest, most direct and most appropriate answers were:

(i) electricity

(ii) electric current

(iii) electric energy

(iv) electric charges

Students were then broken up into their working groups for the next stage of the lesson.

Stage II: Group Discussions and Activities

1. Students were asked to discuss in their respective groups the differences between electricity, electric current, electric energy and electric charges. These were the terms accepted as correct answers to the two questions posed at the introductory stage of the lesson (see Stage I). The guiding questions to which students were to supply answers were:

   (a) Are these terms synonymous? Do they all mean the same thing?

   (b) What are the similarities between them? Or what do they all have in common?

   (c) What are the differences between them?

Students were required to briefly write down the answers to each of the questions as they arrived at them (the answers) in their group discussions. The answers were read out to the whole class by each group leader when the class reconvened.

2. Each group then performed the underlisted activities or experiments using the three sets of apparatus provided. Students were to note their observations and answer the short questions at the end of the activities.

Apparatus:

(i) 2 dry cells (one good the other dead) labelled A and B, switch, electric lamp (1.5V), connecting wires.

(ii) A strip of plastic, piece of woollen cloth, toilet paper.

(iii) Drawing board, empty milk tin, small beaker of water.

Activity 1: Connect cell A to the lamp as shown in the circuit diagram. Close the switch and note what happens. Repeat the experiment with Cell B and note what happens.

Why did the lamp light with cell A but not with cell B?

Activity 2: Rub the plastic strip with the dry woollen cloth. Then hold the plastic strip near some dry tiny pieces of toilet paper. Note and explain your observation.

Rub your hand over the plastic and hold it once more near some tiny pieces of dry toilet paper. State and explain what happens.

Activity 3: Place the drawing board flat on the bench. Pour a little water on the board and note what happens. Wipe off the water from the board and support one edge of it on the empty milk tin to form an inclined plane. Pour small water at the top of the board and note what happens.
Now pour little water at about the middle of the board and note what happens.

(i) Why did the water remain stationary in the first case?

(ii) Why did the water run down the board in the second and third cases?

(iii) Why did the water not move up the board in the second and third cases?

(iv) Explain why heat may flow from a body C to another body D.

The teacher went round the groups during the activities and discussions to supervise the students and offer help where necessary.

Stage III: Concluding General Class Discussion

The class reconvened after the activities. Each group leader read out the findings or answers of his/her group which were then discussed by the class. The acceptable answers were written on the board and formed the summary of the lesson and notes for the day.

The teacher cleaned the chalkboard and evaluated the class by asking questions to test students' understanding of the lesson.

For the control class the teacher came in and wrote the topic of the lesson on the chalkboard. He then introduced the lesson by putting on the electric lights and a ceiling fan in the classroom and then posed the usual introductory questions to the students. After a few attempts by students to answer the questions, the teacher supplied the answers and explanations to the class, putting the main points on the board.

Using the same sets of apparatus as for the experimental group, the teacher briefly demonstrated each activity or experiment before the students, asked for explanations of the observations and then offered the answers and explanations to the class after some attempts by the students.

The teacher wrote down the main points on the board as he supplied them to the class. These points constituted the summary of the lesson and the notes for the day.

At the end of the lesson the teacher cleaned the chalkboard and evaluated the students by asking the same type of questions that were used for the experimental group to test students' understanding of the lesson.

The lessons lasted eight weeks between January and March, 1991. At the end of the eight weeks period the posttest was administerd to all the students in both the experimental and control groups.

3.7 Treatment of Data

The PCST contains 40 items each of which has four responses related to an introductory statement or diagram called the stem. Each stem and each of its corresponding four options contains correct scientific information. Students were asked to indicate their preference of the options in each item by alloting 4 marks to the most preferred, 3 marks to the next, then 2 marks to the next and 1 mark to the least preferred option. The responses, therefore, yielded ipsative data since all the responses to the four options in an item contribute to a student's overall cognitive style profile.

The IPI comprises 105 items and in each item a respondent is asked to indicate the level of his/her physics interest on a five-point scale of the Likert type by putting a tick in the box corresponding to his/her level of interest. Students' responses were scored by awarding 5 points to the "very high". 4 points to the "high", 3 points to the "moderate" or "average", 2 points to the "low" and 1 point to the "very low" level. The responses also yielded ipsative data since "each score reflects the individual's strengths and weaknesses without showing how strong or how weak he/she is in relation to another person" (Hills, 1982:181).

The analyses of data were done with the computer services of the Institute of Agricultural Research (IAR), Ahmadu Bello University, Zaria. Cognitive style and interest as measured in the present study by the PCST and the IPI are examples of rank-order variables or ordinal scale variables. The data are,

therefore, ordinal data apart from being ipsative in nature and hence lacking normal distribution. Siegel (1956: 26, 29) stated that "parametric statistical tests, which use means and standard deviations (i.e. which require the operations of arithmetic on the original scores), ought not to be used with data in an ordinal scale" and that "data measured by either nominal or ordinal scales should be analysed by the non-parametric methods". The nonparametric statistics were, therefore, used to analyse the data of the present study. An alpha level of 0.05 was set to test the seven null hypotheses of the study, namely:

Hypothesis 1

1(a) There is no significant difference in the cognitive styles of the four groups of physics students in the experimental design using Heath's (1964) four-mode dimension (Recall, Principles, Application and Questionning) of cognitive style.

1(b) There is no significant difference in the physics interests of the four groups of students in the experimental design using the three-dimensional model (Topic, Activity and Motive) of interest proposed by Gardner (1988) and recently employed by Haussler (1987) and Gardner and Tamir (1989).

Hypothesis 2

2(a) There are no significant differences in cognitive styles between male and female students who participated in the study.

2(b) There are no significant differences in physics interests between male and female students who participated in the study.

Hypothesis 3

3(a) There are no significant differences in cognitive styles between students of different ages who participated in the study.

3(b) There are no significant differences in physics interests between students of different ages who participated in the study.

Hypothesis 4

4(a) Students in the four groups of the experimental design who aspire to different careers in science and technology do not exhibit significantly different cognitive styles.

4(b) Students in the four groups of the experimental design who aspire to different careers in science and technology do not exhibit significantly different physics interests.

Hypothesis 5

There is no significant relationship between students' physics cognitive styles as measured by the PCST and their physics interests as measured by the IPI.

Hypothesis 6

The teacher-directed discussion method of teaching (the experimental treatment) has no significant effect on the cognitive style distribution of the subjects.

Hypothesis 7

The teacher-directed discussion method of teaching (the experimental treatment) has no significant effect on the interest profiles of the subjects.

Hypotheses 1 and 2 were tested by means of the Mann-Whitney U test. The Mann-Whitney U test was used because it is one of the most powerful of the nonparametric tests and specifically it is the most suitable nonparametric equivalent of the parametric t-test that would have been otherwise employed (Siegel, 1956: 116; Roscoe, 1969; Twaite and Monroe, 1979: 408-409).

The general patterns (order) of the distribution of the cognitive style profiles and interest orientations were obtained from contingency tables for the means and standard deviations of the cognitive style and interest scores.

Hypotheses 3 and 4 were tested by means of the Kruskal-Wallis one-way analysis of variance (ANOVA) by ranks (the Kruskal-Wallis H test). The Kruskal-Wallis test is the most suitable non-parametric equivalent of the parametric analysis of variance, the F-test. The test is used for comparing three or more independent groups on a rank-order or ordinal variable. It may also be used with interval data (numerical scores) which are suspected or known not to meet all the assumptions required to use the standard parametric ANOVA or F-test.

The Kruskal-Wallis test assumes that the variable under study has an underlying continuous distribution, a condition satisfied by the data of the present study. According to Siegel (1956: 192-193) the test has an asymptotic power - efficiency of 3/pi = 95.5 per cent when compared with the most powerful parametric equivalent test, the F-test.

Hypothesis 5 was tested by means of the Pearson product-moment correlation coefficient, rho (r) or the Pearson r. The Pearson r was selected for this particular analysis because the nonparametric correlation coefficients, the Spearman rank correlation coefficient, rho (rs) or the Kendall rank correlation coefficient, tau (τ) which would have been employed are only suitable for the analysis of data from a sample whose size is less than 30 ($N < 30$). The sample size in the present case is 162 ($N = 162$).

There seemed to be no better alternative than to fall back on the parametric Pearson product-moment correlation coefficient for the analysis of the data of hypothesis 5. In any case, Roscoe (1969) stated that theoretical arguments advanced by mathematical statisticians and empirical evidence gathered by many other statisticians have led to conclusions which "suggest that the distinction between ordinal and interval data is not a particularly relevant one with respect to selecting a method of statistical analysis". Indeed many researchers have employed parametric statistics to analyse ordinal data (Tamir and

Lunetta, 1978; Tamir, 1981, 1985; Okebukola and Jegede, 1988 and Gardner and Tamir, 1989).

Roscoe (1969:24) further explained as follows: "Nevertheless, there are circumstances in which the use of the common arithmetic operations with ordinal data will obviously distort the meaning that the investigator attaches to his data. Under these circumstances he must resort to the use of the nonparametric statistics". The circumstance of the present analysis is not the type referred to here by Roscoe. The Pearson r was, therefore, deemed appropriate by the researcher and was employed for this particular analysis.

Hypotheses 6 and 7 were both tested by means of the Mann-Whitney U test for the comparison of two independent groups on rank-order or ordinal data. Paired comparisons of the posttest and pretest cognitive style and interest scores for the experimental groups (E1, E2) and the control groups (C1, C2) of students were made by means of the nonparametric statistic. The paired comparisons were used for assessing the effects of both the treatment and the pretest on cognitive styles and physics interests of the students.

Compared with the most powerful parametric equivalent test, the t-test, the Mann-Whitney U test has a power-efficiency which approaches 3/pi = 95.5 per cent as N increases. Even for moderate-sized samples, the U test has a power-efficiency which is close to 95 per cent (Siegel, 1956:126).

Chapter 4

RESULTS, ANALYSES AND DISCUSSIONS

4.1 Introduction

In this chapter the statistical analyses of the pretest and posttest data collected by means of the Physics Cognitive Style Test (PCST) and the Interest in Physics Inventory (IPI) are presented. The procedure for testing the hypotheses of the study using the analysed data is outlined. Each set of analysed data is presented together with the particular hypothesis which it is used to test. The chapter then ends with a discussion of the results and main findings of the study.

4.2 Results and Analyses

Data on cognitive styles of the subjects were collected by means of the PCST while interest data were obtained by means of the IPI. Students were randomly assigned to four different groups used in the study (the Solomon 4-way design) as already

described in the previous chapter. The first hypotheses (1(a) and (b)) were intended to establish the equivalence of the four groups before the experiment with respect to their cognitive style profiles and the orientations of their physics interests and to identify the patterns of distribution of the cognitive styles and physics interests.

Hypothesis 1(a)

There is no significant difference in the cognitive styles of the four groups of physics students in the experimental design, using Heath's (1964) four-mode dimension (Recall, Principles, Application and Questioning) of cognitive style.

To test this hypothesis, the mean ratings per cognitive style (R,P,A,Q) were obtained for the experimental group (E1) and the control group (C1) who took the pretest using the 40-item PCST. Table 6 shows the means and standard deviations of the cognitive style ratings for the two groups, E1 (N = 82) and C1 (N = 80).

Table 6: Means and Standard Deviations of Cognitive Styles Scores of Students in the Experimental and Control Groups on the Pretest (N = 162)

Groups	N	R		P		A		Q	
		Mean	S.d.	Mean	S.d.	Mean	S.d	Mean	S.d.
E1 Pre	82	104.60	11.80	110.30	10.10	99.22	9.63	85.70	11.3
C1 Pre	80	105.40	12.90	113.20	11.90	97.20	13.40	84.00	13.4
Totals	162	210.00		223.50		196.42		169.70	

Pattern: P - R - A - Q

Ratio: 1.32 : 1.24 : 1.16 : 1.00

The information in Table 6 shows that the subjects scored highest in P and least in Q using the PCST. The full distribution pattern was P _ R - A - Q in the ratio 1.32 : 1.24 : 1.16 : 1.00 for groups E1 and C1 combined. The pattern was the same (with comparable ratios) when the groups were considered severally. The ratio was 1.29 : 1.22 : 1.16 : 1.00 for E1 alone and 1.35: 1.25 : 1.16 : 1.00 for C1 considered separately.

The results confirmed the general order of cognitive style distribution obtained in the pilot study for a similar sample of physics students. They are also in agreement with the cognitive style distribution patterns obtained by Abah (1988) for different samples of secondary, pre-degree and undergraduate physics students.

The distribution patterns portrayed in Table 6 suggest equivalence of the groups of students at the start of the experiment. To confirm this the data of Table 6 were further analysed for any evidence of significant difference between the group means using the Mann-Whitney U test. The results of the analysis are presented in Table 7.

Table 7: Mann-Whitney U Test for Differences in the Cognitive Style Mean Ranks of Students in the Experimental and Control Groups (Pretest) (N = 162)

		Cognitive Styles			
	N	R	P	A	Q
E1 Pre	82	105.00	109.50	98.50	86.50
C1 Pre	80	106.00	113.00	96.00	83.50
U		6611.5	7077.5	6081.0	6134.5
Z		1.000	3.000	-3.000	-3.000
P		0.761	0.062	0.142	0.197

The results show that none of the Z values obtained for all cases of comparison was significant at $P \leq 0.05$. This means that there was no significant difference in the cognitive styles of the physics students in the experimental and control groups using Heath's (1964) 4-mode model of cognitive style. Therefore,

hypothesis 1(a) could not be rejected at the 0.05 level of significance. Group equivalence in cognitive styles at the start of the experiment was confirmed.

Hypothesis 1(b)

There is no significant difference in the physics interests of the four groups of students in the experimental design using the three-dimensional model (Topic, Activity and Motive) of interest proposed by Gardner (1985) and recently employed by Haussler (1987) and Gardner and Tamir (1989).

To test this hypothesis, the mean scores per interest mode, namely Topic (T), Activity (A') and Motive (M) were computed for the experimental group (E1) and the Control group (C1) on the pretest using the 105-item IPI. Table 8 shows the means and standard deivations of the interest ratings for the two groups.

Table 8: Means and Standard Deviations of Imterest Scores of Students in the Experimental and Control Groups on the Prest
(N = 162)

		T		A'		M	
Groups	N	Mean	s.d.	Mean	s.d.	Mean	s.d.
E1 Pre	82	210.8	25.2	95.8	13.2	91.9	15.4
C1 Pre	80	210.8	30.3	96.4	13.2	92.8	16.8
Totals		421.6		192.2		184.7	

Pattern: T - A' - M

Ratio: 2.28 : 1.04 : 1.00

Table 8 shows that the students registered their highest interest scores in the topic (T) dimension and their least interest scores in the motive (M) dimension using the Interest in Physics Inventory (IPI). The actual distribution pattern was T - A' - M in the ratio 2.28 : 1.04 : 1.00. As in the case of cognitive style scores, the pattern of interest scores was the same (with identical ratios) when the groups E1 and C1 were considered separately. The ratio was 2.29 : 1.04 : 1.00 for E1 only and 2.27 : 1.04 : 1.00 for C1 alone.

The results again confirmed the pattern of the distribution of interest orientations obtained for a similar set of physics students in the pilot study. Group equivalence with respect to physics interests at the beginning of the experiment is also indicated by the data of Table 8.

To confirm group equivalence in interest orientations the data were further subjected to the Mann-Whitney U test for significant differences between the group means. The results of the analysis are presented in Table 9.

Table 9: Mann-Whitney U Test for Differences in the Interest Mean Ranks of Students in the Experimental and Control Groups on the Pretest (N = 162)

		Interest Modes		
	N	T	A'	M
E1 Pre	82	211.50	97.00	94.00
C1 Pre	80	213.50	96.50	95.00
U		6617.5	6535.0	6630.0
Z		2.000	0.001	1.000
P		0.745	0.961	0.714

The information in Table 9 shows that no significant Z value was obtained for the scores in all the three dimensions of interest. This implies that there was no significant difference in the interest scores of the students in the experimental and control groups using Gardner and Tamir's (1989) three-dimensional model of interest. Hence hypothesis 1(b) was supported at the 0.05 level of significance. Group equivalence with respect to physics interests of students at the start of the experiment was similarly confirmed.

Hypothesis 2(a)

There are no significant differences in cognitive styles between male and female students who participated in the study.

This hypothesis was tested by comparing the mean ranks of male and female students on R,P,A and Q as measured by the PCST. Only students in the experimental group E1 and the Control group C1 (N = 162) who took the pretest were involved in the analysis. The means and standard deviations of the scores are presented in Table 10 while Table 11 shows the comparison of the mean ranks for significant differences by means of the Mann-Whitney U test.

Table 10: Means and Standard Deviations of Cognitive Style Scores of Male and Female Students in the Experimental and Control Groups (Pretest) (N = 162)

		R		P		A		Q	
Gender	N	Mean	s.d.	Mean	s.d.	Mean	s.d.	Mean	s.d.
Male	128	104.50	12.90	111.40	11.50	98.70	11.90	85.20	12.80
Female	34	106.76	9.88	112.85	9.45	96.40	10.80	83.60	10.50
Total	162								

Distribution Pattern (Male and Female): P - R - A - Q
Distribution Ratio (Male): 1.31 : 1.23 : 1.16 : 1.00
Distribution Ratio (Female): 1.35 : 1.28 : 1.15 : 1.00

Table 10 shows that Principles (P) is the most dominant cognitive style followed by Recall (R) among both male and female physics students while Questioning (Q) is the least dominant cognitive style among both sexes. The pattern of distribution

is the same for both male and female students and is the same as was obtained earlier for the generality of the students, namely P _ R _ A _ Q . The distribution ratios are also similar for both genders: 1.31 : 1.23 : 1.16 : 1.00 for males and 1.35 : 1.28 : 1.15 : 1.00 for females.

The results in Table 10 also reveal that females scored higher than males in P and R while male students scored higher in A and Q than female students.

Table 11: Mann-Whitney U Test for Differences in the Cognitive Style Mean Ranks of Male and Female Students in the Experimental and Control Groups (Pretest) (N = 162)

		Cognitive Styles			
	N	R	P	A	Q
Male	128	104.50	111.00	98.00	85.00
Female	34	107.50	113.00	96.00	81.00
U		10215.5	10196.5	10625.5	10591.0
Z		-2.000	-2.000	2.000	2.000
P		0.374	0.334	0.430	0.515

The comparison of the mean ranks of male and female students in Table 11 shows no significant difference between any of the pairs of scores. This means that there are no gender differences in cognitive style among the subjects in the experimental design. It also means that the higher mean scores

of female students in P and R (or their lower mean scores in A and Q) which were pointed out in Table 10 were not statistically significant. Therefore, hypothesis 2(a) could not be rejected at the 0.05 level of significance. It was concluded that male and female students who participated in the study did not differ significantly in their scores on all the four modes of cognitive style R,P,A and Q.

Hypothesis 2(b)

There are no significant differences in physics interests between male and female students who participated in the study.

In testing this hypothesis the mean scores of male and female students in each of the three modes of interest T, A' and M as measured by the IPI were compared. The pretest scores alone of the experimental and control groups (N = 162) were analysed. The means and standard deviations of the scores are presented in Table 12.

Table 12: Means and Standard Deviations of Interest Scores of Male and Female Students in the Experimental and Control Groups (Pretest) (N = 162)

		T		A'		M	
Gender	N	Mean	s.d.	Mean	s.d.	Mean	s.d.
Male	128	214.1	26.6	97.2	13.1	94.8	14.9
Female	34	198.5	28.9	91.9	12.8	82.7	17.4
Total	162						

Distribution Pattern (Male and Female): T - A' - M
Distribution Ratio (Males only): 2.26 : 1.03 : 1.00
Distribution Ratio (Females only): 2.40 : 1.11 : 1.00

The data in Table 12 show that both male and female students had their highest interest scores in the topic dimension and their least scores in the motive dimension of interest. The pattern of distribution of the interest was the same for both male and female students, namely T - A' - M in the ratios 2.26 : 1.03 : 1.00 for male students and 2.40 : 1.11 : 1.00 for female students.

Table 12 also shows that male respondents scored consistently higher than their female counterparts on all three modes of (physics) interest. The proportion of females who had the pretest was approximately one-fifth (21 percent) - a further indication of the fact that females are less interested in physics than males. To test for significant differences in these scores the data were further analysed using the Mann-Whitney U test. Table 13 gives the results of the Mann-Whitney analysis.

Table 13: Mann-Whitney U Test for Differences in the Interest Mean Ranks of Male and Female Students in the Experimental and Control Groups (Pretest) (N = 162)

		Interest Modes		
	N	T	A'	M
Male	128	214.00	98.50	96.00
Female	34	201.00	93.00	85.00
U		11107.5	10962.0	11249.0
Z		14.9945	6.0009	11.0017
P		0.0055*	0.0294*	0.0002*

* Z significant at $p \leq 0.05$

The Z values obtained in all comparisons of the scores of male and female students presented in Table 13 were significant at the 0.05 level of significance. This means that there was a significant difference at the 0.05 level of significance in the scores of male and female students on all three modes (Topic, Activity and Motive) of interest in physics. Therefore, hypothesis 2(b) was rejected. It was concluded that there is a significant difference in the physics interests of male and female students who participated in the study. The data showed convincingly that males had greater interests than females in all the three modes of physics interest explored.

Hypothesis 3(a)

There are no significant differences in cognitive styles between students of different ages who participated in the study.

This hypothesis was tested by comparing the mean scores of students of different ages on Recall, Principles, Application and Questioning as measured by the PCST. Only students in the experimental group (E1) and the Control group (C1) who took the pretest (N = 162) were involved in the analysis. The ages of all the 326 students who participated in the study ranged between 16 and 27 years. Table 14 shows the means and standard deviations of the cognitive style ratings for the different (ungrouped) ages.

Table 14: Means and Standard Deviations of Cognitive Style Scores of Students of Different Ages in the Experimental and Control Groups (Pretest) (N = 162)

		R		P		A		Q	
Ages	N	Mean	s.d.	Mean	s.d.	Mean	s.d.	Mean	s.d.
16	3	110.00	8.00	110.00	8.00	98.00	9.00	82.00	9.54
17	1	140.00	0.00	75.00	0.00	107.00	0.00	78.00	0.00
18	17	101.12	13.76	111.88	12.20	99.18	13.72	85.82	12.89
19	39	107.33	13.41	113.23	8.84	96.92	11.73	82.41	11.11
20	39	105.49	11.50	110.38	11.19	99.97	12.22	84.77	12.86
21	31	103.90	9.21	110.84	8.59	97.94	10.06	86.61	7.35
22	13	104.77	13.15	114.00	13.40	95.54	12.77	86.15	15.44
23	6	109.17	5.67	109.00	10.99	102.83	4.75	78.17	10.78
24	5	93.40	16.12	113.00	14.46	96.60	16.85	97.00	17.79
25	5	102.20	13.95	109.00	13.93	97.80	12.13	91.20	24.91
26	2	106.00	14.14	131.00	16.97	85.00	9.90	78.00	11.31
27	1	95.00	0.00	128.00	0.00	105.00	0.00	74.00	0.00
Total	162								

An examination of the mean scores in Table 14 compels the following observations:

(i) Most of the students in the experimental and control groups who took the pretest (85.8 percent) were in the age range of 18–22 years at the time of the study.

(ii) The highest and lowest mean scores on all four cognitive style modes were obtained by students in the age cadres with small samples (few students), namely age cadres of 16, 17, 24, 25, 26 and 27 years.

(iii) The single 17-year old student had the highest scores in R and A, the least score in P and the second least score in Q.

(iv) The lone 27-year old student (the oldest student in the entire sample) obtained the least score in Q, the second least score in R and the second highest scores in P and A.

(v) The highest P-score and the least A-score were both made by the two students in the 26-year age class.

(vi) Students in the 24-year age class scored highest in Q and least in R.

(vii) With the exception of only the 17-year and the 24-year groups, all other age groups scored highest in P and least in Q.

(viii) The general order or pattern of distribution of cognitive styles P - R - A - Q is common to all age cadres except the 17-, 24- and 27-year groups.

The Kruskal-Wallis one-way analysis of variance (the Kruskal-Wallis H test) was employed to test for age differences in the cognitive styles of the subjects. To do this the ages were grouped to avoid having small samples in the distribution which would have rendered the Kruskal-Wallis H test unsuitable for the analysis. According to Winer (1971:849) the Kruskal-Wallis test in which the H statistic is approximated to chi square is valid only for sample sizes greater than 5 ($N > 5$).

