THE EFFECT OF PROCESS SKILLS INSTRUCTION ON FORMAL REASONING ABILITY AMONG SENIOR SECONDARY SCHOOL STUDENTS IN KADUNA STATE.

BY

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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 search work. It has not been presented in any previous application for higher degree. All notations are indicated by quotation marks or indentation, and the sources of information are ecifically acknowledged by means of references.

Jonathan S. Mari.

CERTIFICATION

This dissertation entitled "The Effect of Process Skills Instruction on Formal Reasoning Ability Among Senior Secondary School Students in Kaduna state" by Jonathan Salihu Mari, meets the regulations governing the award of the degree of Doctor of Philosophy of Ahmadu Bello University, Zaria and is approved for its contribution to knowledge and literary presentation.

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DEDICATION

This work is dedicated to Almighty God and to the memory of beloved parents – late Rev. Salihu Mari and Mrs. Laraba Salihu Mari.

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First and foremost, I must express my appreciation and thanks to the Lord Almighty for his abundant love, mercies and grace that made it possible for me to accomplish this work.

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ABBREVIATION

TOPS	-	Test of process skills.
GALT	-	Group Assessment of Logical thinking.
SCIS	-	Science Curriculum improvement Study.
STAN	-	Science Teachers Association of Nigeria
SSS	-	Senior Secondary Schools

DEFINITION OF TERMS

TOPS - A test designed to measure students performance of Science Process Skills.

GALT - A test designed to measure formal reasoning ability.

Schemata or Schemas - These are the underlying genotypes that make the phenotypes of hypothetical-deductive reasoning, scientific reasoning and reflective abstraction possible i.e proportional schema, combinatorial schema etc. (Flavel, 1970).

ABSTRACT

The study was carried out to determine the effects of process skills instruction on formal reasoning ability of the subjects under study. The target population was SS II students drawn from selected schools in Kaduna state. To determine the effect of process skills on formal reasoning ability, 76 subjects were selected from two secondary schools in Zaria metropolis. The two schools randomly selected, were found after matching them, to be equivalent in their formal reasoning ability and level of acquisition of science process skills. One of the schools served as the control and the other served as experimental group was exposed to science process skills instruction while the control group which was exposed to lecture-based instruction. The two groups were both pre and post tested using the following tests:

a. Test of formal reasoning ability

b. Science process skills acquisition test

The data were collected and analyzed using t- test statistics at 0.05 level of significant. Six hypotheses were tested ad the following findings were obtained:

i. A high proportion of the subjects (74%) were operating at the concrete operational stage,

ii. The experimental group performed significantly better than the control group in formal reasoning ability tasks after treatment,

iii. Female subjects benefited from science process-based instruction more than their male counterparts,

iv. The initial gap between the male and female subjects in formal reasoning ability was bridged in all the Schemata (conservation, control of variables, proportional reasoning, probabilistic reasoning, combinational reasoning) except in correlational

reasoning,

v. Science process skills instruction was found to be more effective in promoting the acquisition of science process skills in females than in their male counterparts,

vi. Though the subjects showed an appreciable increase in their mean scores in the posttest over the pretest, the difference in the mean scores was, however, only significant in the schemas of combinatorial reasoning, proportional reasoning and control of variables,

vii. Though both the concrete and formal operational subjects benefitted from the treatment, the concrete operational subjects seemed to have benefited more than their formal operational counterparts.

Based on these results, one of the major recommendations made was that process-based instruction should be introduced in the early years in the secondary schools as a means to reduce, if not totally eliminate, the gender-related differences in reasoning ability.

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CHAPTER ONE.

THE PROBLEM

1.1. INTRODUCTION.

A long term goal of science education has been that students learn science concepts in a meaningful way and apply them to solving problems (Reif and John 1979, Brisco, 1993) Educators have emphasized that science concepts can only be meaningful if students understand the processes involved in generating them. Abah (1988) observed that the central purpose behind the new curriculum projects launched in Western countries in 1960s was basically aimed at presenting science to students, the way science really is. Science education in the school was to be seen to provide students with adequate understanding of the nature and basic process of the scientific enterprise. The new curriculum according to him, was designed to shift emphasis significantly from the old methods of presenting science as mere collection of facts and terms to be memorized by students to a deeper understanding of the key concepts and fundamental principles of the subject through appropriate use of the inquiry processes.

For students to have deeper understanding of the key concepts and fundamental principle of science, the processes involved in generating these concepts and principles must be learnt. It has been pointed out in Wisconsin bulletin no. 161, that "because man both designs the observation system, selects and groups pertinent observation from the system, one must understand the processes employed in generating observations and concepts if one is to understand and use concepts". It is pertinent that students have deep understanding of these concepts, so as to effectively apply them to solve problems.

Developing students problem solving ability has long been a major objective of science instruction (Champagene and Klofer, 1981, and Shaw, 1983). Since the early 1960s a major emphasis in science curriculum development has been on the process –

oriented problem solving skills. Part of the rationale behind this emphasis has been that the student will develop the ability of applying the processes and principles of science to solving a wide range of problems, social as well as scientific. Since science education is a systematic training and instruction of the individual to enable him to lead a productive life through solving his day to day problem (Onwuka, 1984), it may be argued that problem solving processes should feature prominently in the learner's educational training in order to equip him with the "tool" that is instrumental to success in his future life.