Grouping the individual ages in threes was the least possible combination of the ages which ensured the complete elimination of small samples. Table 15 shows the means and standard deivations of the cognitive style ratings for students of different age groups.

Table 15: Means and Standard Deviations of Cognitive Style Scores of Students of Different Age Groups in the Experimental and Control Groups (Pretest)
(N = 162)

		R		P		A		Q	
Age Groups	N	Mean	s.d.	Mean	s.d.	Mean	s.d.	Mean	s.d.
16 - 18	21	104.24	15.33	109.86	13.77	99.38	12.72	84.90	12.10
19 - 21	109	105.70	11.63	111.53	9.68	98.30	11.44	84.45	10.93
22 - 24	24	103.50	13.19	112.54	12.68	97.38	12.21	86.42	15.71
25 - 27	8	102.25	12.30	116.88	16.46	95.50	12.09	85.75	20.76
Total	162								

The following deductions may be made from the information in Table 15:

(i) About two-thirds (67.3 percent) of the students in the experimental and control groups who took the pretest were between 19 and 21 years of age. Very few students (about 4.9 percent) were over 24 years of age.

(ii) The youngest age group (16-18 years) had the highest A-score and the least P-score.

(iii) The oldest age group (25-27 years) had the least R-score, the least A-score and the highest P-score.

(iv) The age group with the largest number of students (19-21 years) had the highest score in R and the least score in Q.

(v) The most critical students in the sample were from the 22-24 years age group. The group obtained the highest Q-score .

(vi) The same general order or pattern of distribution of cognitive styles was shown by students in all the age groups, namely P - R - A - Q. This also implies that for each age group the highest score was in P while the least score was in Q.

(vii) A faint decrease of R-scores with age and an equally faint increase of P -, A - and Q - scores with age (with the increases in P- and A-scores being more steady and slightly more pronounced) are discernible.

Further analysis of the data (with the ages grouped) was carried out to identify any significant age-related differences in cognitive styles of the subjects. The results of the Kruskal-Wallis H test are presented in Table 16.

Table 16: Kruskal-Wallis H Test for Differences in Cognitive Style Mean Ranks by Age Groups for Students in the Experimental and Control Groups on the Pretest (N = 162)

		Cognitive Styles			
Age Groups	N	R	P	A	Q
16 - 18	21	76.8	76.2	85.4	80.2
19 - 21	109	84.2	81.1	82.1	81.4
22 - 24	24	79.3	81.7	78.9	84.4
25 - 27	8	64.5	99.7	70.7	77.1
H(adj. for ties)		1.670	1.480	0.666	0.179

The critical value of H at 3 df, 0.05 level of significance was 7.82. All the calculated values of H as shown on Table 16 were less than the critical value. Therefore, none of the calculated H values was significant at the 0.05 level of significance. This means that there are no significant differences in cognitive styles between students of different ages who participated in the study. Hypothesis 3(a) could not, therefore, be rejected.

Hypothesis 3(b)

There are no significant differences in physics interests between students of different ages who participated in the study.

To test this hypothesis the mean scores of students of different ages on the three modes of physics interest, namely Topic (T), Activity (A') and Motive (M) as measured by the interest inventory (IPI) were compared. Only students in the experimental group (E1) and the control group (C1) who took the pretest (N = 162) were involved in the analysis. Table 17 shows the means and standard deviations of the interest scores for the different (ungrouped) ages.

Table 17: Means and Standard Deviations of Interest Scores of Students of Different Ages in the Experimental and Control Groups on the Pretest (N = 162)

		T		A'		M	
Ages	N	Mean	s.d.	Mean	s.d.	Mean	s.d.
16	3	173.33	18.88	90.00	7.00	81.33	10.26
17	1	200.00	0.00	105.00	0.00	95.00	0.00
18	17	201.82	28.65	91.47	13.12	83.88	13.23
19	39	219.46	25.89	97.49	13.31	92.90	19.84
20	39	208.28	28.72	98.51	11.82	94.67	10.17
21	31	215.27	23.74	96.53	11.59	95.27	17.07
22	13	201.21	25.18	90.50	14.21	91.93	18.81
23	6	224.00	21.85	102.50	12.60	93.00	14.60
24	5	216.80	21.51	97.20	19.27	90.40	23.85
25	5	215.20	47.51	94.40	21.47	95.60	15.42
26	2	179.50	12.02	93.50	7.78	86.50	3.54
27	1	176.00	0.00	71.00	0.00	75.00	0.00
Total	162						

The analysis presented in Table 17 supports the following inferences:

(i) Just as in the case of cognitive styles, the highest and lowest mean scores on all three modes of interest were obtained by students in the age categories with small samples, namely age classes of 16, 17, 24, 25, 26 and 27 years.

(ii) The solitary 17-year old student had the highest score recorded on the activity mode A'.

(iii) The only 27-year old student (and the oldest student in the entire sample) had the least A'- and M-scores.

(iv) The youngest group of students (the 16-year class) had the least T-score.

(v) The six 23-year old students and the five 25-year old respondents had the highest mean T-score and the highest mean M-score respectively.

(vi) All age categories had their highest mean scores in the topic (T) dimension of interest. All the categories (except the 22, 25 and 27 age cadres) also had their least mean scores in the motive (M) dimension of interest.

(vii) The general pattern of distribution of interest profiles is T - A' - M except for the age cadres of 22, 25 and 27 years who had their least scores in A' rather than in M.

In order to obtain more reliable results the data were grouped to eliminate the small samples. The ages were again grouped in threes as in the case for cognitive styles and this yielded a total of four age groups. Table 18 shows the means and standard deivations of the interest ratings for students of the four age groups.

Table 18: Means and Standard Deviations of Interest Scores of Students of Different Age Groups in the Experimental and Control Groups (Pretest)
(N - 162)

		T		A'		M	
Age Groups	N	Means	s.d.	Mean	s.d.	Mean	s.d.
16 - 18	21	197.67	28.22	91.91	12.32	84.05	12.56
19 - 21	109	214.26	26.59	97.59	12.23	94.19	16.02
22 - 24	24	209.80	24.97	94.72	15.20	91.88	18.21
25 - 27	8	201.37	40.94	91.25	18.41	90.75	13.97
Total	162						

The following observations may be made from a close examination of the interest mean scores in Table 18:

(i) The youngest age group (the 16-18 years group) recorded the least T-score and the least M-score .

(ii) The oldest age group (25–27 years) recorded the least A'-score.

(iii) The age group with the largest sample (greatest number of students) i.e. the 19–21 years group registered the highest T-, A'- and M-scores.

(iv) The order of distribution of physics interest profiles was T - A' - M for all age groups. This also implies that each age group recorded its highest interest score in the topic (T) dimension and the least interest score in the motive (M) dimension.

(v) The following age - interest relationship is noticeable in all three interest modes: Between 16 and 21 years of age interest in physics increased as students got older while between 21 and 27 years physics interest tended to dwindle as students got older.

To detect any significant age-related differences in the physics interest of the subjects the grouped data were further analysed using the Kruskal-Wallis H test. The results of the analysis are presented in Table 19.

Table 19: Kruskal-Wallis H Test for Differences in Interest Mean Ranks of Students of Different Age Groups in the Experimental and Control Groups on the Pretest (N = 162)

Age Groups	N	Interest Modes		
		T	A'	M
16 - 18	21	59.3	65.2	52.3
19 - 21	109	87.2	86.7	87.6
22 - 24	24	78.1	76.1	82.3
25 - 27	8	73.6	70.7	73.1
H(adj. for ties)		6.654	4.627	10.22*

* H significant at $p \leq 0.05$

The critical value of H at 3 df, 0.05 level of significance was 7.82. Table 19 shows that only the calculated H value for the motive (M) dimension of interest (10.22) was greater than the critical value of H. This means that only the calculated H value for the motive dimension of interest was significant at the 0.05 level of significance. The implication of this finding is that there are significant differences in the motive (M) dimension of physics interests between students of different ages who participated in the study but no significant differences in the topic (T) and activity (A') dimensions. Therefore, hypothesis 3(b) was only partially rejected and that

is in respect of motives (M) for studying physics but was partially accepted in respect of interest in physics topics (T) and interest in physics learning activities (A'). It was concluded that the pre-degree physics students of different age groups differed significantly in the motive (M) dimension of physics interest but did not differ significantly in their interests in physics topics (T) and activities (A') for learning physics.

By taking a look again at the mean interest scores as presented in Table 18, the differences in motives for studying physics among students of different age groups may be generally described or summarised as follows: students in the 19-21 years age cadre showed the highest motivation for studying physics followed by students in the 22-24 years category. The youngest age group (16-18 years) were the least motivated to learn physics. Furthermore, students' interests decreased steadily from age 21 as they became older.

Hypothesis 4 (a)

Students in the four groups of the experimental design who aspire to different careers in science and technology do not exhibit significantly different cognitive styles.

To test this hypothesis the mean scores of students with different career aspirations on the four cognitive style modes R, P, A and Q as measured by the PCST were computed and compared.

The pretest data of students in the experimental group E1 and the control group C1 alone (N = 162) were used for the analysis.

Classification of the students into different career groups was done on the basis of the information they supplied in the relevant portion of the personal data section of each test instrument. Each student was asked to indicate his/her expected future career on each instrument. The different forms of engineering (mechanical, civil, electrical, agricultural, computer, etc) were put together under one general class of "engineering". In the same way all computer-related or computer-based career expectations (except "computer engineering") were classified as interest in a career in "computer science". In all, seven career groups were obtained, namely engineering, computer science, architecture, biochemistry, farming/agriculture, quantity surveying and others. The seventh and last career group labelled "others" comprised other career expectations than the first six listed which were indicated by the students in the test materials and for which the numbers of students showing interest were few. These "other careers" (with the numbers of students indicating interest in them shown in brackets) were: geophysics (2), nuclear physics (2), microbiology (1), army (1), land surveying (1), pharmacy (1), academics (1), food science technology (1), veterinary medicine (1), business consultant (1) and undecided (1). The "farming/agriculture" category comprised farming and all other agro-based types of occupation excepting

"agricultural engineering" (which was classified under "engineering") and "food science technology". Specific examples included agriculture, agricultural science and agricultural technology. Table 20 shows the means and standard deviations of the cognitive style ratings for students in the different career groups.

Table 20: Means and Standard Deviations of Cognitive Style Scores of Students with Different Career Aspirations in the Experimental and Control Groups (Pretest)
(N= 162)

		R		P		A		Q	
Careers	N	Mean	s.d.	Mean	s.d.	Mean	s.d.	Mean	s.d.
Engineering	81	104.86	12.99	111.15	10.89	99.32	11.24	83.99	11.36
Computer Science	54	105.98	12.19	112.52	10.54	96.90	12.09	85.00	12.49
Architecture	4	103.50	3.00	121.00	19.54	99.75	13.72	76.25	12.45
Biochemistry	1	110.00	0.00	108.00	0.00	86.00	0.00	96.00	0.00
Farming/ Agriculture*	5	102.00	3.74	115.50	7.51	103.75	6.29	79.00	16.87
Q. Surveying	4	112.25	7.89	109.25	15.35	98.25	13.48	79.25	10.21
Others**	13	100.92	13.44	109.31	11.93	94.85	13.31	95.31	13.33
Total	162								

* Includes agro-based occupations such as agriculture, agricultural science and agricultural technology.

** All other careers indicated by students but not listed in the table, e.g. nuclear physicist, geophysics, microbiology pharmacy, food science technology, etc.

The information in Table 20 supports the following inferences:

(i) Half of the students (50 percent) aspired towards careers in engineering while one-third of them (33.3 percent) hoped to be computer scientists. The number of students in each of the remaining five groups were few. Put together they constituted only about 16.7 percent, i.e. less than one-fifth (20 percent) of the entire sample.

(ii) The highest and the least mean scores on all four cognitive styles were recorded by students in the career groups with few students (small samples), namely architecture, biochemistry, farming/agriculture, quantity surveying and "others". None of the eight possible extreme scores was registered by any of the large sample career groups of engineering and computer science.

(iii) The four architecture hopefuls had the highest P-score, the least Q-score and the second highest A-score.

(iv) The solitary aspirant to a career in biochemistry had the highest Q-score, the second highest R-score and the least P- and A-scores.

(v) The highest A-score was obtained by the five students who hoped to become farmers or to take up agro-based occupations.

(vi) The highest R-score was obtained by the four students who expected to take up quantity surveying as their future career.

(vii) The least R-score and the second highest Q-score were recorded by the group of students who aspired to careers other than those listed in the table (Table 20).

(viii) The general pattern of distribution of cognitive styles (P- R - A - Q) already identified for this category of physics students was maintained for the engineering, computer science and architecture career groups but not for the other occupational cadres.

In order to test for any significant differences in cognitive style among students who aspired to different future careers in science and technology using the Kruskal-Wallis one-way ANOVA, the data were further grouped so as to eliminate small samples in the distribution. This grouping yielded three distinct career classes, namely engineering, computer science and "other careers" ("others"). In other words, all other career cadres except engineering and computer science were grouped together to form a third career class labelled "others". Table 21 shows the means and standard deviations of the cognitive style scores for students in the three resultant career groups.

Table 21: Means and Standard Deviations of Cognitive Style Scores by Career Groups for Students in the Experimental and Control Groups (Pretest) (N = 162)

Career Groups	N	R		P		A		Q	
		Mean	s.d.	Mean	s.d.	Mean	s.d.	Mean	s.d.
Engineering	81	104.86	12.99	111.15	10.89	99.32	11.24	83.99	11.
Computer Science	54	105.98	12.19	112.52	10.54	96.90	12.09	85.00	12.
Others	27	103.58	10.71	112 .00	13.03	97.15	12.25	87.42	15.
Total	162								

The following observations may be made concerning the mean scores presented in Table 21:

(i) Students who aspired to careers in engineering had the highest A-score and the least P- and Q-scores.

(ii) Students who aspired to careers in computer science recorded the highest R- and P-scores and the least A-score.

(iii) Students who aspired to careers in areas other than engineering and computer science obtained the highest Q-score and the least R-score.

(iv) The order or pattern of distribution of cognitive styles was P - R - A - Q for students in each of the three career groups.

To test for significant differences in cognitive styles between students in the three career cadres, the data were further analysed using the Kruskal-Wallis H test. The results of the statistical analysis are presented in Table 22.

Table 22: Kruskal-Wallis H Test for Differences in Cognitive Style Mean Ranks for Students in Different Career Groups in the Experimental and Control Groups on the Pretest (N = 162)

Career Groups	N	Cognitive Styles			
		R	P	A	Q
Engineering	81	81.2	79.1	86.7	78.3
Computer Science	54	84.3	85.6	75.0	81.4
Others	27	76.8	81.1	77.8	91.9
H(adjusted for ties)		0.446	0.622	2.205	1.660

The critical value of H at 2 df, 0.05 level of significance was 5.99. All the calculated values of H as shown on Table 22 were less than the critical value. Therefore, none of the calculated H values was significant at the 0.05 level of significance. This implies that there are no differences in cognitive styles between students with different career expectations who participated in the study. Therefore, hypothesis 4(a) could not be rejected.

Hypothesis 4(b)

Students in the four groups of the experimental design who aspire to different careers in science and technology do not exhibit significantly different physics interests.

This hypothesis was tested by computing and comparing the mean scores of students of different career expectations on the three modes of physics interest, namely T, A' and M as measured by the interest instrument, the IPI. Only the scores of students in the experimental group (E1) and the control group (C1) who took the pretest (N = 162) were analysed. Table 23 shows the means and standard deviations of the interest scores of the students aspiring to different careers. The same career groupings used in testing for career differences in the cognitive styles of the subjects were also employed in this case.

Table 23: Means and Standard Deviations of Interest Scores of Students with Different Career Aspirations in the Experimental and Control Groups on the Pretest
(N = 162)

		T		A'		M	
Careers	N	Mean	s.d.	Mean	s.d.	Mean	s.d.
Engineering	81	212.99	25.42	97.39	11.90	93.81	14.62
Computer Science	54	207.12	30.71	94.83	15.80	89.67	18.19
Architecture	4	204.60	31.87	97.40	5.32	93.80	12.83
Biochemistry	1	238.00	0.00	100.00	0.00	96.00	0.00
Farming/Agric.*	5	219.75	48.04	98.50	12.87	96.00	19.75
Quantity Surveying	4	200.75	29.58	92.00	13.56	85.00	5.89
Others**	13	212.00	23.14	92.69	12.33	94.08	19.47
Total	162						

* Includes agro-based occupations such as agriculture, agricultural science and agricultural technology.

** All other careers indicated by students but not among the six listed here, e.g. nuclear physicist, geophysics, microbiology, pharmacy, food science technology, etc.

The information in Table 23 leads to the following deductions:

(i) The extreme scores (i.e. the highest and least scores) on all three interest modes T, A' and M were made by students in the small sample career groups, namely biochemistry, farming/agriculture and quantity surveying. The two largest samples (the engineering and computer science groups) did not record any of the extreme scores.

(ii) The lone biochemistry aspirant had the highest score registered on each of the three interest modes. That is he/she had the highest T-, A- and M- scores. However, the highest M-score was shared with the farming/agriculture group owing to the tie in the scores.

(iii) Students who hoped to enter into the career of quantity surveying consistently recorded the least scores on all the three interest modes, i.e. they had the least T-, A'- and M- scores.

(iv) The pattern of distribution of physics interest orientations was T- A'- M for all career groups except the group labelled "others", i.e. the group of students aspiring to careers other than those listed in Table 23. This also implies that except for the said career group, all other groups recorded their highest score in the topic (T) dimension and their least score in the motive (M) dimension.

In order to test for significant differences in physics interest among students who aspired to different careers the analysis was carried out using the same career groupings employed in testing for career differences in the cognitive styles of the subjects (See Tables 21 and 22). Table 24 shows the means and standard deviations of the interest scores for students in the three career categories.

Table 24: Means and Standard Deviations of Interest Scores of Students of Different Career Groups in the Experimental and Control Groups on the Pretest
(N = 162)

		T		A'		M	
Careers Groups	N	Mean	s.d.	Mean	s.d.	Mean	s.d.
Engineering	81	212.99	25.42	97.39	11.90	93.81	14.62
Computer Science	54	207.12	30.71	94.83	15.80	89.67	18.19
Others	27	211.07	28.90	94.59	11.08	93.04	16.18
Total	162						

From the information in Table 24 the following inferences may be made:

(i) Students who were aspiring to careers in the field of engineering had the highest score on all the three modes of interest. That is they had the highest T-score, the highest A'-score and the highest M-score.

(ii) Students hoping to enter into occupations in Computer Science recorded the least T-score and the least M-score.

(iii) The least A'-score was made by the group of students who expected to take up careers other than engineering and computer science.

(iv) The order of distribution of interest orientations is T— A'— M for all three career groups. This also means that respondents in each career group had their highest score in the topic (T) dimension and their lowest score in the motive (M) dimension of interest.

Table 25 shows the results of further analysis of the data using the Kruskal-Wallis one-way ANOVA (the H test). The purpose of the analysis was to test for significant differences in interest mean rank scores of the students aspiring to different careers in science and technology. The values of H calculated for each of the three modes of interest are shown in the table.

Table 25: Kruskal-Wallis H Test for Differences in Interest Mean Ranks of Students in Different Career Groups in the Experimental and Control Groups on the Pretest (N = 162)

Career Groups	N	Interest Modes		
		T	A'	M
Engineering	81	84.3	86.0	84.7
Computer Science	54	76.9	78.6	75.4
Others	27	81.9	73.3	83.4
H(adjusted for ties)		0.794	1.792	1.325

The critical value of H at 2 df, 0.05 level of significance was 5.99. The calculated values of H for the three modes of interest T, A' and M were all less than the critical value. Therefore, none of the calculated values of H was significant at the 0.05 level of significance. This means that students in the experimental design who aspire to different future careers do not differ significantly in their physics interests. Therefore, hypothesis 4(b) was accepted (could not be rejected) at the 0.05 level of significance.

Hypothesis 5

There is no significant relationship between students' physics cognitive styles as measured by the PCST and their physics interests as measured by the IPI.

A major aim of the present study was to find out if cognitive styles of learners in a science subject are related to the learners' interest orientations in that subject. The subject in this case was physics. The research question was: "Are there any relationships between cognitive style profiles and interest orientations among the physics students"? Hypothesis 5 was supposed to provide clue to the answer(s) to this research question.

To test this hypothesis the cognitive style scores of the students as measured by the PCST were correlated with their interest scores as measured by the IPI. First, the overall mean scores on R, P, A and Q for all the 40 items in the PCST were correlated with the total mean interest scores on T, A' and M for all the items in the IPI. Pearson product-moment correlation was employed for the analysis.

Tables 26 - 34 present the correlation matrices showing the values of the Pearson product-moment correlation coefficient (r) for the various relationships. The critical value of r (the Pearson r) at 0.05 level of significance (N = 162) was 0.154. All calculated values of r greater than 0.154 were, therefore, statistically significant at 0.05 level of significance. All other coefficients of correlation whose values reached at least 80 percent of the critical value (i.e. from 0.123 upwards) were considered to be reasonably strong (though not statistically significant) and were noted accordingly.

Table 26 shows Pearson product-moment correlations between the overall means cognitive style and interest scores of the students.

Table 26: Correlations Between Overall Cognitive Style Scores and Overall Interest Scores for Students in the Experimental and Control Groups on the Pretest (N = 162)

Cognitive Styles	Interest Dimensions		
	Topic (T)	Activity (A')	Motive (M)
Recall (R)	-0.078	-0.104	0.004
Principles (P)	-0.008	-0.103	-0.131x
Application (A)	0.061	0.168*	0.075
Questioning (Q)	0.019	-0.017	0.071

* Significant at $p \leq 0.05$

x High but not significant at $p \leq 0.05$

The following observations may be made from Table 26:

(i) The application (A) cognitive style was positively and significantly correlated with the activity (A') mode of interest. This means that students whose dominant physics cognitive style is application tend to show high interest in activities for learning physics.

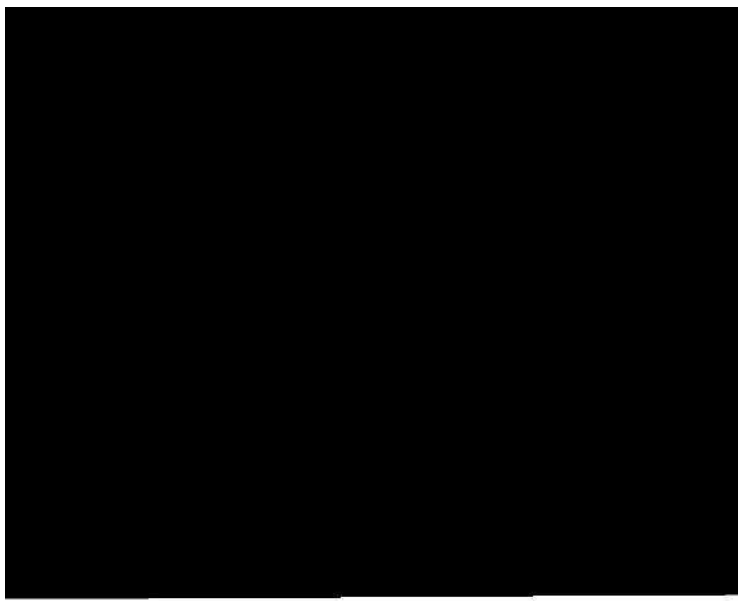
(ii) The negative correlation between P and M was reasonably high but not significant at the 0.05 level of significance. It, however, suggests that students who are highly motivated to learn physics would be little inclined to learn physics principles or to accept an information in physics because it illuminates some fundamental physics principle.

The critical value of r , the Pearson product-moment correlation coefficient, at 0.05 level of significance and N = 162 was 0.154. This value was used to assess the significance of the calculated r values which are shown on the table.

For subsequent correlational analyses the R-, P-, A- and Q-scores in the seven major physics content areas or topics covered by the PCST were computed. The 40 items of the PCST were distributed over the seven major content areas as shown in Table 1. The scores in each cognitive style in each content area were computed so that seven sub-scores, (R1, R2,..., R7; P1, P2, ..., P7; A1, A2, ...,A7 and Q1, Q2, ...,Q7) were obtained for all cognitive style sub-scales. Thus R1, is the R-score in mechanics, R2 is the R-score in heat, R3 is the R-score in light or optics, . . ., R7 is the R-score in sound and so on (see Table 1, p. 145).

Similarly the 56 items of the topic (T) sub-scale of the IPI were distributed over the same seven physics content areas as in the PCST. Therefore, the T-scores (T_1, T_2,..., T_7) for the different content areas were also computed. T_1 is the T-score in mechanics, T2 is the T-score in heat, T3 is the T-score in light or optics,..., and T_7 is the T-score in sound. Thus cognitive styles (Ri, Pi, Ai, Qi) and interests (Ti) in different physics topics were computed (i = 1,2,...,7). In like manner the scores on the three sub-dimensions of the activity (A') dimension of interest were calculated yielding a set of three sub-scores A'1, A'2 and A'3 for this particular interest mode. The scores on the two sub-dimensions of the motive (M) mode of interest were also computed. Altogether four sets of 7 sub-scores were obtained for the cognitive style criterion measure while three sets of 7, 3 and 2 sub-scores were assembled for the interest measure. These sets of scores were then correlated as described in the following pages using Pearson product-moment correlation.

Table 27 shows the correlations between cognitive style recall scores (R1, R2,..., R7, R) and interest scores in the topic dimension (T1, T2,..., T7, T). The overall cognitive style and interest scores R and T respectively were included for completeness purposes.



The critical value of r at 0.05 level of significance and N = 162 was 0.154. Comparing this with the calculated values of r shown in the table, the following deductions can be made:

(i) R3 (the recall cognitive style in optics) was significantly and negatively correlated with T4 (interest in electricity), T6 (interest in waves), T7 (interest in sound) and T (overall interest in the knowledge content of physics). R3 is also reasonably correlated with T1 (interest in mechanics) and T5 (interest in magnetism) but the correlations are not significant at the 0.05 level of significance.

This means that students with high R-score in optics would record low T-scores in physics generally and in electricity, waves and sound particularly. The implication is that students who are good at remembering facts and knowledge items in optics tend to have low interest in physics topics generally but with particular reference to electricity, waves and sound and to some extent mechanics and magnetism.

(ii) Sizeable but non-significant negative correlations were also shown between R2 (recall style in heat) and T4 (interest in electricity), R2 and T5 (interest in magnetism) and between R (recall style in physics) and T5 (interest in magnetism).

Table 27: Correlations Between Cognitive Style Mean Scores in Recall ($R_1, R_2, \ldots, R_7, R$) and Interest Mean Scores in the Topic Dimension ($T_1, T_2, \ldots, T_7, T$) for Students in the Experimental and Control Groups(Pretest) (N=162)

Cognitive Style Sub-Scales	Interest Sub-dimensions							
	T_1:Int. in Mechanics	T_2:Int. in Heat	T_3:Int. in Optics	T_4:Int. in Electricity	T_5:Int. in Magnetism	T_6:Int. in Waves	T_7:Int. in Sound	T:Int. in Physics
R_1: R Mechanics	0.052	0.052	-0.051	-0.071	-0.105	-0.050	-0.120	-0.049
R_2: R Heat	-0.070	-0.054	-0.048	-0.138 +	-0.128 +	-0.065	-0.041	-0.107
R_3: R Optics	-0.133 +	-0.086	-0.111	-0.230 *	-0.137 +	-0.236 *	-0.179 *	-0.201 *
R_4: R Electricity	0.056	0.074	-0.027	-0.035	-0.047	-0.089	-0.100	-0.021
R_5: R Magnetism	0.033	0.116	0.065	-0.112	-0.031	0.017	0.042	0.014
R_6: R Waves	0.001	0.081	0.048	-0.055	-0.090	-0.024	-0.005	-0.010
R_7: R Sound	0.128 +	0.105	-0.057	-0.057	-0.081	0.063	-0.018	0.009
R: R Physics	0.006	0.055	-0.052	-0.052	-0.147 +	-0.102	-0.109	-0.098

* Correlations significant at $P \leq 0.05$
\+ Correlation reasonably strong but not significant at $P \leq 0.05$

Table 28 shows the correlation matrix for the relationship between cognitive style scores in principles (P1, P2,..., P7, P) and interest scores in the topic dimension (T1, T2,..., T7, T). Again the total scores P and T are included in order to make the correlation complete.

Comparing the calculated values of r shown in the table with the critical value (r = 0.154) at 0.05 level of significance and N = 162, it is observed that none of the correlations in the table was significant at the 5 percent level of significance. Two reasonably high but non-significant correlations were, however, noted:

(i) P1 (principles cognitive style in mechanics) was negatively correlated with T7 (interest in sound). The indication here is that students with high P-score in mechanics would tend to have little interest in the area of sound.

(ii) P4 (P-score in electricity) was negatively correlated with T2 (interest in heat). This relationship suggests that students with low P-score in electricity would be highly interested in heat.

Table 29 shows the relationships between cognitive style scores in application (A1, A2, .., A7, A) and interest scores in the topic dimension (T1, T2, ..., T7, T). A and T are the overall scores in application and physics interest (topic mode)

respectively included so as to complete the correlational analysis. By comparing the calculated values of r presented in the table and the critical r value (0.154) at 0.05 level of significance and N = 162, the following observations can be made from the table:

Table 28: Correlations Between Cognitive Style Mean Scores in Principles (P_1, P_2,..,P_7,P) and Interest Mean Scores in the Topic Dimension (T_1,T_2,...,T_7,T) for Students in the Experimental and Control Groups Pretest)

(N = 162)

Cognitive Style Sub-Scales	Interest Sub-dimensions							
	T_1:Int. in Mechanics	T_2:Int.in Heat	T_3:Int. in Optics	T_4:Int. in Electricity	T_5:Int. in Magnetism	T_6:Int. in Waves	T_7:Int. in Sound	T:Int. in Physics
P_1: P Mechanics	-0.010	0.055	-0.071	-0.096	-0.020	-0.061	-0.150 +	-0.058
P_2: P Heat	-0.008	-0.025	-0.070	-0.118	-0.038	0.027	0.006	-0.055
P_3: P Optics	0.59	0.083	0.006	-0.042	-0.003	0.045	-0.001	0.023
P_4: P Electricity	0.090	0.130 +	-0.005	0.021	0.082	0.070	-0.016	0.070
P_5: P Magnetism	-0.030	0.018	-0.108	0.043	0.027	0.029	-0.052	-0.009
P_6: P Waves	0.063	0.037	-0.014	-0.020	-0.059	-0.085	0.020	-0.011
P_7: P Sound	-0.048	0.032	-0.032	0.011	0.081	0.005	0.021	0.012
P: P Physics	0.024	0.076	-0.075	-0.055	0.019	0.022	-0.045	-0.008

+ Correlations reasonably strong but not significant at $P \leq 0.05$

Table 29: Correlations Between Cognitive Style Mean Scores in Application ($A_1, A_2, .., A_7$, A) and Interest Mean Scores in the Topic Dimension ($T_1, T_2, \ldots, T_7, T$) for Students in the Experimental and Control Groups (Pretest)
(N = 162)

Cognitive Style Sub-Scales	Interest Sub-dimensions							
	T_1:Int. in Mechanics	T_2:Int. in Heat	T_3:Int. in Optics	T_4:Int. in Electricity	T_5:Int. in Magnetism	T_6:Int. in Waves	T_7:Int. in Sound	T:Int. in Physics
A_1:A Mechanics	-0.118	-0.002	0.131 +	0.106	-0.117	-0.034	0.094	0.060
A_2:A Heat	-0.005	-0.023	-0.056	0.086	-0.051	-0.033	-0.052	0.005
A_3:A Optics	0.028	0.038	-0.004	0.200 *	0.095	0.136 +	0.077	0.108
A_4:A Electricity	-0.002	0.047	0.054	0.077	0.118	0.003	0.040	0.068
A_5:A Magnetism	0.027	-0.047	0.023	0.105	-0.071	-0.132 +	-0.028	0.021
A_6:A Waves	-0.104	-0.118	-0.037	0.094	0.023	0.104	0.063	-0.001
A_7:A Sound	-0.030	0.009	0.067	0.042	-0.013	-0.058	0.022	0.018
A: A Physics	-0.036	-0.012	0.045	0.176 *	-0.122	-0.014	0.046	0.072

* Correlations Significant at $P \leq 0.05$
\+ Correlations reasonably strong but not significant at $P \leq 0.05$.

(i) T4 (interest in electricity) was positively and significantly correlated with A3 (application in optics) and A (application in physics). This means that students with high interest in electricity are predominantly appliers in physics generally and in optics particularly.

(ii) The following correlations which were not significant at the 0.05 level of significance but were deemed reasonably high because their values reached at least 80 percent of the critical r value were noted:

(a) T3 (interest in optics) correlated positively with A1 (application in mechanics) suggesting that students with high interest in optics would tend to learn or accept knowledge content in the area of optics mainly for their utilitarian values.

(b) T6 (interest in waves) correlated positively with A3 (application style in optics) but negatively with A5 (application style in magnetism). This implies that students with high interest in waves would tend to be high in application in optics but low in the same application in magnetism.

The correlation matrix in Table 30 shows the relationships between cognitive style scores in questioning (Q1, Q2, ...,Q7, Q) and interest scores in the topic dimension (T1, T2, ..., T7, T). Q and T are the overall scores on questioning and interest

Table 30: Correlations Between Cognitive Style Mean Scores in Questioning (Q_1,Q_2,..,Q_7, Q) and Interest Mean Scores in the Topic Dimension (T_1,T_2,..,T_7, T) for Students in the Experimental and Control Groups (Pretest).

(N = 162)

S Cognitive Style Sub-Scale	Interest Sub-Dimensions							
	T_1:Int. in Mechanics	T_2:Int.in Heat	T_3:Int.in Optics	T_4:Int.in Electricity	T_5:Int.in Magnetism	T_6:Int.in Waves	T_7:Int.in Sound	T:Int.in Physics
Q_1: Q Mechanics	0.033	-0.144 +	-0.053	0.057	-0.022	0.103	0.094	0.001
Q_2: Q Heat	0.092	0.099	0.165 *	0.139 +	0.102	0.066	0.084	0.145 +
Q_3: Q Optics	0.058	-0.037	0.100	0.058	0.029	0.081	0.133 +	0.070
Q_4: Q Electricity	-0.085	-0.150 +	0.031	-0.069	-0.129 +	0.030	0.093	-0.069
Q_5: Q Magnetism	-0.033	-0.106	0.022	-0.047	-0.089	0.120	0.050	-0.030
Q_6: Q Waves	0.020	-0.069	0.004	-0.028	0.073	-0.059	-0.060	-0.015
Q_7: Q Sound	-0.043	-0.166 *	0.033	-0.017	-0.008	-0.020	-0.046	-0.046
Q: Q Physics	0.019	-0.117	0.089	0.038	-0.009	0.090	0.107	0.030

* Correlations Significant at $P \leqslant 0.05$
\+ Correlation reasonably strong but not significant at $P \leqslant 0.05$

(topic dimension) included for completeness purposes.

Comparison of the calculated r values with the critical value of r which was 0.154 at 0.05 level of significance $N = 162$ led to the following inferences from the correlational analysis:

(i) T2 (interest in heat) was negatively and significantly correlated with Q7 (critical questioning in sound). This implies that students who have low interest in heat would tend to attend to knowledge items in sound with critical mind.

Similar negative relationships were also portrayed between (a) T2 and Q1 (Q-score in mechanics) and (b) T2 and Q4 (Q-score in electricity) but these were not statistically significant.

(ii) Q2 (Q-score in heat) correlated positively and significantly with T3 (interest in optics). This means that high interest in optics is congruent with a dominant questioning style in heat among the subjects of the study. Q2 also had identical correlations with T (interest in physics topics generally) and T4 (interest in electricity) though the correlations were not statistically significant.

(iii) Other substantial but non-significant correlations identified were:

(a) T7 (interest in sound) correlated positively with Q3 (critical questioning in optics) implying that students with high interest in sound would tend to be critical questioners in learning or dealing with knowledge content in optics.

(b) T5 (interest in magnetism) was negatively correlated with Q4 (critical questioning in electricity) suggesting that students with high interest in magnestism are likely to attend to knowledge items in electricity with uncritical minds.

Table 31 shows the correlational matrix for the relationships between recall scores (R1, R2, ..., R7, R) and interest scores in the activity and motive dimensions (A'1, A'2, A'3, A', M1, M2, M). The results of the analysis as shown on the table support the following deductions:

(i) R3 (recall in optics) was negatively and significantly correlated with A'1, (interest in reception learning), A'3 (interest in engaging in higher cognitive operations) and A' (interest in types of activities for learning physics generally). These relationships imply that students who are predominantly recallers in optics exhibit low interest in activities for learning physics generally but particularly in reception learning and engaging in higher cognitive operations.

Table 31: Correlation Between Cognitive Style Mean Scores in Recall (R_1, R_2,...,R_7, R) and Interest Mean Scores in Activity (A'_1, A'_2, A'_3, A') and Motive (M_1, M_2, M) for Students in the Experimental and Contrl Groups (Pretest)

(N = 162)

Cognitive Style Sub-Scales	Interest Sub-Dimensions						
	A'_1	A'_2	A'_3	A'	M_1	M_2	M
R_1: R Mechanics	-0.005	-0.012	-0.055	-0.029	-0.079	0.021	-0.019
R_2: R Heat	-0.055	-0.016	-0.027	-0.039	0.000	-0.014	-0.010
R_3: R Optics	-0.188 *	-0.108	-0.166 *	-0.189 *	-0.033	-0.021	-0.030
R_4: R Electricity	-0.024	-0.022	-0.015	-0.014	0.020	-0.006	0.004
R_5: R Magnetism	-0.127 +	-0.036	-0.047	-0.084	0.021	0.115	0.094
R_6: R Waves	-0.052	-0.034	-0.094	-0.073	0.027	-0.009	0.005
R_7: R Sound	-0.012	0.101	-0.097	0.005	0.046	-0.060	-0.024
R: R Physics	-0.116	-0.035	-0.110	-0.0104	-0.006	0.009	0.004

* Correlations Significant at $P \leq 0.05$

\+ Correlation reasonably strong but not significant at $P \leq 0.05$

Activity Sub-Dimensions:

A': Interest in activities for learning Physics
A'_1: Interest in reception learning
A'_2: Interest in learning "by doing"
A'_3: Interest in engaging in higher cognitive operations

Motive Sub-Dimensions

M: Interest in motives for learning Physics
M_1: Interest in social aspects of Physics
M_2: Interest in Physics-related careers.

(ii) A reasonably high (though not significant) negative correlation was noted between R5 (recall in magnetism) and A'1 (interest in reception learning) suggesting that recallers in magnetism tend to show low interest in reception learning.

Table 32 shows the relationships between scores in principles (P1, P2, ..., P7, P) and interest scores in the activity and motive dimensions (A'1, A'2, A'3, A', M1, M2, M) for students who took the pretest (N = 162). The following inferences are derived from the results of the analysis:

(i) P1 (fundamental principles in mechanics) correlated negatively and significantly with M2 (interest in physics-related careers). This means that students who are highly interested in physics-related careers are unlikely to be oriented towards fundamental principles in their exhibition of cognitive styles in mechanics. The same type of relationship was also noted between P1 and M (interest in motives for learning physics generally) though the correlation was not significant.

(ii) A'2 (interest in learning "by doing") was negatively and significantly correlated with P7 (fundamental principles in sound). The relationship implies that high interest in learning "by doing" is congruent with poor orientation towards fundamental principles in sound. There is also

Table 32: Correlations Between Cognitive Style Mean Scores in Principles (P_1, P_2...,P_7, P) and Interest Mean Scores in Activity (A'_1, A'_2, A'_3, A) and Motive (M_1, M_2, M) for Students in the Experimental and Control Groups (Pretest)

(N = 162)

Cognitive Style Sub-Scales	Interest Sub-Dimensions						
	A'_1	A'_2	A'_3	A'	M_1	M_2	M
P_1: P Mechanics	-0.085	-0.122	0.073	-0.119	0.016	-0.198 *	-0.138 +
P_2: P Heat	-0.091	-0.016	0.009	-0.039	-0.135 +	-0.087	-0.121
P_3: P Optics	0.049	-0.001	-0.024	0.009	-0.050	-0.051	-0.059
P_4: P Electricity	-0.057	-0.133 +	0.003	-0.083	-0.020	-0.080	-0.067
P_5: P Magnetism	-0.053	-0.141 +	0.033	-0.073	-0.070	-0.097	-0.102
P_6: P Waves	0.041	-0.044	-0.003	-0.006	0.005	-0.044	-0.030
P_7: P Sound	-0.039	-0.165 *	-0.062	-0.117	0.070	-0.023	0.013
P: P Physics	-0.065	-0144 +	-0.025	-0.103	-0.061	-0.144 +	-0.131 +

* Correlations Significant at $P \leq 0.05$
\+ Correlations reasonably strong but not significant at $P \leq 0.95$

Activity Sub-Dimensions:

A': Interest in activities for learning Physics
A'_1: Interest in reception learning
A'_2: Interest in learning "by doing"
A'_3: Interest in engaging in higher cognitive operations.

Motive Sub-Dimensions

M: Interest in Motives for learning Physics
M_1: Interest in social aspects of Physics
M_2: Interest in Physics-related careers.

evidence that A'2 was similarly correlated with P4 (fundamental principles in electricity), P5 (fundamental principles in magnetism) and P (fundamental principles in physics as a whole) although the correlations were not significant.

(iii) Other correlations which were not significant but were sufficiently high to be noted (their values reached at least 80 percent of the critical value of r) were:

(a) P(fundamental principles in physics) was negatively correlated with M(interest in motives for studying physics generally) and M2 (interest in physics-related careers). This suggests that students whose dominant cognitive style in physics is P are unlikely to (1) bother about reasons or motives for studying physics and (2) be keen on physics-related careers.

(b) M1 (interest in social aspects of physics) was negatively correlated with P2 (fundamental principles in heat). This implies that students who are highly motivated to study physics because of its social importance are unlikely to focus on fundamental principles in learning or in dealing with knowledge content in the area of heat.

Table 33: Correlations Between Cognitive Style Mean Scores in Application (A_1, A_2,...,A_7, A) and Interest Mean Scores in Activity (A'_1,A'_2,A'_3,A') and Motive (M_1, M_2, M) for Students in the Experimental and Control Groups(Pretest)

(N = 162)

Cognitive Style Sub-Scales	Interest Sub-Dimensions						
	A'_1	A'_2	A'_3	A'	M_1	M_2	M
A_1: A Mechanics	0.010	0.069	0.096	0.073	0.125 +	0.167 *	0.176 *
A_2: A Heat	0.086	0.022	0.024	0.053	-0.009	0.033	0.021
A_3: A Optics	0.104	0.178*	0.160 *	0.186 *	0.042	-0.033	-0.006
A_4: A Electricity	0.055	0.053	0.080	0.077	-0.049	0.086	0.042
A_5: A Magnetism	0.178 *	0.140 +	0.089	0.169 *	0.070	0.036	0.056
A_6: A Waves	-0.045	0.103	-0.020	0.023	0.043	-0.054	-0.021
A_7: A Sound	0.045	0.006	0.103	0.060	-0.051	0.065	0.025
A: A Physics	0.122	0.141 +	0.140 +	0.168 *	0.043	0.077	0.075

*Correlations significant at $P \leq 0.05$
+Correlations reasonably high but not significant at $P \leq 0.05$

Activity Sub-Dimensions:

A' : Interest in activities for learning Physics
A'_1: Interest in reception learning
A'_2: Interest in learning "by doing"
A'_3 Interest in engaging in higher cognitive operations.

Motive Sub-Dimensions

M: Interest in Motives for learning Physics
M_1: Interest in social aspects of Physics
M_2: Interest in Physics-related careers.

Table 33 shows the correlations between application scores (A1, A2, ..., A7, A) and interest scores in the activity and motive dimensions (A'1, A'2, A'3, A', M1, M2, M). The results of the analysis presented in the table permit the following inferences:

(i) A1 (application in mechanics) was positively and significantly correlated with M(motivation to learn physics generally) and M2 (interest in physics-related careers). This implies that students whose predominant cognitive style in mechanics is application are highly interested in motives for learning physics generally and specifically in learning physics because of prospects of taking up physics-related occupations. A similar correlation between A1 and M1 (interest in learning physics because of its social implications) was noted but the correlation was not statistically significant.

(ii) A3 (application in optics) was positively and significantly correlated with A'2 (interest in learning physics "by doing"), A'3 (interest in engaging in higher cognitive operations) and A (interest in activities for learning physics). This means that students who are predominantly appliers in optics generally have high interest in how physics should be learnt (i.e. through what type of activities) and specifically in learning physics "by doing" and by "engaging in higher cognitive operations".

(iii) A5 (application in magnetism) was positively and significantly correlated with A'1 (learning by reception) and A' (interest in activities for learning physics). This implies that students who are essentially appliers in the area of magnetism demonstrate a high level of concern for activities for learning physics generally and particularly on learning physics by reception. A similar relationship between A5 and A'2 (interest in learning physics "by doing")was noted though it was not statistically significant.

(iv) The positive and significant correlation between A(application in physics) and A' (interest in activities for learning physics) which was reported earlier (see Table 26, p. 215) was again portrayed here. Similar high positive correlations between A and A'2 on the one hand and between A and A'3 on the other were noted. These correlations were appreciably high but not statistically significant. They however, indicate that appliers in physics are highly interested in learning physics "by doing" and "by engaging in higher cognitive operations".

Table 34 shows the correlation matrix outlining the relationships between critical questioning scores (Q1, Q2, ..., Q7, Q) and interest scores in activity and motive dimensions (A'1, A'2, A'3, A', M1, M2, M) for students in the experimental and control groups who took the pretest (N = 162). The following inferences are derived from the information contained in the table:

(i) None of the calculated r values was statistically significant at 0.05 level of confidence.

(ii) Two correlations whose values reached at least 80 percent of the critical r value at the 0.05 confidence level (r = 0.154) were considered worthy of note. The correlations which were positive but not significant are Q2 (critical questioning in heat) correlated with (1) M (interest in motives for studying physics) and (2) M1 (motivation to study physics because of its social role). The two relationships suggest that students whose cognitive styles in heat are geared towards critical questioning would tend to demonstrate high level of interest in motives or reasons for learning physics generally and specifically in learning physics because of the social importance of the knowledge gained.

Table 34: Correlations Between Cognitive Style Mean Scores in Questioning (Q_1, Q_2,...,Q_7, Q) and Interest Mean Scores in Activity (A'_1,A'_2,A'_3,A') and Motive (M_1,M_2,M) for students in the Experimental and Control Groups (Pretest)

(N = 162)

Cognitive Style Sub-Scales	Interest Sub-Dimensions						
	A'_1	A'_2	A'_3	A'	M_1	M_2	M
Q_1: Q Mechanics	0.009	-0.055	-0.056	-0.044	-0.026	-0.013	-0.021
Q_2: Q Heat	0.071	-0.021	-0.006	0.015	0.131 +	0.092	0.124 +
Q_3: Q Optics	0.038	-0.068	0.007	-0.014	0.034	0.108	0.094
Q_4: Q Electricity	0.010	0.044	-0.070	-0.003	0.059	0.050	0.062
Q_5: Q Magnetism	-0.023	0.028	-0.101	-0.035	-0.040	-0.063	-0.063
Q_6: Q Waves	0.023	-0.032	0.046	0.012	-0.039	0.115	0.067
Q_7: Q Sound	0.007	-0.004	-0.000	-0.001	-0.070	0.023	-0.017
Q: Q Physics	0.037	-0.028	-0.046	-0.017	0.031	0.079	0.071

+ Correlations reasonably high but not significant at P 0.05

Activity Sub-Dimensions:

A' : Interest in activities for learning Physics
A'_1: Interest in reception learning
A'_2: Interest in learning "by doing"
A'_3: Interest in engaging in higher cognitive operations.

Motive Sub-Dimensions

M: Interest in Motives for learning Physics
M_1: Interest in social aspects of Physics
M_2: Interest in Physics-related careers.

Another major concern in the present study was to explore the possibility of modifying the cognitive style profiles and the interest orientations of a group of physics students using the teacher-directed discussion (TDD) mode of instruction. Hypotheses 6 and 7 were intended to provide evidence of the effect (or lack of it) of the treatment on the cognitive styles and interests of the respondents. The Solomon 4-group design model was adopted in testing these two hypotheses. Half of the experimental class (E1) and half of the control class (C1) were pretested while the other halves E2 and C2 were not.

Students in the experimental class were taught for 8 weeks by means of the TDD method while the control class was taught by the traditional lecture method. At the end of the 8 weeks, all groups were given the posttest. The effects of the treatment and the pretest were determined by means of paired comparisons which were carried out using the Mann-Whitney U test.

Hypothesis 6

The teacher-directed discussion method of teaching (the experimental treatment) has no significant effect on the cognitive style distribution of the subjects.

Table 35 shows the comparison of the pretest and posttest scores of the experimental group (E1). If the treatment was effective then the posttest scores should be higher than the pretest scores especially with respect to A and Q.

Table 35: Comparison of Experimental Pretest (E1 Pre) with Experimental Posttest (E1 Post) Cognitive Style Mean Ranks

	N	Cognitive Styles			
		R	P	A	Q
E1 Pre	82	105.00	109.50	98.50	86.50
E1 Post	82	103.00	105.00	98.00	92.00
U		7085.5	7650.0	6622.0	5703.5
Z		2.000	5.000	-0.001	-6.000
P		0.231	0.002*	0.736	0.001*

* Z significant at $p \leqslant 0.05$

The results of the comparison show that there was a significant decrease in the P-score and a significant increase in the Q-score. The drop in R-score although it was not significant at the 0.05 level of significance was noted. There was also a rather negligible drop in the preference for A.

The effect of the treatment seemed to have decreased the mean scores for P and R and increased the mean score for Q while causing only a slight drop in the A-score. This means that fewer students were oriented towards recall and principles while more students were questioners in the posttest than in the pretest as was expected. However, the slight drop in preference for A was the reverse of what was expected from the experimental treatment. Therefore, hypothesis 6 was rejected in respect of preference for P and Q but could not be rejected in respect of preference for R and A.

Table 36 shows the comparison of the experimental group (E1) posttest scores and the control group (C1) posttest scores. If the treatment was effective, then it would be expected that E1 posttest scores would be higher than C1 posttest scores particularly on A and Q. Assuming that the effect of the pretest over the eight weeks period was minimal, C1 posttest scores were expected to be approximately equal to C1 pretest scores.

Table 36: Comparison of Cognitive Style Mean Ranks of Experimental Posttest (E1 Post) with Scores of Control Posttest (C1 Post)

	N	Cognitive Styles			
		R	P	A	Q
E1 Post	82	103.00	105.00	98.00	92.00
C1 Post	80	107.00	107.50	95.00	89.00
U		5986.5	6054.5	7226.0	6973.50
Z		-3.000	-3.000	-3.000	2.999
P		0.052*	0.087	0.025*	0.164

* Z significant at $p \leq 0.05$

Results of the comparison show that the mean score for R significantly dropped while the mean score for A rose significantly. The changes in the mean scores for P and Q were not significant but a decrease in the P-score and an increase in the Q-score were noted. The effect of the treatment on each cognitive style was

in the direction expected, namely decrease in the R- and P-scores and increase in the A- and Q-scores. On the basis of the results the null hypothesis (hypothesis 6) was rejected as it affected R and A but could not be rejected for P and Q.

Table 37 shows the effect of the instructional mode by comparing the experimental group ($E2$) posttest scores with the control group (C_1) posttest scores.

The C_1 group had the pretest but the E_2 group did not have the pretest. If the instructional mode was effective, E_2 posttest scores should be significantly greater than C_1 posttest scores.

Table 37: Comparison of Cognitive Style Mean Ranks of Experimental Posttest (E_2 Post) with Control Posttest (C_1 Post)

	N	Cognitive Styles			
		R	P	A	Q
E_2 Post	86	106.00	105.50	100.00	87.00
C_1 Post	80	107.00	107.50	95.00	89.00
U		7069.0	6913.0	7798.0	6950.0
Z		-1.001	-0.999	3.000	-1.001
P		0.719	0.387	0.046*	0.457

* Z significant at $p \leq 0.05$

The results in Table 37 show that there was a significant increase in the mean score for Application (A). There were also decreases in the mean scores for Recall (R), Principles (P) and Questioning (Q). Apart from the decrease in the mean score for Q (which is the reverse of what was expected), all the other changes were as expected. The null hypothesis was, therefore, rejected for Application (A) and could not be rejected for R, P and Q.

Table 38 shows an estimation of the effect of the treatment by comparing the experimental group (E2) posttest scores with the control group (C2) posttest scores. The comparison also indirectly assesses the effect of the pretest. Both groups did not take the pretest but the experimental group (E2) had the treatment. Thus, if the treatment was effective, then the scores of the experimental group should evidently be greater than the scores of the control group.

Table 38: Comparison of Cognitive Style Mean Ranks of Experimental Posttest (E2 Post) with Scores of Control Posttest (C_2 Post)

	N	Cognitive Styles			
		R	P	A	Q
E_2 Post	86	106.00	105.50	100.00	87.00
C_2 Post	78	106.00	106.00	99.00	90.00
U		7181.5	7370.5	7230.0	6580.5
Z		0.001	1.000	0.000	-3.000
P		0.889	0.449	0.765	0.069

The results in Table 38 show that there was no significant difference between E2 and C2 posttest scores on all cognitive style modes. However, there was a decrease in the Q-score, a slight increase in the A-score and a slight decrease in the P-score. No change whatsoever occurred in the mean score for R. The changes in P and A (though negligible) were as expected but the change in Q was the reverse of what was expected. On the basis of the results, hypothesis 6 could not be rejected for all four cognitive style modes.

Table 39 shows the effect of the treatment by comparing the experimental group (E2) posttest scores with the control group (C1) pretest scores. This comparison also serves to reconfirm the effect of testing on the control group. E2 posttest scores should clearly be greater than C1 pretest scores, if the treatment was effective and the effect of testing was removed. Since the experimental group (E2) did not take the pretest but had the treatment before the posttest, any difference between E2 and C1 should probably be due to the effect of the treatment.

Table 39: Comparison of Cognitive Style Mean Ranks of Experimental Posttest (E2 Post) with Control Pretest (C1 Pre)

	N	Cognitive Styles			
		R	P	A	Q
E2 Post	86	106.00	105.50	100.00	87.00
C1 Pre	80	106.00	113.00	96.00	83.50
U		7212.5	6089.0	7612.0	7965.5
Z		-0.001	-6.999	3.000	5.001
P		0.9202	0.0004*	0.1641	0.0113*

* Z significant at $p \leq 0.05$

The results in Table 39 show that there was a significant decrease in the scores from C1 to E2 for Principles (P) and a significant increase in the scores from C1 to E2 for Questioning (Q). There was also an appreciable increase in the score for Application (A) but the increase was not statistically significant. No change occurred in the scores for Recall (R). It is noteworthy that the changes in P, A and Q were all in the directions expected. Hypothesis 6 was accordingly rejected for Principles (P) and Questioning (Q) but could not be rejected for Recall (R) and Application (A).

In order to determine the effect of pretesting comparisons were made among sub-groups of those students who had the pretest and those who did not have the pretest.

Table 40 shows the effect of pretesting by comparing the pretest and posttest scores of the control group (C1). If the pretest had any residual effects, it should be evident in the differences between the pretest and posttest scores of this sub-group on R, P, A and Q.

Table 40: Comparison of Cognitive Style Mean Ranks of Control Pretest (C1 Pre) with Control Posttest (C1 Post)

		Cognitive Styles			
	N	R	P	A	Q
C1 Pre	80	106.00	113.00	96.00	83.50
C1 Post	80	107.00	107.50	95.00	89.00
U		6350.0	7176.5	6555.0	5554.0
Z		-1.000	5.001	1.001	-6.000
P		0.760	0.012*	0.696	0.003*

* Z significant at $p \leq 0.05$

The results obtained in Table 40 indicate that there was a significant decrease in the mean values of P and a significant increase in the mean value of Q. There was also an increase in the mean value of R and a decrease in the mean value of A but the changes were not statistically significant at 0.05 level of significance. The results suggest that the cognitive styles affected most by the pretest were Principles (P) and Questioning (Q).

Table 41 compared the experimental group (E1) and the control group (C2) posttest scores. E1 had both the pretest and the treatment while C2 had neither the pretest nor the treatment. Thus any differences in cognitive style scores would probably be due to the combined effect of the pretest and the treatment, if both were effective.

Table 41: Comparison of Cognitive Style Mean Ranks of Experimental Posttest (E1 Post) with Control Posttest (C2 Post)

	N	Cognitive Styles			
		R	P	A	Q
E1 Post	82	103.00	105.00	98.00	92.00
C2 Post	78	106.00	106.00	99.00	90.00
U		6046.5	6433.0	6635.0	6709.0
P		-2.002	0.000	0.999	0.999
Z		0.106	0.767	0.697	0.521

The results show that there were decreases in the mean values of R, P and A while the mean value of Q increased. None of the differences in scores, however, was statistically significant at the 0.05 level of significance. The results suggest that the combined effect of pretest and treatment produced more questioners and fewer recallers, principlers and appliers among the students who participated in the study.

Table 42 shows the comparison of the posttest scores of the experimental sub-groups E1 and E2. E1 had the pretest and the treatment while E2 had only the treatment but no pretest. Therefore, any differences in cognitive style mean scores were likely to be due to effect of pretesting alone.

Table 42: Comparison of Cognitive Style Mean Ranks of Experimental Posttest (E1 Post) with Experimental Posttest (E2 Post)

	N	Cognitive Styles			
		R	P	A	Q
E1 Post	82	103.00	105.00	98.00	92.00
E2 Post	86	106.00	105.50	100.00	87.00
U		6275.0	6496.0	6831.0	7554.0
Z		-3.001	-0.999	0.001	3.999
P		0.091	0.325	0.932	0.016*

* Z significant at $p \leq 0.05$

The results of the comparison show that there was a significant increase in the mean value of Q. The mean values of R, P and A decreased but the decreases were not statistically significant at the 0.05 level of significance. This implies that the main effect of the pretest was to produce more questioners and less recallers, principlers and appliers.

Table 43 portrays the effect of pretesting by comparing the posttest scores of the control sub-groups C1 and C2. C1 had the pretest but C2 had no pretest. If the pretest had any effect, it would be reflected in the differences in the cognitive style scores of the two sub-groups.

Table 43: Comparison of Cognitive Style Mean Ranks of Control Posttest (C1 Post) with Control Posttest (C2 Post)

	N	Cognitive Styles			
		R	P	A	Q
C1 Post	80	107.00	107.50	95.00	89.00
C2 Post	78	106.00	106.00	99.00	90.00
U		6534.5	6839.0	5858.5	6137.5
Z		0.999	3.000	-3.000	-1.999
P		0.644	0.131	0.062	0.367

The results in Table 43 indicate that the mean scores on R and P increased while the mean scores on A and Q decreased. However, none of the differences in scores was statistically significant at the 0.05 level of significance. The results in this case suggest that the pretest had the effect of raising the values of R and P while lowering the values of A and Q. This was the exact opposite of the effect expected of the experimental treatment and which it (the treatment) seems to have actually had on the cognitive styles of the students.

The summaries of the findings on the effects of the experimental treatment and the pretest on the cognitive styles of the students are presented in Tables 44 and 45 respectively.

Table 44: A Summary of the Findings on the Effect of Experimental Treatment on Students' Cognitive Styles

Paired Comparisons	Cognitive Styles			
	R	P	A	Q
E1 Pre and E1 Post	Decreased	Decreased *	Decreased	Increased
E1 Post and C1 Post	Decreased *	Decreased	Increased *	Increased
E2 Post and C1 Post	Decreased	Decreased	Increased *	Decreased
E2 post and C2 Post	No Change	Decreased	Increased	Decreased
E2 Post and C1 Pre	No Change	Decreased *	Increased	Increased

* Increase/Decrease significant at $p \leq 0.05$

Table 45: A Summary of the Findings on the Effect of Pretesting on Students' Cognitive Styles

Paired Comparisons	Cognitive Styles			
	R	P	A	Q
C1 Pre and C1 Post	Increased	Increased*	Decreased	Increased*
C1 Post and C2 Post	Increased	Increased	Decreased	Decreased
E1 Post and C2 Post	Decreased	Decreased	Decreased	Increased
E1 Post and E2 Post	Decreased	Decreased	Decreased	Increased*

* Increase/Decrease significant at $p \leqslant 0.05$

Table 44 shows that essentially the treatment caused the mean values of R and P to decrease and the mean values of A and Q to increase. In other words more students as a result of the treatment became critical questioners and appliers than recallers and principlers. This suggests that the treatment in general had the desired effect on respondents' cognitive styles. It seems, therefore, that the teacher-directed discussion (TDD) mode of instruction was effective in shifting students' cognitive styles from predominantly R and P to A and Q.

In addition, it is clear that the treatment had the most pronounced effects on P and Q, causing a highly significant decrease in the former and an equally highly significant increase in the latter. Hence it appears that the treatment

was specifically effective in shifting subjects' cognitive styles from predominantly principle-oriented to predominantly questioning-oriented.

Table 45 indicates that the most significant and marked effects of the pretest were on the Principles (P) and the Questioning (Q) styles. In the case of Principles the effect of pretest was in opposition to the effect of treatment. It seems, however, that the effect of treatment outweighed the effect of pretest as indicated by the results of the comparison of the posttest scores of sub-groups E1 and C2 (See Table 41).

In the case of the Questioning (Q) style the effects of both the pretest and the treatment were in the same direction, namely to increase the mean value of Q. This implies that the pretest aided the treatment in helping students to become critical questioners. The finding is in consonance with Ausubel's (1963) subsumption theory about advanced organisers and prior knowledge which was later extended by Gagne (1968) in his ideas about learning hierarchies or modes of knowledge acquisition in science.

Hypothesis 7

The teacher-directed discussion method of teaching (the experimental treatment) has no significant effect on the interest profiles of the subjects.

This hypothesis was tested by means of the same paired comparisons between groups in the experimental design as were carried out for hypothesis 6 using students' interest scores as measured by the IPI and the Mann-Whitney U test.

Table 46 shows the comparison of the pretest and posttest scores of the experimental group (E1). If the treatment was effective, then the posttest scores should be greater than the pretest scores.

Table 46: Comparison of Interest Mean Ranks of Experimental Pretest (E1 Pre) with Experimental Posttest (E1 Post)

	N	Physics Interests		
		T	A'	M
E1 Pre	82	211.50	97.00	94.00
E1 Post	82	214.00	95.00	95.00
U		6686.5	6762.0	6667.0
Z		-0.999	0.001	-0.001
P		0.902	0.901	0.851

The results of the comparison show that there were increases in the mean values of T and M and a decrease in the mean value of A'. None of the differences in mean scores was statistically significant. The increase in the mean value of T and the decrease in the mean value of A' were the reverse of what was expected from

the experimental treatment. Therefore, hypothesis 7 could not be rejected in respect of all the three modes of physics interest.

Table 47 shows the comparison of the experimental group (E1) with the control group (C1) posttest scores. If the treatment was effective, then E1 posttest scores should be higher than C1 posttest scores especially on A' and M. C1 posttest scores were expected to be approximately equal to C1 pretest scores, assuming that the effect of the pretest over the eight weeks period was negligible.

Table 47: Comparison of Interest Mean Ranks of Experimental Posttest (E1 Post) with Control Posttest (C1 Post)

	N	Physics Interests		
		T	A'	M
E1 Post	82	214.00	95.00	95.00
C1 Post	80	219.00	99.00	94.00
U		6232.0	6150.5	6349.5
Z		-6.002	-3.001	-2.000
P		0.267	0.166	0.476

The results of the analysis show that there were decreases in the mean values of T and A' and a slight increase in the mean value of M. None of the changes in mean values was statistically significant at the 0.05 level of significance.

The decrease in T value and increase in M were as expected. Thus hypothesis 7 could not be rejected for the three dimensions of physics interest.

Table 48 presents the comparison of the experimental group (E2) posttest scores and the control group (C1) posttest scores. If the treatment was effective, then E2 posttest scores should be higher than C1 posttest scores particularly on A' and M. The C1 group had the pretest but the E2 group had no pretest.

Table 48: Comparison of Interest Mean Ranks of Experimental Posttest (E2 Post) with Control Posttest (C1 Post)

		Physics Interests		
	N	T	A'	M
E2 Post	86	214.00	98.50	94.50
C1 Post	80	219.00	99.00	94.00
U		6926.0	6889.0	7022.5
Z		-3.999	-1.999	-1.000
P		0.411	0.346	0.610

The results in Table 48 indicate that none of the Z values was statistically significant at the 0.05 level of significance. This means that the differences between the E2 posttest and C1 posttest scores were not statistically significant. However, it was observed that there were decreases in the mean values

of T and A' and a small increase in the mean value of M. Again the drop in the mean value of T and the rise in the mean value of M were as expected. Therefore, the null hypothesis (hypothesis 7) could not be rejected at the 0.05 level of significance for all the three modes of physics interest.

The results of the comparison between the experimental group (E2) posttest scores and the control group (C2) posttest scores are presented in Table 49. This comparison also assesses the effect of the pretest. Both groups did not take the pretest but the experimental group (E2) had the treatment. Accordingly, if the treatment was effective, then the scores of the experimental group should evidently be greater than the scores of the control group.

Table 49: Comparison of Interest Mean Ranks of Experimental Posttest (E2 Post) with Control Posttest (C2 Post)

	N	Physics Interests		
		T	A'	M
E2 Post	86	214.00	98.50	94.50
C2 Post	78	156.00	68.00	63.00
U		10073.5	10310.5	10276.5
Z		57.9983	30.9990	30.9998
P		0.0000*	0.0000*	0.0000*

* Z significant at $p \leq 0.05$

The results in Table 49 show that the Z values for the three interest modes T, A' and M were all significant at the 0.05 level of significance. Thus, the observed increases in the mean values of T, A' and M were all statistically significant at the 0.05 level of significance. The increases in the values of A' and M were as expected but the gain in T was the reverse of what was expected. Therefore, hypothesis 7 was rejected for all the three modes of physics interest.

Table 50 shows the effect of the treatment by comparing the experimental group (E2) posttest scores with the control group (C1) pretest scores. The comparison also serves as a further confirmation of the effect of the pretest on the control group. If the treatment was effective, then E2 posttest scores should evidently be greater than C1 pretest scores with the effect of testing removed. Since the experimental group (E2) did not take the pretest but had the treatment before the posttest, any difference between the scores of E2 Post and C1 Pre was likely to be due to the effect of the treatment.

Table 50: Comparison of Interest Mean Ranks of Experimental Posttest (E2 Post) with Control Pretest (C1 Pre)

	N	Physics Interests		
		T	A'	M
E2 Post	86	214.00	98.50	94.50
C1 Pre	80	213.50	96.50	95.00
U		7300.5	7318.5	7206.0
Z		2.001	1.000	0.001
P		0.701	0.658	0.937

The results of the analysis as presented in Table 50 show that there was a slight increase in the mean value of T, an appreciable increase in the mean value of A' and a small decrease in the mean value of M. None of the Z values was statistically significant implying that none of the stated differences in the values of T, A' and M was statistically significant at the 0.05 level of significance. The changes in T and M were the reverse of what was expected. Therefore, hypothesis 7 could not be rejected for all the three modes of physics interest at the 0.05 level of significance.

In order to determine the effect of pretesting on the interest orientations of the subjects, comparisons were again made among the sub-groups of students who had the pretest and those who did not have the pretest.

Table 51 shows the effect of pretesting on the respondents' physics interests by comparing the pretest and posttest scores of the control group (C1). If the pretest had an effect, it should be reflected in the differences between the pretest and posttest scores of this sub-group on T, A' and M.

Table 51: Comparison of Interest Mean Ranks of Control Pretest (C1 Pre) with Control Posttest (C1 Post)

	N	Physics Interests		
		T	A'	M
C1 Pre	80	213.50	96.50	95.00
C1 Post	80	219.00	99.00	94.00
U		6117.0	6097.0	6275.0
Z		-6.003	-3.001	-1.001
P		0.271	0.243	0.575

The results in Table 51 show that there were no significant differences between the pretest and posttest scores of the control (C1) sub-group at 5 percent level of significance. However, there were appreciable increases in the mean values of T and A' and a small decrease in the mean value of M. The results suggest that interest in physics topics (T) was most affected while interest in motives for learning physics (M) was least affected by pretesting.

Table 52 compared the posttest scores of the experimental group (E1) and the control group (C2). E1 had both the pretest and the treatment while C2 had neither the pretest nor the treatment. Accordingly, any differences in interest scores were likely to be due to the combined effect of the pretest and the treatment, that is if the pretest was effective.

Table 52: Comparison of Interest Mean Ranks of Experimental Posttest (E1 Post) with Control Posttest (C2 Post)

	N	Physics Interests		
		T	A'	M
E1 Post	82	214.00	95.00	95.00
C2 Post	78	156.00	68.00	63.00
U		9336.5	9481.5	9445.5
Z		55.9999	30.0009	30.9997
P		0.0000*	0.0000*	0.0000*

* Z significant at $p \leq 0.05$

The results show that the differences between the scores on all three modes of interest T, A' and M were statistically significant at 0.05 level of significance. There were increases in the mean values of the three modes of interest. The results suggest that the pretest was effective in raising the level of physics interest in all the three dimensions. It was also observed that the most marked effect of the pretest was again on T while A' was the least affected mode.

Table 53 presents the comparison of the posttest scores of the experimental sub-groups E1 and E2. E1 had the pretest and the treatment while E2 had only the treatment but no pretest. Thus, any differences in interest scores were likely to be caused by the pretest effect.

Table 53: Comparison of Interest Mean Ranks of Experimental Posttest (E1 Post) with Experimental Posttest (E2 Post)

	N	Physics Interests		
		T	A'	M
E1 Post	82	214.00	95.00	95.00
E2 Post	86	214.00	98.50	94.50
U		6634.5	6602.0	6747.5
Z		-3.001	-1.001	0.000
P		0.588	0.519	0.858

The results of the comparison show that no change occurred in the mean value of T, there was a decrease in the mean of A' while the mean value of M increased by a small amount. No significant differences were obtained between the scores on all three modes of interest at the 0.05 level of significance. This means that the pretest had no effect on T, little or no effect on M and an appreciable but non-significant effect on A'.

Table 54 shows the effect of testing by comparing the posttest scores of the control sub-groups C1 and C2. C1 had the pretest but C2 had no pretest. If the pretest was effective, it would be manifested in the differences in interest mean scores of the two sub-groups.

Table 54: Comparison of Interest Mean Ranks of Control Posttest (C1 Post) with Control Posttest (C2 Post)

	N	Physics Interests		
		T	A'	M
C1 Post	80	219.00	99.00	94.00
C2 Post	78	156.00	68.00	63.00
U		9115.5	9436.0	9304.0
Z		61.9976	32.9993	31.9993
P		0.0000*	0.0000*	0.0000*

* Z significant at $p \leq 0.05$

The results of the analysis indicate that the mean values in all the three modes of interest T, A' and M increased and that all the increases were statistically significant at the 0.05 level of significance. The results again suggest that the pretest was effective in raising the level of interest in each of the three interest modes. It was also further observed that the most pronounced effect of pretest was on T, interest in physics topics.

Tables 55 and 56 present the summaries of the findings on the effects of the experimental treatment and the pretest respectively.

Table 55: A Summary of the Findings on the Effect of Experimental Treatment on Students' Interests

Paired Comparisons	Physics Interests		
	T	A'	I
E1 Pre and E1 Post	Increased	Decreased	Increased
E1 Post and C1 Post	Decreased	Decreased	Increased
E2 Post and C1 Post	Decreased	Decreased	Increased
E2 Post and C2 Post	Increased*	Increased*	Increased*
E2 Post and C1 Pre	Increased	Increased	Decreased

* Increase significant at $p \leq 0.05$

Table 56: A Summary of the Findings on the Effect of Pretesting on Students' Interests

Paired Comparisons	Physics Interests		
	T	A'	M
C1 Pre and C1 Post	Increased	Increased	Decreased
E1 Post and C2 Post	Increased*	Increased*	Increased*
E1 Post and E2 Post	No Change	Decreased	Increased
C1 Post and C2 Post	Increased*	Increased*	Increased*

* Increase significant at $p \leq 0.05$

Table 55 shows that the main effect of the treatment was to raise the mean values of the scores on the three modes of physics interest T, A' and M. There was no significant decrease of interest score in any of the three interest dimensions particularly the topic (T) dimension where a decrease in score was desired. This implies that the treatment raised the level of physics interest in all the three modes investigated but did not cause a shift from one interest mode to another.

Similarly Table 56 reveals that the main effect of pretesting was also to raise the level of physics interest in all the three interest dimensions T, A' and M. The results suggest that the pretest enhanced the effect of the treatment in raising the levels of students' interests in physics thus

lending further support to Ausubel's (1963) view of the importance of prior knowledge as advanced organisers in meaningful learning.

It seems that in the present study the pretest provided the "previous knowledge" which served as suitable "cognitive structure" or "advanced organisers" that enabled the learner to

(i) exhibit a higher cognitive style such as Application (A) or Questioning (Q);

(ii) portray a higher level of interest in physics.

The implication is that learners who do not have such advanced organisers would find it difficult to develop such "superior" cognitive styles or higher levels of science interest.

4.3 Discussions

The first research problem of the present study was to identify the pattern of distribution of cognitive styles among the subjects and hence to find out if there were any group differences in cognitive style among the subjects at the time they were entering into the predegree programme of the Federal University of Technology, Minna.

The results in Table 6 show that at entry into the predegree programme, the distribution pattern of the students' cognitive styles in physics was P- R- A - Q. This general order of cognitive styles means that the Principles (P) and Recall (R) styles are more dominant among the physics students than Application (A) and Questioning (Q). Similar patterns had been obtained in earlier studies for different samples of science learners in Nigeria, although in some cases Recall (R) rather than Principles (P) was shown to be the most dominant of the four cognitive styles (Shuaibu and Ogunsola-Bandele, 1983; Okebukola, 1984/85; Omoifo, 1986; Ogunsola-Bandele, 1987 and Abah, 1988). This finding is in consonance with the results of other studies in Nigeria which had reported the predominance in Nigerian secondary schools of teaching styles that are more disposed towards the nurture of recall and memorization skills (Bajah, 1975; Agwari, 1978; Shuaibu, 1979 and Attah, 1981).

In more specific terms, however, the order of cognitive styles (as obtained from Table 6) indicates that the most dominant style among the students was Principles (P) while Questioning (Q) was the least. This is in agreement with Abah's (1988) finding for different samples of students studying physics and biology at the secondary, predegree and undergraduate levels of education in Zaria area of Kaduna State, Nigeria. For biology students at the three levels the same order of cognitive styles was obtained, namely P- A- R- Q. For the secondary and

predegree physics students the order was P- R- A- Q while the pattern was P- R- Q- A for the cognitive styles of undergraduate physics students. Omoifo (1986) obtained the pattern P-R-A-Q for the cognitive styles of a sample of SBS biology students at Ahmadu Bello University, Zaria. Physics and biology students in Nigeria seem generally to resemble Israeli high school children who had a cognitive style pattern of P-R-A-Q (Tamir and Kempa, 1978).

In the case of Nigerian chemistry students at the secondary, predegree and undergraduate levels the same order (R- P- A- Q) of cognitive styles has been identified (Shuaibu and Ogunsola, 1983; Omoifo, 1986 and Abah, 1988). It seems that in Nigeria physics and biology learners are predominantly principlers while chemistry students are mostly recallers. It is reasoned that this observed difference in the most dominant cognitive style among Nigerian physics and biology students on the one hand and their chemistry counterparts on the other may be attributed to the nature of the science disciplines in question. Unlike physics and biology, chemistry by nature is made up of a knowledge content comprising a myriad number of symbols, formulas, terms, specific facts and relationships, reaction equations, and so on which requires a lot of rote learning and memorization for effective grasp.

The patterns of distribution of cognitive styles of subjects as shown in Table 6 also suggest the equivalence in cognitive styles of the groups of students at the start of the experiment. This was confirmed by the results of the analysis presented in Table 7 which were used to test hypothesis 1(a) of the present study. The Mann-Whitney U test showed no significant differences (at the 0.05 level of significance) in the cognitive style mean scores of students in the experimental (E1) and control (C1) groups on the pretest.

The second research problem had to do with the pattern of distribution of interest orientations of the subjects and the equivalence of the experimental and control groups of students with respect to physics interests at the start of the experiment.

Table 8 shows that at entry into the predegree course the general order of distribution of students' physics interests was T-A'-M. This means that students' interests was highest in physics topics and lowest in motives for studying physics. The result is probably another reflection of the dominance in Nigerian schools of teaching styles oriented more towards the exposition of science facts and principles rather than towards the teaching of science process skills or the social roles of the scientific enterprise.

The results in Table 9 confirm the equivalence of the experimental and control groups with respect to the physics interests of subjects at the point of entry into the predegree course. The Mann-Whitney U test which was used to test hypothesis 1(b) revealed no significant differences in interest between the experimental and the control groups of students who took the pretest.

The third and fourth research questions were concerned with the identification of differences in the cognitive styles and physics interests of subjects in relation to their gender, age and future career aspirations. Hypothesis 2(a) which states that there are no significant differences in cognitive style between male and female students that participated in the study could not be rejected at 0.05 level of significance (See Table 11). It was concluded that there were no gender differences in cognitive style among the students who took part in the study. This result is in agreement with earlier findings by Tamir and Kempa (1977), Shuaibu and Ogunsola (1983) and Joe (1983). Table 10 actually shows that females scored higher than males in P and R while male students scored higher in A and Q than their female counterparts but the differences (as shown in Table 11) were not statistically significant beyond the 0.05 level of significance. This researcher did not come across any study on cognitive styles in Nigeria which reported significant gender differences in the cognitive styles of subjects.

So far it is only among Israeli children that any meaningful sex-related differences in cognitive styles have been observed. Tamir (1975) found that male students in a sample of 989 Israeli 12th grade biology students (468 males and 521 females) showed higher preference for Q and A while female students had higher preference for P. The study also revealed significant interactions between gender and type of curriculum studied. The results suggested that the type of curriculum studied affected female students' cognitive styles more than that of the males. In another study Tamir and Kempa (1978) investigated the cognitive styles of a sample of Israeli 10th graders (N = 599) across three science disciplines of physics, chemistry and biology. The results of the study revealed only two sex-related differences in cognitive style, namely: boys had a higher P-score in physics than girls while girls had a higher P-score in chemistry than boys. In all other comparisons there were no significant differences. The two differences were considered by the authors to be rather small since three different science disciplines were involved. In Nigeria it does seem that gender exerts little or no influence on the cognitive styles of science learners.

Hypothesis 2(b) which states that there are no significant differences in physics interests between male and female students who participated in the study was rejected at 0.05 level of significance. It was, therefore, concluded that male and

female students differred significantly in the orientations of their physics interests. The results (See Tables 12 and 13) showed that:

(i) Male students scored consistently higher than female students in all three modes of physics interest.

(ii) The order of physics interests was T - A' - M for both male and female students.

The results corroborate the findings reported by earlier studies (Gardner, 1974, 1985; Hasan, 1975 and Haussler, 1987). In summarizing the findings of such earlier studies Gardner (1985) had stated that "males are more likely to be interested in physics and technology, in understanding how things work and in learning practical skills". The low interest of females in technology is even reflected in the proportion of female students who enrolled in the predegree programme of MUT, Minna and who constituted the subjects for the present study. Of the 326 students who participated in the study, only 69 of them (21 percent) were females. The university offers only science and technology-based courses.

The order of physics interests shows that students' interests were greatest in physics topics and least in motives for studying physics. The same order of interests was obtained for the combined group of boys and girls (See Table 8) and shows that the order of students' interest orientations is independent of gender.

Hypothesis 3(a) states that there are no significant differences in cognitive styles between students of different ages who participated in the study. The results of data analyses to test the hypothesis (See Tables 15 and 16) show that hypothesis 3(a) could not be rejected at 0.05 level of significance. It was concluded that students of different ages who participated in the study did not differ significantly in their exhibition of cognitive styles in physics. The researcher did not come across any report of an earlier research study which investigated the relationship between cognitive styles and age. Tamir and Kempa (1978) examined the relationship between cognitive styles and grade level (or year in school) among a group of talented high school students in the United States. They found that students in higher grades on the average had lower preference scores for R and higher preference scores for P. The results of the present study suggest that cognitive styles are independent of age.

The results of the analyses also indicate that 85.8 percent of the students were between 18 and 22 years of age while about two-thirds of the students (67.3 percent) were between 19 and 21 years. This suggests that most of the students were fresh school leavers who had just completed their School Certificate courses. The sample may, therefore, be said to be relatively homogeneous with respect to age. It is also noted that the general order of cognitive styles (P-R-A-Q) was the same for students of different age groups.

Hypothesis 3(b) states that there are no significant differences in physics interests between students of different ages who participated in the study. The results of the data analyses used to test this hypothesis as presented in Tables 18 and 19 show that the hypothesis was partially rejected in respect of motives (M) for studying physics but could not be rejected in respect of physics topics (T) and activities for learning physics (A'). It was concluded that students of different age groups differred significantly in their interests in motives for studying physics but did not differ significantly in their interests in physics topics and activities for learning physics. The age group with the largest number of students (the 19-21 years group) had the highest M-score followed by the 22-24 years group while the yongest age group (the 16-18 years group) had the least M-score.

Although no significant differences in interest were identified between students of different ages in respect of T and A', the following general patterns which emerged from the data analyses are noteworthy:

(i) The general order of interest profiles, T-A'-M, was the same for all age groups. This shows that each age group had their highest interest in physics topics and their least interest in motives for studying physics.

(ii) Interest in physics initially increased between 16 and 21 years but tended to dwindle between 21 and 27 years as students got older. This trend has been reported in earlier studies and seems to be sharper in physics and chemistry than in biology (Gardner, 1985; Haussler, 1987). In many countries and for many students science appears to be a subject that is initially liked but which later comes to be disliked and discontinued.

Ahlgreen (1969) had sought to explain this decline of science interest with age by means of the colourful *analogy of the "seven-course meal effect":* one enters the restaurant but after a massive dinner, one's hunger is satisfied and food becomes less appealing. One, however, wonders why the seven-course meal effect should be applicable to science subjects alone (particularly physics and chemistry) and not to all school subjects. Gardner (1985: 17) has pointed out that the analogy (though ingeniously conceived) would have applied to all school subjects if it were valid.

Hypothesis 4(a) which states that students in the four groups of the experimental design who aspire to different careers in science and technology do not exhibit significantly different cognitive styles could not be rejected at 0.05 level of significance. All the calculated Kruskal-Wallis H values were less than the critical value at the 0.05 level of

significance (See Table 22). This means that students' future career expectations were not influenced by their cognitive styles in physics. Tamir and Kempa (1977) had found some significant relationships between the cognitive styles of first year college students in Israel and Canada and their career expectations. Medical students who would like to work in clinics tended on the average to be highest in R and lowest in Q thereby possessing a negative Q-R mean score. Those aiming at teaching and university careers had the highest Q-R score.

Kempa and Dube (1973b) had proposed two cognitive style scales, namely: the R-Q curiosity scale representing measures of a person's scientific curiosity or his commitment to the learning of science and the A-P or scientific utilization scale measuring an individual's vocational science orientation towards "pure science" or "applied science". A high R and a low Q implies a low score on the scientific curiosity scale. Similarly a high P and low A indicates an inclination towards "pure science" while a low P and high A points to a leaning towards "applied science".

Abah (1988) found that pure and applied science undergraduates offering physics courses at A.B.U., Zaria during the 1986/87 academic session differed significantly on P and A but not on R and Q. The pure science undergraduates were more inclined towards Principles (P) and less inclined towards Application (A) than the applied science undergraduates as would be expected.

In the present study, although the differences were not statistically significant, it should be noted that the results have suggested that students who aspired to careers in engineering scored (i) highest in A and lowest in P and

(ii) high in R and lowest in Q. This implies that this group of students had a strong orientation towards "applied science" but had a low score in the curiosity (R-Q) scale as expected. On the other hand, students hoping to take up careers in computer science were low on the R-Q scale and were inclined towards "pure science". They had the highest R-score and low Q-score, highest P-score and least A-score.

The group classified as "others", i.e. those students aspiring to careers other than engineering and computer science also had the least R-score and the highest Q-score which implies a high mean score on the curiosity scale. They were also low in A and high in P, indicating an orientation towards "pure science". This group, it should be recalled, included students who hoped to become academicians, nuclear physicists, biologists, microbiologists, geophysicists and so on. It is, therefore, noted that, although they were not statistically significant, the relationships between cognitive styles and career expectations of subjects were in the directions expected and reconfirmed Kempa and Dube's (1973b) scientific curiosity (R-Q) and scientific utilization (A-P) scales.

Hypothesis 4(b) which states that students in the four groups of the experimental design who aspire to different careers in science and technology do not exhibit significantly different physics interests was accepted at 0.05 level of significance. None of the

H values of the Kruskal-Wallis test was significant at the 5 percent level of significance (See Table 25). This suggests that students' career expectations did not depend on their physics interests. However, the results of the analysis presented in Table 24 show that:

(i) Students who were aspiring to careers in engineering had the highest mean interest score on all three modes of physics interest T, A' and M. This is not surprising since (just like mathematics) physics is a strong prerequisite subject for enrolment into a course in engineering. Students with low interest in physics are not likely to seek enrolment or to fare well in courses leading to the engineering profession.

(ii) Students expecting to take up careers in computor science had the lowest mean scores in interest in physics topics (T) and interest in motives for studying physics (M). This is also as should be expected since computer science requires prospective entrants to be mainly proficient in mathematics. Physics is hardly a requisite subject either for entry into the profession or for taking up courses leading to the profession.

(iii) The proportion of students expecting to take up careers in engineering and computer science constituted 83.3 percent (135 out of 162) of the total sample of students studied. Being a university of technology the Federal University of Technology, Minna offers only applied science or technology courses. Students who apply for admission into the university (even into the predegree programme of the university) would be those who are from the outset interested in applied science courses such as engineering and computer science.

(iv) The order of physics interests was T-A'-M for the groups of students aspiring to be engineers and computer scientists. For students hoping to enter into other occupations the pattern of distribution of physics interests was T-M-A' showing that all the career groups had their highest level of interest in physics topics (T).

The fifth research question had to do with the identification of relationships between cognitive styles and physics interests of the subjects. The prospects of predicting learners' cognitive styles through knowledge of their physics interests (or vice versa) seem rather low. Pearson product-moment correlations between

overall cognitive style mean scores and overall interest mean scores (Table 26) show that only interest in activities for learning physics (A') correlates significantly with the Application (A) cognitive style ($r = 0.168$). Except for the appreciably strong but non-significant correlation ($r = -0.131$) between interest in motives for studying physics (M) and the Principles (P) style, all other correlations were weak.

The low correlations between R, P cognitive styles and T interest mode are rather surprising. High mean scores in R and P are expected to be congruent with high interest in physics topics (T) but this does not seem to be supported by the data of the present study.

However, more significant correlations were obtained when cognitive style scores in different physics topics were correlated with the scores in the various sub-dimensions of the three main dimensions of physics interest investigated. Table 27 shows that R_3 (recall style in optics) was significantly and negatively correlated with T, T4, T6 and T7 and also reasonably and negatively (though not significantly) correlated with T1 and T5. This suggests that students who are low in R in optics are likely to have high interest in learning physics generally and particularly in studying mechanics, electricity, magnestism, waves and sound. The result is interesting and instructive and has useful implications for physics teaching and curriculum development. One such implication is that teaching optics in

a way that discourages recall and memorization among learners is likely to promote (among the students) the development of high interest in (i) physics generally, and (ii) mechanics, electricity, magnetism, waves and sound specifically. This seems to provide a useful short-cut to a much desired pedagogical outcome, a sort of "killing so many birds with a single stone"!

The correlation matrix in Table 28 reveals no statistically significant correlations at 0.05 level of significance. However, the reasonably strong but non-significant correlations between (a) P_1 and T_7, and (b) P_4 and T_2 again suggest that teaching mechanics in such a way as to promote the development of low preference for Principles (P) and electricity in such a way as to further the development of high preference for Principles (P) would promote high interests in sound and heat respectively.

The results in Table 29 show that a learner who is high in Application (A) in physics generally and optics (A3) specifically is likely to have high interest in electricity (T_4). Similarly students who have high interest in optics (T_3) are likely to be low in Application (A_1) in mechanics while learners who have high interest in waves (T6) are likely to be high in Application (A3) in optics and low in Application (A5) in magnetism.

Table 30 shows only two significant and positive correlations: Questioning in heat (Q2) with interest in optics (T3) and Questioning in sound (Q7) with interest in heat (T2). Six other reasonably high but non-significant correlations (three positive and three negative) are as indicated in the table. The correlations imply that:

(i) Students who are low in questioning in either mechanics (Q1) or electricity (Q4) are more likely to have high interest in heat (T2).

(ii) Students who are strongly inclined towards questioning in heat (Q2) are likely to be highly interested in electricity (T4) specifically and physics (T) generally.

(iii) Whereas a critical questioner in optics (Q3) is likely to have high interest in sound (T7), a critical questioner in electricity would tend to have low interest in magnetism!

Table 31 reveals significant negative correlations between R3 (recall style in optics) and A', A'_1 and A'_3. The results here are similar to what was obtained in Table 27 and suggest that non-recallers in optics are likely to have high interest in activities for learning physics generally and specifically in learning physics by reception and in engaging in higher

cognitive operations in physics. In all these cases OPTICS stands out among all branches of physics as an area teachers need to take good care of how they handle in real classroom situations. It seems that the way OPTICS is taught might influence numerous dimensions and sub-dimensions of learners' interests in physics.

The non-significant but appreciably strong correlations between R_5 (recall style in magnetism) and A'_1 (interest in reception learning) suggests that recall style in magnetism has a similar but weaker relationship with interest in learning physics by reception as does recall style in optics.

Results in Table 32 indicate that only two correlations are statistically significant, namely, the negative correlation of (i) P_1 (principles style in mechanics) with M_2 (interest in physics-related careers), and (ii) P_7 (principles style in sound with A'_2 (interest in learning physics "by doing"). Seven other reasonably high but non-significant correlations were also revealed as indicated.

The negative correlation between P_1 and M is shown to be more specifically focussed on M_2 and suggests that students who are low on fundamental principles (P) in mechanics are likely to be highly interested in physics-related careers.

The negative relationship between A'_2 (interest in learning physics "by doing") and the Principles (P) style in physics is shown in more specific terms as the significant correlation between A'_2 and P_7 (principles style in sound) and the weaker non-significant relations of A'_2 with P_4 (principles style in electricity) and P_5 (principles style in magnetism). The seeming apathy of principlers towards learning physics "by doing" is to be expected since students who are high in P would tend to lean more towards "pure science" rather than show keen interest in the practical or scientific uses of physical knowledge.

The suggestion that students who are highly motivated to study physics because of its social importance are unlikely to focus on fundamental principles in learning or dealing with knowledge content in the area of heat is instructive. More research is required to investigate and to understand more clearly the relationship of the Principles (P) style with the various dimensions and sub-dimensions of interest in a science subject such as physics. It should be recalled that no statistically significant correlations were obtained between the Principles (Pi) style and the interest (Ti) in different physics topics (See Table 28).

Table 33 revealed a number of significant correlations between the Application (Ai) style and the interest (Ai; Mi) sub-modes.

The positive and significant correlation between A1 and M, M2 implies that students whose predominant cognitive style in mechanics is application would in general be highly motivated to learn physics and specifically tend to study physics because of the prospects of taking up physics-related careers in the future. A similar but non-significant relationship between A1 and M1 was also indicated. This means that physics teachers should focus not merely in making students "non-principlers" (See Table 32) but specifically in making them "appliers" in the area of mechanics in order to nurture high interest in M (motives for learning physics) generally and M1 (social aspects of physics) and M2 (physics-related careers) specifically.

The strong, positive and significant relationships between A3 (application style in optics) and A', A'2 and A83 remind one of the following major relationships identified earlier:

(i) R3 (recall style in optics) negatively correlated with T, T1, T4, T5, T6 and T7 (Table 27);

(ii) A3 (application style in optics) positively correlated with T4 and T6 (Table 29);

(iii) R3 (recall style in optics) negatively correlated with A', A'1 and A'3 (Table 31).

The implication of all this for physics education is simple and clear, namely: physics teachers should discourage the nurture of the "recall" style (R) but rather emphasize or concentrate

on the nurture of the "application" style (A) in the teaching of OPTICS in order to promote high levels of learners' interests in various aspects of physics.

There is also an indication in Table 33 - in the relationship between A5 (application style in magnetism) and A', A'1 and A'2 - that students who are appliers in magnetism would tend to be highly interested in learning physics particularly by reception and to a lesser extent by doing.

The relationship between A and A' initially portrayed in Table 26 and amplified or further elucidated in Table 33 suggests that the relationship is specifically between A and A'2 on the one hand and between A and A'3 on the other, although these latter correlations were not statistically significant.

The Questioning (Q) cognitive style seems to offer little promise as a potential predictor of learners' interests in physics. No significant correlations were obtained between scores in critical questioning styles (Qi) and the sub-scores (A'i, Mi) on the activity and motive dimensions of interest respectively (Table 34). However, the relatively strong but non-significant relationship between Q2 (questioning style in heat) and M (motivation for learning physics) appears to be specifically directed on M1 (interest in social aspects of physics). It seems that a questioning style in heat is congruent with a strong interest in learning physics because of its social implications.

The sixth and last research question of the present study dealt with the modifiability of cognitive style profiles and interest orientations of subjects through the TDD method of teaching (the experimental treatment) employed.

The data analyses presented in Tables 35 to 39 were used to test hypothesis 6 which states that the teacher-directed discussion method of teaching (the experimental treatment) has no significant effect on the cognitive style distribution of the subjects. The effects of the pretest on subjects' cognitive styles are outlined in the data analyses shown in Tables 40 to 43. The summaries of the findings on the effects of experimental treatment and the pretest on students' cognitive styles are presented in Tables 44 and 45 in terms of the effects of treatment and pretest on particular cognitive styles of the experimental group relative to the cognitive styles of the control group.

Table 57 presents the summary of the findings on the effect of the experimental treatment on the cognitive styles of respondents in terms of the relative advantage of the experimental class (E) over the control class (C) as a result of the treatment. The aim in the study was to shift students' cognitive styles from predominantly P and R to A and Q and more specifically from P to Q. The advantage which was estimated in terms of difference in mean scores is considered positive

(E-C = +ve) if the difference implies change in the desired direction (that is, a decrease in the mean values of P and R and an increase in the mean values of A and Q) and negative (E-C = -ve) if the difference implies change is in the reverse of the expected direction. The advantage is nil or zero (E-C = 0) when there is no difference in the mean scores of the cognitive styles of the experimental (E) and control (C) groups.

Table 57: A Summary of the Findings on the Effect of Experimental Treatment on Students' Cognitive Styles

Paired Comparisons	Cognitive Styles			
	R	P	A	Q
E1 Pre and E1 Post	+ve	+ve*	-ve	+ve*
E1 Post and C1 Post	+ve*	+ve	+ve*	+ve
E2 Post and C1 Post	+ve	+ve	+ve*	-ve
E2 Post and C2 Post	0	+ve	+ve	-ve
E2 Post and C1 Pre	0	+ve*	+ve	+ve*

KEY

+ve means the treatment is effective in desired direction

-ve means the treatment is effective in the reverse of the expected direction.

0 means the treatment has no effect

* means the effect of treatment is significant at $p \leqslant 0.05$.

From the summaries in Tables 44 and 57 it is inferred that the TDD mode of instruction was effective in shifting the cognitive styles of subjects not only from P to Q but also from P, R to A, Q. Out of the five paired sub-group comparisons, the treatment had effect in the desired direction in three of the comparisons for the Recall (R) style and in one of those three cases the effect was statistically significant. In the remaining two cases, the treatment had no (zero) effect on the recall style. For the Principles (P) cognitive style the treatment was effective in the desired direction in all five cases and in two of the cases (E1 Pre compared with E1 Post scores and E2 Post compared with C1 Pre scores) the treatment effects were highly significant statistically ($p \leq 0.05$).

For the Application (A) cognitive style, it was only in one out of the five cases that the treatment effect was not in the desired direction and the difference in the said case was not statistically significant. In two of the four cases in which treatment effects were in the desired direction the differences in cognitive styles were statistically significant. Out of the five paired comparisons, it was only in two cases (E2 Post with C1 Post scores and E2 Post with C2 Post scores) that the treatment produced an effect in the reverse of the expected direction for the Questioning (Q) style and the effects were not statistically significant. In two out of the other three cases in which differences were in the desired direction, the treatment

effects were highly significant statistically ($p \leq 0.05$). The data have thus shown that it is possible to shift the cognitive styles of (physics) students from predominantly Principles (P) and Recall (R) to Application (A) and Questioning (Q) by means of the teacher-directed discussion (TDD) mode of instruction. More specifically the TDD method of teaching has been shown to be effective in moving students cognitive styles from predominantly Principles (P) to Questioning (Q).

The summary of the findings on the effects of pretesting (Table 45) suggest that the main effect of the pretest was to increase the mean values of the cognitive style. This effect was most pronounced (and statistically significant) on Principles (P) and Questioning (Q) thus enhancing the effect of treatment on Q but reducing the effect of treatment on P.

In a similar study Ogunsola-Bandele (1987) found convincing indications that cognitive styles of learners could be shifted from predominantly Recall (R) to Questioning (Q) by means of the Difining Issue Discussion (DID) mode of instruction. The present study has demonstrated in a more convincing manner that cognitive styles are modifiable. In particular it has shown that cognitive styles can be moved from predominantly P and R to A and Q using the teacher-directed discussion method of teaching. Perhaps the apparently more convincing results of the present study may not necessarily be due to the superiority of the

teacher-directed discussion over the defining issue discussion mode of teaching. The differences in results may be attributable to the disparity in the durations of the experimental treatments in the two studies. In Ogunsola-Bandele's study the treatment was given for only three weeks while in the present study the treatment was given for a period of eight weeks.

Hypothesis 7 which states that the teacher-directed discussion method of teaching (the experimental treatment) has no significant effect on the interest profiles of the subjects was tested by means of the data analyses shown in Tables 46-50. The effects of the pretest on students' physics interests are outlined in the data analyses presented in Tables 51-54. The summaries of the findings on the effects of the experimental treatment and the pretest on the physics interests of subjects are set out in Tables 55 and 56 respectively in terms of the effect of treatment and pretest on specific interest modes of the experimental group relative to those of the control group. Table 58 shows the summary of the findings on the effect of the treatment on students' physics interests in terms of the relative advantage of the experimental (E) group over the control (C) group as a result of the treatment.

The object (in the present study) was to shift learners' interests from predominantly T to A' and M. The treatment effect was considered positive (E-C = +ve) if the corresponding

difference or change in interest mean scores is in the desired direction (i.e. a decrease in T and an increase in A', M) but negative (E-C = -ve) if the corresponding difference in interest mean scores is in reverse to the expected direction.

Table 58: A Summary of the Findings on the Effect of Experimental Treatment on Students' Interests

Paired Comparisons	Physics Interests		
	T	A'	M
E1 Pre and E1 Post	-ve	-ve	+ve
E1 Post and C1 Post	+ve	-ve	+ve
E2 Post and C1 Post	+ve	-ve	+ve
E2 Post and C2 Post	-ve*	+ve*	+ve*
E2 Post and C1 Pre	-ve	+ve	-ve

KEY

+ve means the treatment is effective in desired direction

-ve means the treatment is effective in the reverse of the expected direction.

* means the effect of treatment is significant at $p \leq 0.05$

The summaries in Tables 55 and 58 indicate that the TDD mode of teaching was not effective in moving students' physics interests either in the desired direction (T to A', M) or in any other direction for that matter. Rather the instructional

mode was effective in raising the mean values of interest scores on all three modes of physics interest, namely: Topic (T), Activity (A') and Motive (M).

The treatment was effective in the desired direction for the Topic (T) interest mode in only two out of the five cases of paired sub-group comparisons and in none of the two cases was the said effect statistically significant. In the remaining three cases the effect of treatment was in the reverse of the expected direction (i.e. increase in T) and in one of the three cases (E2 Post compared with C2 Post scores) the increase in T was highly significant statistically ($p \leqslant 0.05$). For the Activity (A') mode of interest, the treatment effect was in the desired direction in two out of the five paired comparisons and in one of these two cases (E2 Post compared with C2 Post scores) the effect was highly significant ($p \leqslant 0.05$). In none of the other three cases where treatment effect was in the opposite direction was the difference in interest scores statistically significant.

The treatment was effective in the desired direction in four out of the five cases of paired comparisons for the Motive (M) interest mode and in one of these four cases (E2 Post compared with C2 Post scores) the effect was again highly significant statistically ($p \leqslant 0.05$). In the remaining single case (E2 Post compared with C1 Pre scores) the effect was in the reverse direction and was not statistically significant.

It is, thus, evident that the experimental treatment was effective in producing significant gains in interest mean scores on all modes of interest but not in shifting the interests from one mode to another. The result is an eloquent vindication of the assertion by Sund and Trowbridge (1973) that a major advantage of the discussion method of teaching is that it "wells up the interest of the students" because they actually participate in the learning process.

The main effect of pretesting as clearly shown in Table 56 was (as in the case of cognitive styles) to increase the mean values of physics interests in all the three modes investigated thus playing the Ausubelian prior knowledge role as "advanced organiser".

Chapter 5

SUMMARY, GENERALIZATIONS AND RECOMMENDATIONS

5.1 Introduction

In this final chapter the aims of the study, its design, procedure, results and conclusions are summarized. The generalizations arising from the study, the problems encountered and the limitations to the study are presented. The implications of the results of the study for science education in general and physics education in particular are discussed and the chapter then ends with some recommendations and a few suggestions for further research.

5.2 Summary and Conclusions

This study attempted to investigate the cognitive styles and physics interests of a group of postsecondary physics students. The subjects were predegree students of the Federal University of Technology, Minna, Niger State, Nigeria.

The purposes of the study were to

(i) ascertain the patterns of distribution of the cognitive styles and physics interests of subjects;

(ii) explore the dependence of cognitive styles and physics interests of subjects on gender, age and career expectations;

(iii) find out if cognitive styles of a physics learner is related to his/her physics interests; and

(iv) examine the possibility of shifting cognitive style profiles and interest orientations of subjects in a desired direction using the TDD method of teaching.

A 40-item physics cognitive style test (PCST) and a 105-item physics interest scale (IPI) each covering all but one (7 out of 8) major physics content areas were designed. The PCST followed the format suggested by Heath (1964) while the IPI followed the pattern proposed by Gardner (1985) and employed by Haussler (1987), Gardner and Toon (1988) and Gardner and Tamir (1989). These two instruments were validated by five secondary school teachers (face validity) and a panel of ten judges comprising physicists and science educators (content validity). A pilot study was carried out to test the instruments and estimate their reliability coefficients. The reliability of the PCST was 0.91 while that of the IPI was 0.99. The

reliability coefficients of the respective sub-scales of the two instruments were as follows: R = 0.85, P = 0.86, A = 0.86 and Q = 0.86 for the PCST sub-scales and T = 0.92, A' = 0.92 and M = 0.89 for the IPI sub-scales. These reliability coefficients were all statistically significant at 0.05 level of significance and were comparable to those reported in the literature in science education.

The class of 360 predegree physics students of the Federal University of Technology (FUT), Minna were randomly divided into two groups, an experimental and a control group. These two groups were further each sub-divided into two main sub-groups one of which was given the pretest. The arrangement conformed to the Solomon 4-way (pretest, posttest, control group) design as described by Campbell and Stanley (1963).

The following hypotheses were tested:

Hypothesis 1

1(a) There is no significant difference in the cognitive styles of the four groups of physics students in the experimental design using Heath's four-mode dimension (Recall, Principles, Application and Questioning) of cognitive style.

1(b) There is no significant difference in the physics interests of the four groups of students in the experimental design using the three-dimensional model (Topic, Activity and Motive) of interest proposed by Gardner (1985) and recently employed by Haussler (1987) and Gardner and Tamir (1989).

The Mann-Whitney U test showed that the Z values obtained for all cases of comparison of cognitive style and interest scores of the experimental and control groups' pretest scores were not statistically significant at the 0.05 level of significance. Hypotheses 1(a) and 1(b) were not, therefore, rejected. It was concluded that at the start of the experiment all the experimental and control groups in the research design were equivalent with respect to both cognitive styles and interests.

The general order of cognitive styles for the students was P-R-A-Q showing that in general terms subjects were more of principlers and recallers than appliers and critical questioners. In specific terms the most dominant single style among the students was Principles (P) while Questioning (Q) was the least dominant. Similarly the general order of orientations of physics interests among the students was T-A'-M implying that students' physics interests were highest in physics topics (T) and lowest in motives (M) for studying physics.

Hypothesis 2

2(a) There are no significant differences in cognitive styles between male and female students who participated in the study.

2(b) There are no significant differences in physics interests between male and female students who participated in the study.

The Mann-Whitney U test showed no significant difference at 0.05 level of significance between any of the pairs of cognitive style scores of male and female students. Hypothesis 2(a) could, therefore, not be rejected. It was concluded that male and female students who participated in the study did not differ significantly in their exhibition of cognitive styles. The order of cognitive styles was also found to be the same (P-R-A-Q) for male and female students.

The Mann-Whitney U test yielded significant differences at 0.05 level of significance in interest scores of male and female subjects for the three modes of interest. Hypothesis 2(b) was, therefore, rejected. It was concluded that male students differed significantly from their female counterparts in the orientations of their physics interests. Males were consistently more interested in physics than females in all the three modes of interest explored.

The proportion of females in the experimental and control groups that had the pretest was approximately 21 per cent, an additional evidence that females are less interested in physics than males.

The order of physics interests was the same (T-A'-M) for male and female students separately as for the combination of both males and females.

Hypothesis 3

3(a) There are no significant differences in cognitive styles between students of different ages who participated in the study.

3(b) There are no significant differences in physics interests between students of different ages who participated in the study.

The Kruskal-Wallis one-way analysis of variance (ANOVA) revealed no significant differences between the cognitive style mean ranks of students of different age groups. Hypothesis 3(a) was, therefore, not rejected. It was concluded that students of different age groups who participated in the study did not differ significantly in their exhibition of cognitive styles in physics.

The general order of cognitive styles remained P-R-A-Q for students of all age groups.

Similar analysis of interest mean rank scores for subjects of different age groups showed that there were significant differences in only the motive (M) dimension of physics interest at 0.05 level of significance. Therefore, hypothesis 3(b) was partially rejected in respect of M but could not be rejected in respect of T and A'. The inference was that the physics interests of students of different age groups differred only in respect of interest in motives for studying physics but not in terms of interest in physics topics or interest in activities for learning physics.

Generally students' interests in physics first increased between 16 and 21 years and then fell steadily between 21 and 27 years as students became older.

The general order of physics interests was T-A'-M for students of all age groups, each group scoring highest in T and lowest in M.

Two-thirds of the students (67.3 per cent) in the experimental and control groups who had the pretest were between 19 and 21 years while more than four-fifths (85.8 per cent) were between 18 and 22 years of age suggesting that most of the subjects for the study were fresh secondary school leavers who had probably just completed their School Certificate or G.C.E. O-level courses.

Hypothesis 4

4(a) Students in the four groups of the experimental design who aspire to different careers in science and technology do not exhibit significantly different cognitive styles.

4(b) Students in the four groups of the experimental design who aspire to different careers in science and technology do not exhibit significantly different physics interests.

The Kruskal-Wallis H test revealed no significant differences at 0.05 level of significance in either cognitive style of interest scores when different career groups were compared. Hypotheses 4(a) and 4(b) could not, therefore, be rejected. The results of

the analyses provided empirical support for the conclusion that respondents in the study who had different future career expectations in science and technology did not differ significantly either in their cognitive style profiles or in the orientations of their physics interests.

83.3 per cent of all the students pretested hoped to become either engineers or computer scientists in the future.

The general orders of cognitive styles and interests were the same for all career groups, viz: P-R-A-Q for cognitive styles and T-A'-M for physics interests.

Aspirants to careers in engineering had the highest scores in all the three modes of interest while those expecting to take up jobs in computer science had the lowest scores in virtually all the interest modes examined. Interest in engineering careers seems congruent with a high level of interest in physics. The reverse appears to be the case for those interested in computer-based occupations.

Hypothesis 5

There is no significant relationship between students' cognitive styles as measured by the PCST and their physics interests as measured by the IPI.

Significant values of the Pearson product-moment correlations between 0.160 and 0.236 at 0.05 level of significance (N = 162) were obtained when cognitive style and interest scores were

correlated. The results suggested that students' physics interests could be successfully predicted through knowledge of their cognitive styles. The specific relationships revealed by the analyses were noted.

Hypothesis 6

The teacher-directed discussion method of teaching (the experimental treatment) has no significant effect on the cognitive style distribution of the subjects.

The results of the analyses of data for testing the sixth null hypothesis lent support to the hope that cognitive styles are modifiable through training and hence are learnable and teachable. The results showed that it was possible to shift cognitive styles of physics learners from Principles (P) and Recall (R) to Application (A) and Questioning (Q) and more specifically from predominantly P to Q using the TDD method of instruction.

Hypothesis 7

The teacher-directed discussion method of teaching (the experimental treatment) has no significant effect on the interest profiles of the subjects.

The analyses of data for testing the seventh hypothesis showed that the experimental treatment (the TDD mode of teaching) was effective in consistently raising students' physics interests in all dimensions but did not produce a shift

from one interest mode to another. Despite the suggested relatedness of cognitive styles and physics interests, the data offer little promise that a shift in a learner's cognitive style would result in a corresponding shift in his/her physics interest. Perhaps the extent of shift in cognitive styles produced by the treatment was not sufficient to produce any corresponding shift in physics interests of the subjects.

5.3 Generalizations

Within the confines of the present study, the following generalizations may be made:

1. The most dominant cognitive style among the subjects of the study is Principles (P) while the least dominant is Questioning (Q). The general order of cognitive styles among the students was P-R-A-Q.
2. The subjects for the study portrayed the highest level of interest in physics topics (T) and the lowest level of interest in motives (M) for studying physics. The general order of physics interests among the students was T-A'-M.
3. No significant gender differences in cognitive style were found among the physics students.
4. Male students who participated in the study consistently demonstrated higher levels of physics interests than their female counterparts.
5. Cognitive styles of students who participated in the study were independent of their ages.

6. Students of different age groups differed only in their motivations (M) to study physics. Their interests in physics topics (T) and activities (A') for learning physics did not seem to be influenced by age.
7. Students between 19 and 21 years of age were the most highly motivated to study physics while those between 16 and 19 years were the least motivated.
8. Beginning from the age of 21 years the physics interests of the students declined steadily as students became older.
9. The cognitive styles and interest profiles of the physics students seemed unrelated to their future career expectations in science and technology.
10. Most of the students (over 80 per cent) enrolling into the predegree programme of the Federal University of Technology, Minna, seem to have their eyes on different aspects of engineering and computer science for their future careers.
11. The general orders of cognitive styles (P-R-A-I) and physics interests (T-A'-M) identified in this study were invariant with gender, age and future career expectations of the physics students.
12. Cognitive style profiles and interest orientations of the physics students correlated significantly and interestingly. There was a strong and rather attractive piece of evidence which suggests that high interest in different aspects of physics(notably in the topic (T) and activity (A')

dimensions) could be promoted among physics students if OPTICS is carefully taught in such a way as to nurture the Application (A) cognitive style.

13. There was a convincing support (from the results of the study) for the view that cognitive styles of learners are modifiable through teaching. In particular the teacher-directed discussion (TDD) method of teaching was found to be effective in moving the cognitive styles of the students from predominantly Principles (P) to Questioning (Q).

14. The TDD method of instruction (the experimental treatment in the study) was effective in raising the levels of physics interests of the subjects in all the three modes of interest explored but could not effect a shift from one interest mode to another as it did to the students' cognitive styles.

5.4 Problems and Limitations

The following problems encountered during the study and the concomitant limitations they caused to the research should be noted:

1. The subjects of the study were limited to a group of physics students in a single tertiary institution. The results of the study can, therefore, be hardly generalized

to larger populations of Nigerian physics students unless similar studies covering wider populations are undertaken.

2. At the experimental stage of the study the classroom teaching was done by the researcher himself. This exposed the researcher and the study to the temptation and danger of having the lessons conducted in such a manner as to achieve the desired results. The possibility of training other teachers to do the teaching was explored by the researcher but it was not logistically feasible given the circumstances and conditions prevailing in the physics department of FUT, Minna at the time of the research. Although the researcher took necessary steps to ensure that his personal biases did not influence the instructional process, the fact that only the researcher's word is available for this merely strengthens rather than weaken this shortcoming as a major limitation to the study.

3. Owing to a sudden change in the predegree admission policy of the FUT, Minna, about three times the usual number of students were admitted into the programme this particular academic session. Accordingly, the experimental class was too large for ideal inquiry lessons. Experiments and learning activities were performed in large groups (about 8 students per group). As a result it was not possible for the students to (i) perform as many such experiments and activities as were originally planned for them, and (ii) exhibit behaviours characteristic of inquiry learning.

4. The tendency for students to migrate from one group to another was observed. Perhaps the students concerned were those who missed the lessons for their group, or who wanted to compare notes out of curiosity or need to solve a genuine problem, or those who wanted to achieve better understanding of the knowledge content by sitting in at extra lessons. The researcher always insisted that such students should leave the group, often using appeals and other measures such as impromptu, short, written quizzes to achieve this objective. Nevertheless, it is still likely that a number of students might have succeeded in infilterating groups other than their own and this could have adverse effects on the results of the study.
5. Since all the students were located in the same environment they were likely to interact with each other after their lessons in a bid to exchange ideas and compare notes. The results of such interactions could have affected the general outcome of the study.
6. Some students in the control group who were taught by the lecture method kept complaining that the other group was performing experiments and learning activities during their lessons and expressed the desire to do the same. The researcher tried to reassure them but it was not certain that they were convinced and satisfied. Any feelings of discontent and unhappiness on the part of

such students was likely to some extent to affect their attitudes and responses and hence the results of the study.

7. Only two cognitive style items appeared in the PCST under "waves" (See Table 1, p. 145). It was relatively more difficult to write satisfactory items in this area of physics than in other areas. Of the six items written initially in this topic only the said two items reached at least 80% consensus among the experts who validated the research instruments. The researcher recognises that the fewness of the items may have affected the results of the study.

5.5 Implications

One of the secondary objects of this study was to determine the patterns of cognitive styles (Heath's model) and physics interests of a group of postsecondary or predegree physics students and, where applicable, to compare the patterns with those obtained in similar earlier studies. The subjects were the predegree students admitted into the FUT, Minna for the 1990/91 academic session. The results showed that the general order of cognitive styles for the subjects was P-R-A-Q. This general order was found to be invariant with gender, age and career aspiration. It was the same as the one obtained earlier by Abah (1988) for different samples of physics students at three different levels of education, namely: secondary, predegree and undergraduate levels.

The order of distribution of cognitive styles is also similar to the pattern found earlier for biology and chemistry students in other studies (Shuaibu and Ogunsola, 1983; Joe, 1983; Omoifo, 1986; Ogunsola-Bandele, 1987 and Abah, 1988). The cognitive style pattern suggests that the physics curricula and the methods of instruction employed in physics education in Nigeria are those more favourably disposed to the nurture of the Principles (P) and Recall (R) styles rather than Application (A) and Questioning (Q). It is not likely that the situation will change unless the issue is deliberately and firmly addressed by science educators, science teachers and curriculists.

The general order of the orientations of students' physics interests was found to be T-A'-M. The pattern reveals the dominance among the students of interest in physics topics (T) over interest in activities (A') for learning physics and motives (M) for studying physics, lending further support to the contention that the curricula and teaching styles in use are those that are rather traditional and expository in nature. Such curricula and teaching approaches favour the age-old practice of equipping students with scientific knowledge (rhetorics of conclusions) but not the process skills through which the knowledge is arrived at or the social usefulness of such knowledge to mankind.

The results of the study have again raised the question as to whether the strident calls of the last one and a half decades to de-emphasize traditional and expository methods of instruction in Nigerian schools and move increasingly towards the use of heuristic and inquiry-oriented approaches of the modern curricula (Bajah, 1975; Shuaibu, 1979) are at all being heeded. Shuaibu (1979) specifically recommended the cautious adoption of measures to bridge the gap between the (traditional/expository) skills teachers already have and those prescribed by newer curriculum programmes and approaches with the aim of equipping teachers with a "repertoire of teaching behaviours" or skills that would subsequently lead to the improvement of science instruction. A new approach to inservice teacher education was also proposed by the author to help redress the situation. The need to pay heed to these calls seems to be even more pertinent today than it was a decade ago.

Gender continues to hold out the promise to serve as a dependable predictor of the science interests of learners but not their cognitive styles. One wonders if it would be possible to take (educational) measures that would enhance the interests of females in science, particularly in the physical sciences and technology. What future roles can women play in the development of science and technology, one may ask, or will this area of human endeavour continue to be an exclusive preserve of men?

Head (1985) reported that despite efforts to remedy the shortfall, the proportion of women entering the physical sciences and engineering in Britain did not improve in recent years.

Age is shown to be related to students' physics interests but again not to their cognitive styles. The results suggest that postsecondary students are most highly motivated to learn physics when they are between 19 and 21 years of age. In general the students of this study tended to lose interest in physics as they got older and the decline in interest seems to begin from 21 years upwards. The same trend has been reported for interest in other science subjects. The 6-3-3-4 system of education currently operating in Nigeria seems to be well suited to capture students interests in science and should be made effectively operational.

Most (over 80 per cent) of the students admitted into the predegree programme of the FUT, Minna expected to enter into careers in engineering and computer science in the future. If the students admitted into the university through JAMB (the Joint Admissions Matriculation Board) are similarly inclined, then there are obvious implications for the provision of adequate staff and other facilities in the School of Engineering and Engineering Technology and the Department of Mathematics and Computer Science of the university in order to cope with the situation.

The study revealed some interesting relationships between cognitive styles and physics interests. In particular learners' physics interests seem to be largely dependent on the type of cognitive styles they exhibit in OPTICS and (to some extent) also mechanics, heat, magnetism and sound. For example a high A-score in PHYSICS generally and OPTICS particularly and a low R-score in OPTICS are congruent with high levels of interest in specific dimensions and sub-dimensions of physics learning. The implication of this finding is that PHYSICS in general and OPTICS in particular should be taught in such a way as to de-emphasize the Recall (R) style but to promote or nurture the Application (A) style.

Finally the results showed that it was possible to shift the cognitive styles of physics students (but not their interest orientations) by means of the TDO mode of instruction. This lends further support to the view that cognitive style is not a fixed character but a trait acquired through training, maturation and life experiences. Viewed against the reported relatedness of cognitive styles and interest it seems that new frontiers of research and new possibilities for teacher-education programmes and science classroom practices (for the improvement of science instruction and for maximizing students' gains in science education) are likely to be opened up. It would be a happy turn of events and a pleasant experience if

interest (a science affect) can be modified by altering or nurturing cognitive style (a cognitive and psychological attribute). That may point to one possible way of successfully teaching similar affective attributes, a problem which has all along proved difficult for science educators.

5.6 Recommendations

The following recommendations are considered appropriate in the light of the findings of this study and their educational implications:

1. Physics in general and optics, magnetism and mechanics in particular should be taught in such a way that the nurture or development of the Recall (R) and Principles (P) cognitive styles are discouraged while the nurture or development of the Application (A) cognitive style is promoted. This would help to build up in learners high levels of interest in the various dimensions of physics interest. From the point of view of nurturing learners' interests in physics, it would seem that A rather than Q is the cognitive style on which physics teachers and curriculists should focus greater attention.

2. In physics teacher education programmes efforts should be made to ensure that physics teachers are trained in such a way that they acquire the Application (A) cognitive style so that (in physics lessons) they should emphasize practical applications related to the scientific information they present to their students. This is important because no teacher would give to his/her students what, in the first instance, he/she has not got.

3. The TDD mode of instruction is recommended for use in physics teaching. The results of the present study suggest that this mode of instruction is

   (i) favourably disposed to the nurture of the A and Q cognitive styles; and

   (ii) effective in raising learners' interests in all the three dimensions of physics interest investigated.

4. Since interest in physics seems to begin to dwindle from age 21, it is recommended that steps should be taken to ensure that young persons are given the opportunity for science education and encouraged to take up same early in life. Students, accordingly, ought to have become well advanced or well established in science education before they attain 21 years of age.

5. Measures should be taken by the government to encourage women education in the sciences, especially the physical sciences. A good starting point might be to focus on teacher education. A deliberate government policy aimed at raising up a corps of women science teachers would help to promote female interest in the sciences and (at the same time) help to alleviate the current problem of male desertion of the teaching profession for greener pastures.

6. The authorities of the Federal University of Technology (FUT), Minna would do well to pay close attention to the School of Engineering and Engineering Technology and the Department of Mathematics and Computer Science with particular reference to the provision of adequate academic staff and instructional facilities so as to be able to cope with the consequences of the high interest of predegree students in the areas of engineering and computer science. The university may in fact wish to consider creating (as soon as practicable) a separate department for computer science.

7. Examination questions set by schools, educational institutions at various levels and examination bodies like WAEC, NTI and JAMB should include questions that should test students' knowledge of the practical application and possible limitations, weaknesses or inadequacies in respect of validity, completeness and generalizability of scientific knowledge acquired by students in the course of instruction and learning.

For Further Research

1. A major weakness of this study is that the teaching of the experimental and control groups of students was done by the researcher himself. Another limitation to the study was that it was difficult for the experimental group to have as many learning activities and experiments as possible during their lessons because of the large number of students involved. Even the way the few experiments and activities were performed was not satisfactory to the researcher because students had to work in large groups. It is recommended that the study be replicated with these two weaknesses eliminated i.e. by having other teachers (than the researcher) to do the teaching and by using a smaller sample of physics students.

2. It would also be a good idea to replicate the study with the experimental and control classes separated from each other (say in two separate institutions) in order to eliminate the possible adverse effects on the results of the study arising from (i) migration of students to groups other than their own during the teaching, (ii) interaction of students with one another outside the classrooms after lessons, and (iii) possible discontent on the part of the control group for not receiving the same treatment as the experimental group.

3. More studies of the present type using the TDD mode of instruction are generally desirable in order to verify the results obtained.

4. There is need for similar studies to explore the effects of other teaching methods on cognitive styles and/or interests of students in different science subjects. Other teaching methods that could be considered include process approach, lecture-demonstration, problem-solving, project, laboratory, and field trip approach. Indeed the effects of two teaching methods on one or both variables may be compared. Such studies would help to determine the methods which have the most generative or modifying effects on learners' cognitive styles and/or interests.

5. The finding in the study that a learners' cognitive styles in OPTICS are probable strong predictors of his interest orientations in physics deserves to be further investigated in separate studies. The results of such studies would help to verify the claims of relationship between cognitive style and interests, throw further light into the purported relationship and perhaps suggest how the potential merits of such relationship may be tapped educationally. For example, it is not clear if the high interest in various areas of physics predicted by a low R- and a high A-score in OPTICS would be realised irrespective of whether the

said areas are taught before or after the lessons in OPTICS. Finding an answer to this problem is an appropriate object of further research.

6. Through the reported relatedness of cognitive style and interest this study has provided indirect evidence that students exhibit different cognitive styles in different content areas of a science subject such as physics. Further research to confirm this indication would be appropriate.

7. Cognitive styles, it has been suggested, can be modified through teaching. It was observed in this study that in every case in which a significant shift in cognitive style occurred, the general order of cognitive styles (P-R-A-Q) remained unchanged. The question one may ask is this: Is it possible to modify cognitive styles sufficiently enough as to alter the general order of cognitive styles as well? This is a question which a further study can attempt to answer. Perhaps a sufficient shift that would also result in a change in the general order of cognitive styles would be possible if the period of the experimental treatment (duration of instruction) is extended up to two terms or two semesters or even a whole academic year.

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APPENDIX I

Dear Sir,

VALIDATION OF PHYSICS COGNITIVE STYLE TEST
(PCST)

The attached is a cognitive preference test designed to measure the cognitive preferences of physics students. It consists of multiple-choice items each starting with a 'stem' which is an introductory statement or diagram in physics. Each stem is followed by four response options labelled A, B, C, D. All the response options are CORRECT. Each response option is intended to correspond to one of the following four different modes of processing scientific information:

Recall (R)

This type of statement represents a knowledge item in physics such as a specific fact or term which had been memorised by the respondent and is easily/readily remembered or recalled in relation to the introductory statement or diagram. Its selection by a respondent suggests preference for or acceptance of factual scientific information for its own sake without consideration of its implications, applications or limitations.

Principles (P)

This type of statement identifies a fundamental principle underlying or associated with the information in the stem. Its choice by a respondent indicates preference for or acceptance of scientific information because it illuminates or exemplifies a basic scientific principle, concept or relationship.

Application (A)

This type of statement points to a practical application of the scientific information in the introductory statement or diagram. Its selection by a respondent indicates preference for or interest in scientific information because of its (potential) usefulness and application in a general, social or scientific context.

Questioning (Q)

This type of statement critically questions or challenges the information in the stem. Its choice by a respondent suggests a predilection to criticise or challenge a scientific information with respect to its completeness, validity, generalizability or limitations.

You are, please, requested to help in validating this instrument by indicating what type of statement (R, P, A or Q) each option corresponds to. You are to write the appropriate letter, R, P, A, or Q beside the letter (A, B, C, D) used to label the options.

Whereever you consider it necessary, you may suggest amendments, modifications or alternatives to stems and/or options so as to make them more suitable.

Thanks for your cooperation and assistance.

N. A. OYEDUM.

APPENDIX II

Dear Sir,

VALIDATION OF INTEREST IN PHYSICS INVENTORY
(IPI)

The attached research instrument is designed to assess the interest of a sample of pre-degree students in physics. Interest in a science subject such as physics is conceptualised as a multidimensional variable. Three major dimensions of interest (topic, activity, motive) each with several categories or sub-dimensions have so far been identified through research.

Research evidence indicates that learners' interests in a subject vary with different

(i) topics (or subject matter areas) of the subject concerned;
(ii) activities through which the subject may be learnt;
(iii) motives (contexts, situations or purposes) for which or in which a particular aspect of the subject may be presented or studied.

The following items written under the three stated dimensions have been adapted for use in the Nigerian setting from two similar interest inventories recently used in Europe (West Germany) and the Middle East (Israel).

You are, please, requested to help in assessing the content and face validities of the items, i.e. whether they are considered suitable for the dimensions under which they have been written and for testing the physics interests of Nigerian students. Any criticisms and/or suggestions for modification would be immensely appreciated.

Thanks for your anticipated kind cooperation and assistance.

N.A. OYEDUM.

APPENDIX III

Name: _____

Group _____ Sex _____ Age _____

Anticipated future career _____

Dear Student,

This test contains 40 items designed to find out your preferences for different types and orientations of physics subject matter.

It is not a test of how much physics you know, but of what type of information you prefer to learn in physics.

A knowledge of what types or orientations of physics matter you prefer will help us to better organise and plan your physics lessons.

Each item begins with an introductory statement or diagram in which some scientific information is presented. This introductory statement or diagram is then followed by four response options labelled A, B, C, D.

You are to show how much you like each of the four responses by arranging them in order of preference. You will do this by awarding

4 marks to the response which you prefer most or like best,

3 marks to the response which you like next,

2 marks to the next, and

1 mark to the response which you like least.

Record each mark in the bracket near the letter (A,B,C,or D) against each response option.

Please, note that in each item the introductory statement (or diagram) and all the response options contain CORRECT scientific information. There is, therefore, no question of a response being right or wrong. Each mark you award only shows your preference, i.e. how the response option appeals to you.

Read through all the responses carefully before awarding your marks.

Example

50. It is a cool dry Saturdy evening.

(3) A. It will be rewarding to weed the cassava farm.

(4) B. The finals of the under-17 World Cup football competition will be relayed live on television.

(2) C. A lawn tennis game would be most pleasant.

(1) D. Visiting a few friends would be quite enjoyable.

From the marks alloted here, watching the World Cup football match is the most preferred, weeding of the cassava farm is the next and visiting some friends is the least appealing response.

Please, answer ALL the items, even though the decisions may be difficult to make.

Thanks for your cooperation.

N. A. OYEDUM.

APPENDIX IV

INTEREST IN PHYSICS INVENTORY (IPI)

Name: _____

Group: _____ Sex _____ Age _____

Anticipated future career: _____

Dear Student,

This inventory contains items which have been designed to determine the level of your interest in different aspects of physics. It is divided into three sections:

1. Interest in physics topics;
2. Interest in learning activities;
3. Interest in motives or purposes for studying physics.

Your answers can help to make physics lessons more interesting in future. You are, therefore, requested to complete this questionnaire as carefully and accurately as possible.

In each item, you are required to indicate how high or how low your interest is by putting a tick (✓) in one of the boxes shown against the item. You should tick the box corresponding to the most appropriate answer for you. Tick only ONE box in each item.

Please, answer ALL the items.

Thanks a lot for your help and cooperation.

N. A. OYEDUM.

APPENDIX V

PHYSICS COGNITIVE STYLE TEST (PCST)

1. Different substances have different densities.

( ) A. An unknown substance can be identified through knowledge of its density.
( ) B. Density = $\frac{\text{Mass}}{\text{Volume}}$
( ) C. This statement does not take into account the effect of temperature on the density of a substance.
( ) D. The density of a substance is the mass of unit volume of the substance.

2. Substances expand when heated and contract when cooled.

( ) A. Water between $0^{\circ}C$ and $4^{\circ}C$ does not obey this rule but rather contracts when heated and expands when cooled.
( ) B. When a substance is heated the motion of the molecules increases with the result that the molecules force each other a little further apart. The reverse is the case when a substance is cooled.
( ) C. The expansion of liquids is employed in liquid-in-glass thermometers.
( ) D. The expansion of solids is less noticeable than the expansion of liquids or gases.

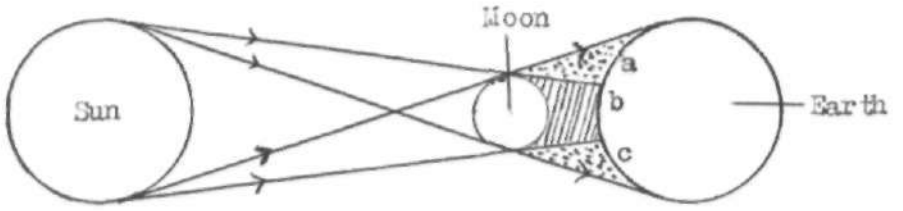
3. A steel bar placed inside a solenoid will become magnetised if current is passed through the solenoid.

( ) A. The steel bar would not be permanently magnetised if alternating current is passed through the solenoid.
( ) B. This process is used for the commercial production of magnets.
( ) C. The magnetisation of the steel bar results from the magnetic effect of the electric current in the solenoid.
( ) D. The best and quickest method of making a magnet is to use the magnetic effect of an electric current.

4. A dry plastic comb, after being used to comb dry hair, will attract small pieces of light paper if brought near to them.

( ) A. The comb has acquired static changes
( ) B. As a result of friction the plastic comb gains electrons from the hair and becomes negatively charged while the hair becomes positively charged.
( ) C. A short length of chain trailing on the ground is often attached to the metal framework of a vehicle or hospital trolley to help conduct away to the earth static charges built on them as a result of friction.
( ) D. Is attraction (or repulsion) really an electric or magnetic effect?

Fig. 1



5. Fig. 1 shows how an eclipse of the sun occurs.

( ) A. The diagram does not explain the formation of an annular eclipse.

( ) B. A total eclipse of the sun occurs in the region marked b while partial eclipse occurs at a and c.

( ) C. An eclipse of the sun occurs when the moon in the course of its rotation comes between the sun and the earth and fully or partially prevents the sun's rays from reaching the earth.

( ) D. The appearance of the shadow of the moon during an eclipse of the sun helps to reconfirm its spherical shape.

6. Waves may be classified into two categories: mechanical waves which require a material medium for their propagation and electromagnetic waves which do not require a material medium for propagation.

( ) A. Light is said to be an electromagnatic wave. If this is so, how is it possible that it also travels in straight lines?

( ) B. Waves on a string or rope, water waves and sound waves are examples of mechanical waves while light, radio waves and x-rays are electromagnetic waves.

( ) C. In a wave motion energy from the source of disturbance is propagated from one place to another as the disturbance moves.

( ) D. Short radio waves are employed in radar equipment used in ships, aircrafts and airfield control towers for detecting the presence and measuring the distance of various objects like other ships, aircrafts or landscapes.

7. The stability of an object depends on the position (height) of its centre of gravity (C.G.).

( ) A. There are three types of equilibrium: stable, unstable and neutral equilibrium.

( ) B. Passengers are not allowed to stand on the upper deck of a double decker bus so that the height of the C.G. of the bus remains fairly low.

( ) C. The width of the base of the object and the moment of the weight of the object about an axis also affect the stability of its equilibrium.

( ) D. A body is in stable equilibrium if a slight displacement produces an increase in potential energy (i.e. the C.G. rises) so that the body falls back to original position when released.

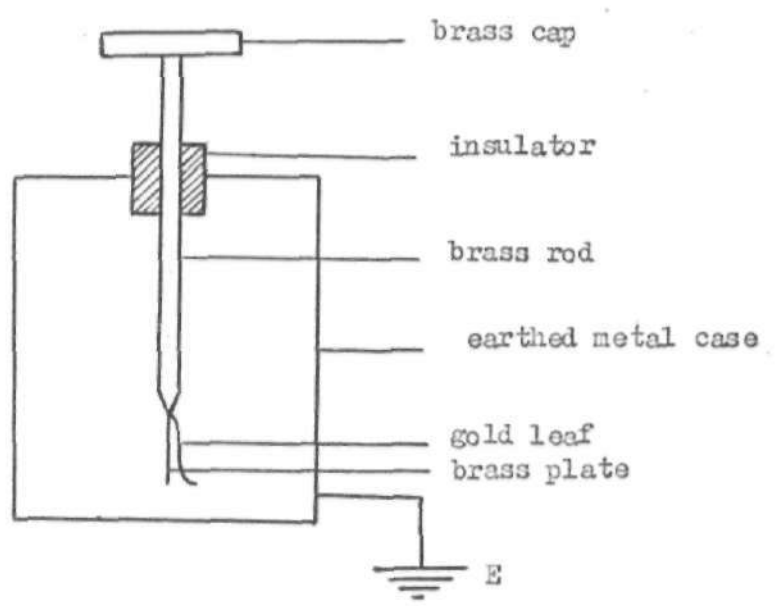
8. The amount of linear expansion in a solid depends on the nature of the substance and the rise in its temperature.

( ) A. The statement is not fully correct because the effect of the original length of the substance is not taken into account.
( ) B. A brass rod expands more than an iron rod of the same length for the same rise in temperature.
( ) C. Bimetal strips made of brass and invar are very sensitive to temperature changes and hence very effective in regulating the temperatures of thermal devices.
( ) D. The higher the linear expansivity or temperature rise of a substance the greater the expansion it will undergo.

9. Soft iron is easily magnetised but also loses its magnetism easily while steel takes time to magnetise but also retains its magnetism for a long time.

( ) A. Soft iron and steel have different magnetic properties.
( ) B. Soft iron is used for making temporary magnets while steel is used for making permanent magnets.
( ) C. The atomic dipoles in the magnetic domains of the soft iron are more susceptible to external magnetic fields than those in the magnetic domains of steel.
( ) D. Is it not possible to produce another substance or alloy which is as magnetically hard as steel?

Fig. 2



10. The diagram of a gold-leaf electroscope is shown in Fig. 2.

( ) A. The device is used for detecting, testing and studying small static electric charges.
( ) B. Divergence of the gold leaf is due to repulsion between the charged metal plate and the leaf as a result of like charges induced in them.
( ) C. The instrument was invented by a Yorkshire clergyman called Abraham Bennet.
( ) D. Can't any other material (e.g. cigarette aluminium foil) be used in the place of the gold leaf?

11. Conjugate foci are any pair of points such that if an object is placed at one of them, a real image is obtained at the other.

( ) A. This implies that infinity (∞) and the principal focus (F) are conjugate foci but one wonders where infinity is actually located.
( ) B. The fact that an object and its image can be interchanged follows from the principle of reversibility of light.
( ) C. The centre of curvature of a concave mirror is a self-conjugate point.
( ) D. Knowledge of conjugate foci facilitate the drawing of accurate ray diagrams.

12. Waves can be reflected, refracted or diffracted. They can also interfere.

( ) A. All these wave properties may be demonstrated using the ripple tank.
( ) B. Refraction of a wave is due to change in its speed when it enters a medium different from that in which it is travelling originally.
( ) C. Reflection of waves is employed in echo sounding to measure the depth of the sea.
( ) D. The diffraction of waves is an interesting and unexpected phenomenon. It would be nice to understand what actually causes it.

13. Frictional force opposes the movement of one surface over another.

( ) A. Attractive force between the molecules of the surfaces in contact plays a major part in bringing about friction.
( ) B. Without friction walking would be impossible.
( ) C. This statement does not seem to account for the friction in liquids which is known as viscosity.
( ) D. The frictional force acting between surfaces at rest with respect to each other is called static frictional force.

14. A bar magnet suspended in such a way that it can swing in a horizontal plane comes to rest in a north-south direction approximately with a particular end always pointing northward.

( ) A. The end which points towards the north is called the north pole; the other end is called the south pole.
( ) B. Navigational compasses used in ships and aircrafts function on this principle.
( ) C. The magnet comes to rest in the stated position due to the influence of the earth's magnetic field.
( ) D. This does not apply to a bar magnet that has similar polarities at its ends (as may be produced by the "divided touch" method of magnetisation).

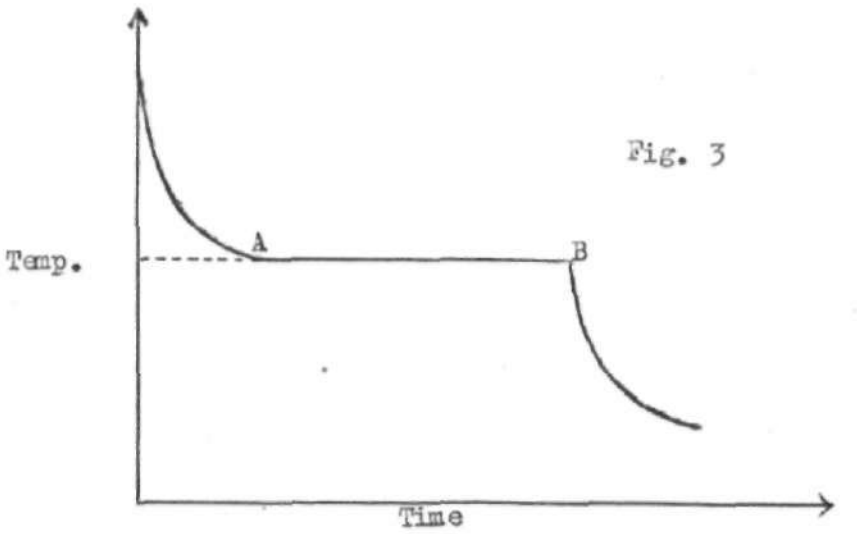


Fig. 3

15. The diagram in Fig.3 shows a sketch of the cooling curve for naphtalene.

( ) A. The cooling curve shown is correct only for pure naphtalene.
( ) B. A pure substance melts at a definite temperature called its melting point and solidifies at the same temperature also termed its freezing point.
( ) C. A cooling curve is used to determine the melting point of a substance.
( ) D. The melting point of naphtalene is $80^{o}C$

16. Two electrical conductors arranged in such a way that they can be given equal and opposite charges from an electrical component is called a capacitor.

( ) A. Capacitors are widely used in electrical circuits, especially radio and television circuits, to smoothen the signals.
( ) B. The capacitance of a capacitor is the ratio of the charge on either conductor to the potential difference between the two conductors.
C. The capacitance of a parallel - plate capacitor depends on the area of the plates, the distance between the plates and the dialectric substance between the plates.
( ) D. Why is the capacitor not used like the resistor in common electricity experiments carried out in the laboratory?

17. The rays of a parallel beam of light incident on a concave mirror may come to focus at different points on the principal axis.

( ) A. The effect is described as spherical aberration.
( ) B. This happens only in concave mirrors with wide sperture.
( ) C. All rays of light parallel and close to the principal axis converge at the principal focus after reflection in a concave mirror.
( ) D. Parabolic rather than spherical mirrors are used in searchlights and headlights of motor vehicles because spherical aberration does not occur in them.

18. Sound requires a solid, liquid or gaseous medium for its propagation.

( ) A. Fish can be attrac ed by the sound of a bell ringing under water. For this reason fishermen make use of transistor beepers which when dipped under water are claimed to be able to attract fish over a radius of about one and a half kilometers.
( ) B. One wonders if the transmission of sound through a material medium affects the total energy state of the medium concerned.
( ) C. Sound is produced by solid, liquid or gaseous matter in a state of vibration.
( ) D. Unlike light, sound cannot travel through a vacuum.

19. An object thrown into the air falls back to the surface of the earth.

( ) A. The phenomenon is due to the force of gravity with which the earth pulls towards itself all objects within its gravitational field.
( ) B. The existence of gravitational force was discovered by Isaac Newton.
( ) C. The earth's gravitational pull is responsible for holding the moon in orbit round the earth.
( ) D. Light objects like paper and cotton lint may float in the air rather than fall back readily to the earth's furface.

20. Both evaporation and boiling require latent heat of vaporisation and result in loss of liquid concerned.

( ) A. Ether has a low boiling point of $35^{\circ}C$ and so evaporates readily at room temperature.
( ) B. This is not to suggest that the two processes are identical.
( ) C. Volatile liquid inside the refrigerator pipes evaporates and takes latent heat of vaporisation thus cooling the refrigerator and contents.
( ) D. During evaporation latent heat of vaporisation is taken from the surroundings and a cooling effect, therefore, results.

21. The most effective way of demagnetising a magnet is to place it in a solenoid in which an alternating current is flowing and then to withdraw it from the solenoid.

( ) A. The magnet should be withdrawn slowly (while the current is still flowing) to a distance of several metres from the solenoid in an east-west direction.
( ) B. Other ways of demagnetisation include heating to redness, vibration or rough treatment such as dropping or hammering.
( ) C. The method is used by watch manufacturers to demagnetise watches, especially those made of steel balance-springs.
( ) D. The alternating current takes the magnet through a series of ever-diminishing magnetic cycles in one second until no magnetism is left in it.

22. Watts = Volts x Amperes.

( ) A. The watt is the electric power generated when a current of 1 ampere flows through a conductor across which there exists a potential difference of 1 volt.

( ) B. The working voltage and power consumption in watts usually indicated on an electrical device can be used to calculate the current in the instrument.

( ) C. P = VI, where P = electric power, V = voltage and I = current.

( ) D. Since mechanical power is also measured in watts, it should be possible to express it in terms of the product of current and voltage.

23. The refractive index of crown glass is 1.52 .

( ) A. The statement does not specify the medium relative to which this value of refractive index for crown glass is obtained.

( ) B. For crown glass, $\frac{\sin i}{\sin r} = 1.52$

( ) C. The refractive index of any medium depends on the speed and wavelength of refracted light.

( ) D. Manufacturers need to know the refractive index of the glass which they use in making lenses for optical instruments like telescopes, microscopes and cameras.

24. If a single tap is made at one end of a long iron fence, a person who places his ear against the fence at the other end will hear two sounds, one coming through the iron followed by another through the air.

( ) A. Sound is transmitted through solids.

( ) B. Sound travels with different speeds in different media. It travels faster through iron than through air.

( ) C. How is one sure that the first sound heard is that transmitted through the iron fence.

( ) D. Some time ago, doctors used thin wooden rods with broadened ends as stethoscopes to hear the sound of heart-beats of their patients.

25. For an object falling freely in air the loss of potential energy at any given instance is exactly equal to the gain in kinetic energy.

( ) A. Is part of the original potential energy not used up in doing work against air resistance?

( ) B. Potential energy and kinetic energy constitute what is known as mechanical energy.

( ) C. Energy is never destroyed but only changes from one form to another.

( ) D. In a hydroelectric power station the kinetic energy gained by the water falling to a lower level is used to rotate the turbine as the water pushes against the turbine blades.

26. Warm liquid or gas rises upwards in its container.

( ) A. This is the process of heat transfer in fluids and is known as convection.
( ) B. Warm fluid expands thus becoming less dense and so bobs up like a cork released under water.
( ) C. Car engines are cooled by convection currents in the water pipes.
( ) D. If hot air rises upwards and air is a poor conductor of heat, how does a fire made in an open place keep the people around it warm?

27. Evidence exists to suggest that the earth is a magnet of some sort.

( ) A. The idea of the earth's magnetism was first suggested by the (English) scientist, William Gilbert, towards the end of the 16th century.
( ) B. What is the origin or source of the earth's magnetism?
( ) C. The earth's magnetic field is similar to that of a short bar magnet located at the centre of the earth with its south pole in the northern hemisphere and inclined at a small angle to the earth's axis of rotation.
( ) D. Air and sea navigators require knowledge of the changes in the earth's magnetic properties to enable them calculate the correct compass course to steer.

28. Faraday's law of electromagnetic induction: Whenever there is a change in the magnetic flux linked with a circuit, an emf is induced the strength of which is proportional to the rate of change of the flux linked with the circuit.

( ) A. The direction of induced current is always such as to oppose the change producing it.
( ) B. Current is induced in the circuit as a result of the magnetic flux being cut by the wire whenever either the magnet or the coil moves.
( ) C. This law underlies the operation of the electric generator (dynamo).
( ) D. One wonders if credit for this law should not be given more to Hans Christian Oersted (who in 1819 discovered that magnetism can be produced by an electric current) than to Michael Faraday.

29. The sun may still appear visible long after it has set in the horizon.

( ) A. This effect is due to the refraction of light from the sun as it enters layers of denser air near the earth's surface.
( ) B. The phenomenon is called "looming".
( ) C. Astronomers make allowance for atmospheric refraction when making precise measurements of the positions of stars.
( ) D. Is it really the sun that is seen or an image of the sun?

30.

Fig. 4

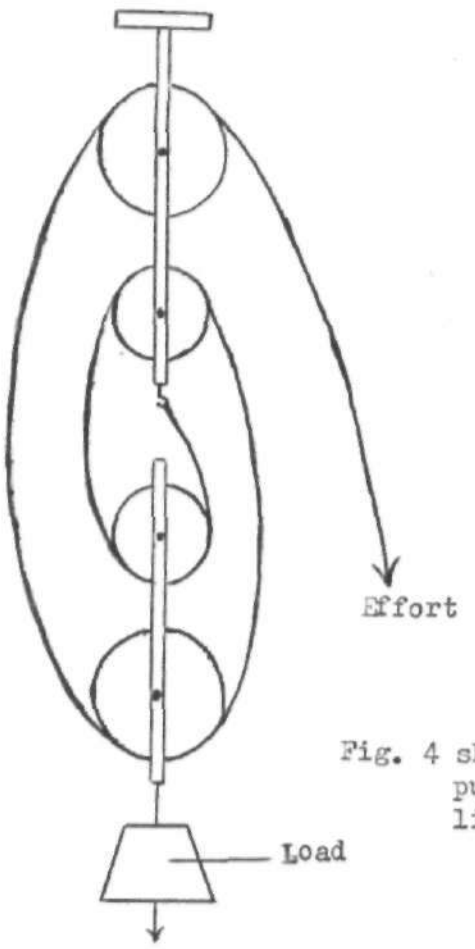


Fig. 4 shows a system of pulleys used for lifting heavy loads.

( ) A. This type of pulley is used in cranes for lifting very heavy loads e.g. in the construction of tall buildings and in loading and offloading ships in the dockyard.
( ) B. The system of pulleys is called a block and tackle.
( ) C. In using a pulley system, it is easier to raise a load by pulling at the free end of the rope because the hauler uses part of his weight as a pulling force in addition to his muscles.
( ) D. In practice most pulleys are not arranged as portrayed in the diagram, rather the pulleys in each block are mounted side by side and run independently on a common axle.

31. Radiation consists mostly of infrared rays and has all the properties of electromagnetio waves.

( ) A. The amount of energy given out by a radiating body depends on the temperature of the body and the nature of its surface.
( ) B. Dull black surfaces are better absorbers and emitters of radiation than white shiny surfaces.
( ) C. In a vacuum flask both walls of the glass vessels are silvered on the vacuum side to reduce heat losses by radiation.
( ) D. One wonders if "radiation" is a process of heat transfer or a form of heat energy.

32. If a soft-iron ring is placed in a magnetic field, it is observed that no flux crosses the space inside the ring.

( ) A. Is the effect independent of the strength of the magnetic field concerned?
( ) B. The effect is known as magnetic screening or magnetic shielding.
( ) C. All the magnetic flux passes through the material of the ring which has a higher magnetic permeability than air.
( ) D. Delicate measuring instruments which could be adversely affected by external magnetic fields are protected by enclosing them in thick-walled soft-iron boxes.

33. It is more economical to transmit electric power at low current and high voltage than at high current and low voltage.

( ) A. In high voltage transmission power losses in form of heat are small and the cost of cables is reduced since relatively thin cables are required to carry a low current.
( ) B. Telephone communication depends on high-voltage alternating current transmission between two speakers over long distances without much loss of energy.
( ) C. Electric power transmission at low current and high voltage is called "high tension (H.T.) transmission".
( ) D. High-voltage transmission is possible only with alternating current (a.c.) since direct current (d.c.) cannot be stepped up or down by means of a transformer.

34. Fig. 5 shows an apparatus which can be used for demonstrating or studying resonance in a closed tube (T).

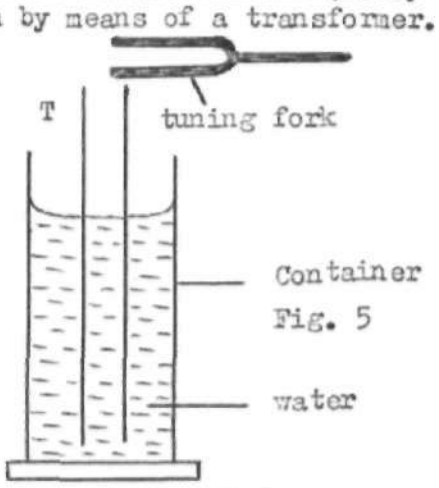


Fig. 5

( ) A. Resonance is obtained when a large sound is heard as the length of air column is varied by adjusting (i.e. raising or lowering) T.
( ) B. A diver jumps repeatedly at one end of a diving board and thus sets it into resonant vibration with the result that he gains a considerable uplift before he dives.
( ) C. During resonance, it is not clear whether the external periodic force which induces resonance is also vibrating at its own natural frequency.
( ) D. At resonance, the vibrating tuning fork forces the air column to vibrate at its natural frequency which is also equal to the frequency of the tuning fork.

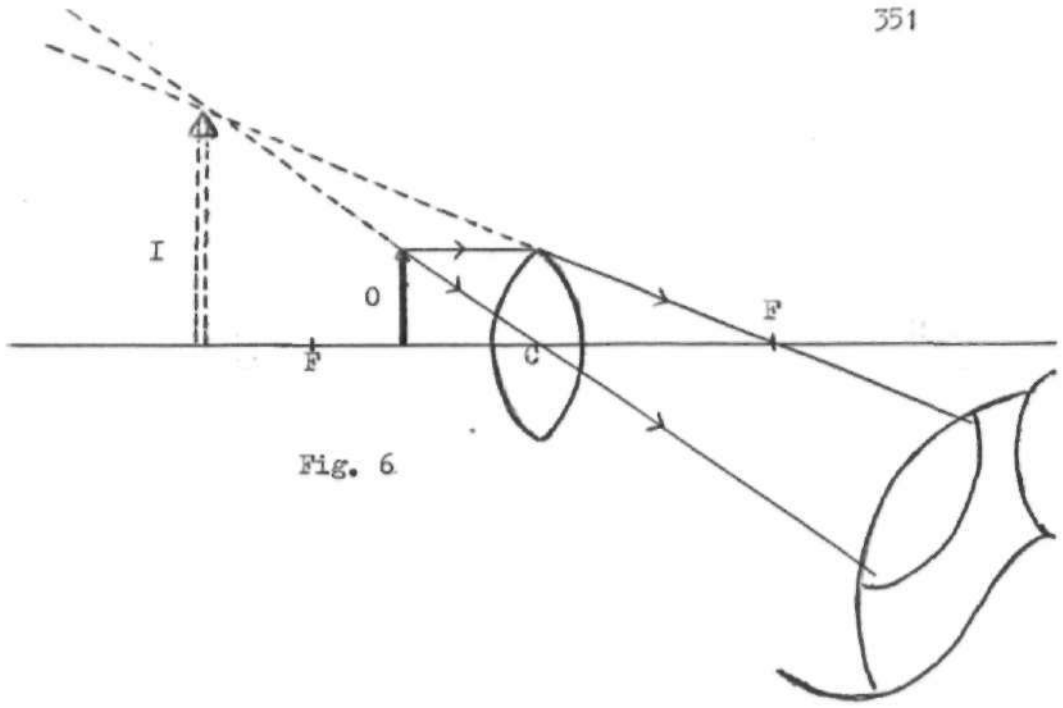


Fig. 6

35. Fig. 6 shows the formation of the image (I) of an object (O) placed between the principal focus (F) and the optical center (C) of a converging lens.

( ) A. Will the magnification of the image vary as the position of the object between F and C is altered?
( ) B. The image is virtual and magnified.
( ) C. The diagram illustrates how a lens may be used as a magnifying glass.
( ) D. The rays from O appear to intersect beyond F after refraction through the lens.

36. A lightening flash is usually seen several seconds before the accompanying thunder is heard.

( ) A. Both light and sound take definite times to travel over a given distance but because the speed of light is high (and by far greater than that of sound) the time it takes to travel a few kilometers is relatively negligible.
( ) B. This phenomenon makes it possible for the speed of light to be measured by noting the time interval between seeing and hearing an event which takes place at a known distance from the observer.
( ) C. The difference between the velocity of sound and the velocity of light is enormous. Has it anything to do with the fact that sound waves require material medium for popagation while light waves do not?
( ) D. The speed of light in air is $3x10^8$ m/s while that of sound is a mere 331 m/s for dry air at 0^oC.

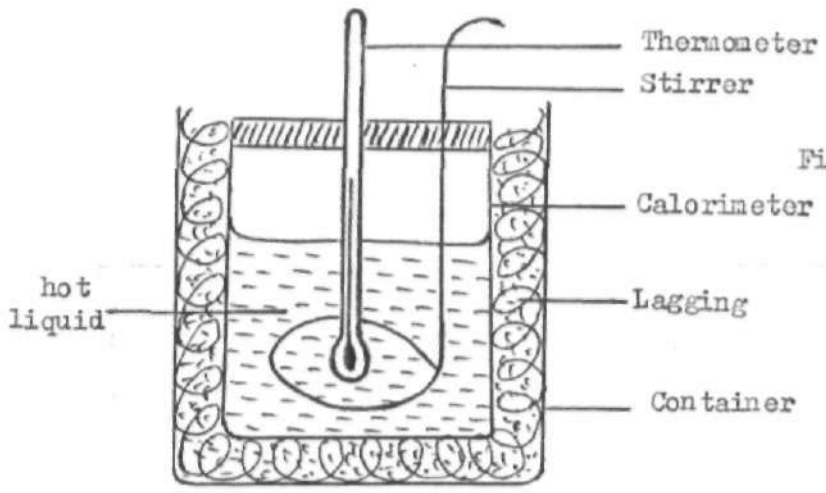


Fig. 7

37. Fig. 7 shows the essential features of the apparatus used in calorimetry experiments.

( ) A. The term "calorimetry" first came into use at a time when heat was still regarded as a fluid called "caloric".

( ) B. Calorimeter measurements are based on the principle that if there is no loss of heat to the surroundings by the calorimeter and contents, heat lost equals heat gained.

( ) C. Would it not be more effective to use plastic rather than copper calorimeters as this would keep heat lost to the surroundings to a minimum?

( ) D. Calorimeters are mainly used in science laboratories for making heat measurements.

38. If white light passes through a triangular prism, it is separated into seven different colours of light.

( ) A. The colours of white light are: red, orange, yellow, green, blue, indigo and violet.

( ) B. The different colours which make up white light travel with different speeds in the glass prism hence the separation.

( ) C. This effect accounts for why precious stones like diamond glitter in bright colours when white light passes through them.

( ) D. Apart from the colours of white light and their possible combinations, do any other coloured lights exist in nature?

39. A liquid boils when its saturation vapour pressure becomes equal to the external atmospheric pressure.

( ) A. The saturation vapour pressure (s.v.p.) of a liquid varies with temperature.

( ) B. Since external atmospheric pressure is equal to the s.v.p., further addition of heat causes bubbles to form inside the body of the liquid and then rise to the surface. This is called boiling or ebullition.

( ) C. In the pressure cooker the time and cost of fuel required for cooking are greatly reduced as the boiling point of water is raised under high external pressure.

( ) D. The external pressure is not necessarily "atmospheric pressure" as in the example of the pressure cooker.

40. The seven colours of white light spectrum may be recombined to give white light.

( ) A. How do we account for the fact that only three out of these seven colours (red, blue and green) also recombine to give white light?

( ) B. Red light + green light = yellow light.

( ) C. The functioning of the colour television depends on the mixing of coloured lights.

( ) D. This happens because the mixing of coloured lights is additive (i.e. colour mixing by reflection from a white surface).

APPENDIX VI

INTEREST IN PHYSICS INVENTORY (IPI)

A. Interest in Physics Topics (IPI)

On the following pages you will find topics which can be studied in physics lessons. Please, indicate how high or low your interest in each topic is by ticking (✓) one of the boxes shown against each topic. Note that the level of your interest in a topic should be one of the following: very high, high, moderate (i.e. neither high nor low), low or very low.

		Very high	High	Moderate	Low	Very low
1.	How the height of the centre of gravity of an object determines its stability	( )	( )	( )	( )	( )
2.	Calculating distance, velocity, acceleration, and time using equations of (uniformly accelerated linear) motion	( )	( )	( )	( )	( )
3.	Meaning of gravitational force and its importance in nature	( )	( )	( )	( )	( )
4.	Advantages and disadvantages of friction and how unwanted friction can be reduced	( )	( )	( )	( )	( )
5.	Conversion of energy from one form to another and its practical importance in everyday life	( )	( )	( )	( )	( )
6.	Determination of the boiling points or feezing points of substances	( )	( )	( )	( )	( )
7.	Expansion and contraction of substances when they gain or lose heat	( )	( )	( )	( )	( )
8.	Verifying Boyle's Law experimentally in the physics laboratory	( )	( )	( )	( )	( )
9.	Solving numerical problems which involve the use or calculation of heat capacities or specific heat capacities of substances	( )	( )	( )	( )	( )
10.	Similarities and differences between evaporation and boiling	( )	( )	( )	( )	( )

		Very high	High	Mode-rate	Low	Very low
11.	*Formation of shadows and* eclipses	( )	( )	( )	( )	( )
12.	How different types of mirrows and lenses affect rays of light which are incident on them	( )	( )	( )	( )	( )
13.	Using lens formula or mirrow formula $(\frac{1}{u} + \frac{1}{v} = \frac{1}{f})$ to solve numerical problems	( )	( )	( )	( )	( )
14.	Making heat measurements in the laboratory using calorimeter	( )	( )	( )	( )	( )
15.	Defects of vision and how they are corrected	( )	( )	( )	( )	( )
16.	Essential components, function and uses of optical instruments (e.g. cameras, binoculars, microscopes,telescopes)	( )	( )	( )	( )	( )
17.	Saturated vapour pressure (s.v.p.) and how it affects the boiling point of a liquid	( )	( )	( )	( )	( )
18.	*Using rope*, 'slinky' coil (spring), stretched string or pool of water to show different types of waves	( )	( )	( )	( )	( )
19.	Solving simple numerical problems *using* the relationship $v = f\lambda$	( )	( )	( )	( )	( )
20.	Illustrating different properties of waves using the ripple tank	( )	( )	( )	( )	( )
21.	How sound is produced and how it spreads or travels	( )	( )	( )	( )	( )
22.	How real and virtual images are formed in a concave mirrow or convex lens	( )	( )	( )	( )	( )
23.	Pitch, loudness and quality (tone) as characteristics of sound waves	( )	( )	( )	( )	( )
24.	Measuring the refractive index of glass or water in the physics laboratory	( )	( )	( )	( )	( )
25.	What electricity actually is and how it can be generated	( )	( )	( )	( )	( )
26.	Solving numberical problems (d.c., circuit calculations) using Ohm's Law formula, $V=IR$ or $E = I(R-r)$	( )	( )	( )	( )	( )
27.	Atmospheric refraction and how it causes the formation of such natural phenomena as mirages and "looming"	( )	( )	( )	( )	( )

		Very high	High	Mode-rate	Low	Very Low
28.	Comparing the speed of light in air with the speed of sound in air	( )	( )	( )	( )	( )
29.	Demonstrating resonance in a closed tube using a tuning fork	( )	( )	( )	( )	( )
30.	What a capicitor is, its practical importance and how it is used in an electrical circuit	( )	( )	( )	( )	( )
31.	Properties of magnets and magnetic materials	( )	( )	( )	( )	( )
32.	Production and uses of temporary and permanent magnets	( )	( )	( )	( )	( )
33.	Differentiating between electrical work (or power) and mechanical work (or power)	( )	( )	( )	( )	( )
34.	Force on a current-carrying conductor in a magnetic field and its application in the electric motor	( )	( )	( )	( )	( )
35.	Electromagnetic induction and the laws (Faraday's law and Lenz's law) governing it	( )	( )	( )	( )	( )
36.	How different types of machine help us to do work more easily	( )	( )	( )	( )	( )
37.	Methods of measuring densities and relative densities of substances	( )	( )	( )	( )	( )
38.	Molecular theory of matter and how it accounts for the differences in the properties of solids, liquids and gases	( )	( )	( )	( )	( )
39.	Different types of motion (translational, rotational, oscillatory and random) which objects can execute	( )	( )	( )	( )	( )
40.	The kinetic theory and how it explains various physical phenomena such as the gas laws, effects of heat and modes of heat transfer	( )	( )	( )	( )	( )
41.	How an object (or a space) can be shielded from magnetic influence	( )	( )	( )	( )	( )
42.	The effect of pressure on the boiling point of liquids and its application in the pressure cooker	( )	( )	( )	( )	( )

		Very high	High	Mode-rate	Low	Very Low
43.	How heat is transferred through conduction, convection and radiation	( )	( )	( )	( )	( )
44.	The use of bimetal strips in appliances for controlling temperature	( )	( )	( )	( )	( )
45.	Breaking down of white light into its component colours (i.e. dispersion)	( )	( )	( )	( )	( )
46.	How coloured pictures are produced in colour television	( )	( )	( )	( )	( )
47.	The different types of radiation which make up the electromagnetic spectrum and their uses	( )	( )	( )	( )	( )
48.	Differentiating between trans-verse and longitudinal waves	( )	( )	( )	( )	( )
49.	What echoes are and how they are usefully employed, for example in depth sounding, and submarines	( )	( )	( )	( )	( )
50.	How electricity is transmitted from the power house to the consumers	( )	( )	( )	( )	( )
51.	Using a goldleaf electroscope to identify and study static electric charges	( )	( )	( )	( )	( )
52.	Plotting magnetic fields (lines of force) and locating neutral points where applicable	( )	( )	( )	( )	( )
53.	How a magnetic material can be magnetised and demagnetised	( )	( )	( )	( )	( )
54.	The earth's magnetism and its practical importance in naviga-tion with magnetic compasses	( )	( )	( )	( )	( )
55.	How alternating current (a.c.) and direct current (d.c.) can be produced using the simple dynamo	( )	( )	( )	( )	( )
56.	Simple alternating current (a.c.) circuits and the solution of numerical problems involving such circuits	( )	( )	( )	( )	( )

B. Interest in Learning Activities (ILA)

Below you will find different activities which can be carried out by students in order to learn physics. Please, indicate how high or how low your interest is in each activity.

		Very high	High	Mode-rate	Low	Very Low
1.	Attending a classroom lecture by a good physics teacher	( )	( )	( )	( )	( )
2.	Reading a physics textbook as a follow-up to a lesson	( )	( )	( )	( )	( )
3.	Reading scientifi : articles in newspapers, maga nes or journals	( )	( )	( )	( )	( )
4.	Getting a difficult concept or point explained by a teacher or someone else	( )	( )	( )	( )	( )
5.	Getting notes or handouts from the physics teacher	( )	( )	( )	( )	( )
6.	Reading up a new topic on your own from a physics textbook	( )	( )	( )	( )	( )
7.	Listening to a talk by a great physicist	( )	( )	( )	( )	( )
8.	Participating in field trips or excursions	( )	( )	( )	( )	( )
9.	Watching a film, slides or videotape	( )	( )	( )	( )	( )
10.	Visiting physics displays in a science fair or science exhibition	( )	( )	( )	( )	( )
11.	Performing an experiment in the physics lab.	( )	( )	( )	( )	( )
12.	Carrying out an individual project in physics which involves reading and experiments	( )	( )	( )	( )	( )
13.	Constructing and testing a simple physics apparatus or device	( )	( )	( )	( )	( )
14.	Demonstrating a simple physical phenomenon	( )	( )	( )	( )	( )
15.	Setting up the apparatus for a physics experiment	( )	( )	( )	( )	( )
16.	Taking apart a physics or technical device and putting it together again after examining it	( )	( )	( )	( )	( )

		Very high	High	Modo-rate	Low	Very Low
17.	Drawing a graph to show the relationship between physical variables	( )	( )	( )	( )	( )
18.	Calculating an unknown physical quantity using a suitable formula	( )	( )	( )	( )	( )
19.	Planning an experiment to test a hypothesis	( )	( )	( )	( )	( )
20.	Designing a piece of apparatus or device to be improvised	( )	( )	( )	( )	( )
21.	Thinking about the validity of a theory or generalization in physics	( )	( )	( )	( )	( )
22.	Deriving mathematical formulas in physics from first principles	( )	( )	( )	( )	( )
23.	Outlining a physics theory or law mathematically	( )	( )	( )	( )	( )
24.	Predicting the results of an experiment	( )	( )	( )	( )	( )

C. Interest in Motives for Studying Physics (IMSP)

Below you will find possible motives (contexts, situations, purposes) or reasons for studying physics generally or for being interested in specific physics topics in particular. Please, indicate your level of interest (very high, high, moderate, low, very low) in each of the motives.

	Interest in Social Aspects of Physics	Very high	High	Mode-rate	Low	Very Low
1.	Effect of hydroelectric dams or power stations on the environment	( )	( )	( )	( )	( )
2.	Ways and means of disposing industrial waste materials	( )	( )	( )	( )	( )
3.	Moral issues related to the manufacture and use of arms and nuclear weapons	( )	( )	( )	( )	( )
4.	Contributions of technical and technological developments to environmental pollution	( )	( )	( )	( )	( )
5.	Use and abuse of physics inventions for civil and military purposes	( )	( )	( )	( )	( )
6.	Controlling natural hazards such as floods, draught, erosion, desert encroachment	( )	( )	( )	( )	( )
7.	Effect of a highly developed computer industry on the human labour force	( )	( )	( )	( )	( )
8.	Improving the life of rural dwellers through road construction, electricity supply and water supply	( )	( )	( )	( )	( )
9.	Applications of discoveries and innovations in physics for the medical treatment of diseases	( )	( )	( )	( )	( )
10.	The role of physics and technology in the detection and prevention of crime	( )	( )	( )	( )	( )

Interest in Physics-related Careers		Very high	High	Mode-rate	Low	Very Low
1.	Professor of physics in a university	( )	( )	( )	( )	( )
2.	Researcher on the harnessing of solar energy for industrial and domestic use	( )	( )	( )	( )	( )
3.	Engineer	( )	( )	( )	( )	( )
4.	Computer specialist in a physics research institute	( )	( )	( )	( )	( )
5.	Physics teacher in a post-primary institution (e.g. a secondary school)	( )	( )	( )	( )	( )
6.	Geophysicist working with an oil company	( )	( )	( )	( )	( )
7.	Researcher on the development of nuclear energy	( )	( )	( )	( )	( )
8.	Physics teacher in a tertiary institution	( )	( )	( )	( )	( )
9.	Researcher designer in a science equipment manufacturing firm	( )	( )	( )	( )	( )
10.	Laboratory technologist in a University or research institute	( )	( )	( )	( )	( )
11.	Researcher developing electronic and telecommunication systems	( )	( )	( )	( )	( )
12.	Physics-related career in the army, airforce or navy	( )	( )	( )	( )	( )
13.	Biophysicist or medical physicist (e.g. radiologist) in a hospital)	( )	( )	( )	( )	( )
14.	Meteorologist	( )	( )	( )	( )	( )
15.	Research officer in an industry, factory or research institute	( )	( )	( )	( )	( )

APPENDIX VII

PHYSICS COGNITIVE STYLE TEST (PCST)

SCORING KEY

ITEM	A	B	C	D
1	A	R	Q	P
2	Q	P	A	R
3	Q	A	P	R
4	R	P	A	Q
5	Q	R	P	A
6	Q	R	P	A
7	R	A	Q	P
8	Q	R	A	P
9	R	A	P	Q
10	A	P	R	Q
11	Q	P	R	A
12	R	P	A	Q
13	P	A	Q	R
14	R	A	P	Q
15	Q	P	A	R
16	A	R	P	Q
17	R	Q	P	A
18	A	Q	P	R
19	P	R	A	Q
20	R	Q	A	P

ITEM	A	B	C	D
21	Q	R	A	P
22	P	A	R	Q
23	Q	R	A	P
24	R	P	Q	A
25	Q	R	P	A
26	R	P	A	Q
27	R	Q	P	A
28	R	P	A	Q
29	P	R	A	Q
30	A	R	P	Q
31	P	R	A	Q
32	Q	R	P	A
33	P	A	R	Q
34	R	A	Q	P
35	Q	R	A	P
36	P	A	Q	R
37	R	P	Q	A
38	R	P	A	Q
39	R	P	A	Q
40	Q	R	A	P