Studies based on developmental views have argued that concept acquisition and ability to solve problems have several inter-relationship with formal reasoning ability, (John and Lawson, 1998). Several authors have hypothesized relationship between integrated process skills and formal reasoning abilities (Padilla, 1979). This seems reasonable as individual development is indeed a function of multiple activities, exercising, experiencing or acting upon environment (Babel and Chipman, 1976). John and Lawson (1998) also posited that formal reasoning ability may be a better predictor of achievement than prior knowledge in inquiry classes because reasoning patterns are presumably used to inquire into phenomena, generate and test alternative hypotheses and otherwise construct meanings from potentially confusing and disequilibrating inquiry experiences. This assertion provides an insight into the significance and influence of process-based activities on the cognitive development of an individual. Further more Piaget (1970) observed that intelligence develops not by virtue of operation (i.e. the ability to carry out activities in one's imagination) alone, but also as a result of interaction of the learner with his environment. Since the use of process – based teaching affords learners opportunity for interacting with the environment through rich and stimulating activities, it is quite a possible influence on individual's reasoning ability.

Formal reasoning is highly relevant to science education as it is involved in most of the scientific process skills, for example, predicting, inferring, interpreting data and problem solving. The teaching of science is often justified on the ground that children need to develop logical and formal reasoning that epitomize science (Lawson, 1993). German (1994) observed that one of the major goals advocated in science education is to help students construct knowledge concerning scientific phenomena and at the same time help them to think critically and solve problems. Many educators have called for infusing the teaching of reasoning skills into regular disciplinary courses. For example, Zoher et al (1994) pointed out that the infusion approach may contribute not only to the development of reasoning skills but also to better understanding of the discipline under study as incorporating the teaching of thinking skill into any curricula of any discipline will decrease reliance on memorization and thus enhance higher order learning. To date, reasoning demands associated with concept achievement in science have been analyzed largely within the context of the instructional process (Wollman and Lawson 1978). Herron (1975) has outlined the capabilities and limits of students who use concrete reasoning patterns. Such students according to him, can make inferences which are direct extrapolations from observations but they cannot make inferences which are "twice removed" from the observation. He suggests that certain chemical concepts, for example, are "formal" because they require formal reasoning patterns to understand, whereas other concepts are "Concrete" because they require only concrete reasoning to comprehend.

The logical relationship between cognitive development and integrated science processes is discussed in some literature. Wood (1974), for example presented a piaget process matrix which focused on the need to consider the cognitive development of learners when planning a science programme to teach science process skills. Wood's particular emphasis was on the direct links between formal thought and integrated science

processes such as identifying and controlling variables and hypothesizing. Good (1977) raised doubts about the integrated process skills for students in lower classes in secondary schools. He noted that current research on cognitive development suggested that ten and eleven years old students would have difficulty in controlling variables, interpreting data and making generalizations. On one hand, therefore, cognitive limitations may prevent students from learning integrated science process skills. On the other hand, exposure to systematic science programme, which emphasized integrated science process skills, may promote cognitive development.

Although many studies in curriculum reform projects like NISP, SEPA etc have been undertaken in Nigeria, however, science teaching remains primarily didactic, dominated by lecture, demonstration, text-book readings and memorization. Biehi (1989) laments that many teachers teach science using lecture method and avoiding the use of instructional methods that provides students first hand experiences and opportunity to solve problems. Araoye (1991) observed that the inability of students to perform higher order skills has been of great concern lately. She stressed that lower order skills of recall and recognition seem to gain more emphasis in schools. This concern according to Good (1983) is as a result of observed passiveness of most students in the classroom and the lack of curiosity of science educators to challenge students to think. Students cannot develop reasoning ability if they are not provided with the activities that could motivate them to reason. Tannenbaun (1971) pointed out that proficiency in every skill can only be developed through practice with same. Thus, learner's formal reasoning capacity can only be developed through exposure to relevant activities. Barbel and Chipman (1976) asserted that individual's development is a function of multiple activities and suggest that the environment influences the physical development of individual and his thought. Jungwirth and Breyfur (1990) pointed out that studies that assess students thinking ability

reveal that students often fail in tasks that require formal reasoning. It appears that formal reasoning does not develop significantly unless explicit and deliberate efforts are made in developing them (Zoher et al 1994). Friedler and Tamir (1986) have also shown that learning experiences that are explicitly designed to develop reasoning skills can achieve their goals to various degrees.

The experiences gained from interaction activities help to develop mental framework which is used to process encounters with the environment. Ogundele (1987) opined that teaching of process skills encourages teachers to administer activities which involve students mentally and provide numerous opportunities for students to think their way out of such problems. Student's active participation in learning activities is known to enhance intellectual development of learners. Berg and Philips (1994) pointed out that active participation (both physical and mental manipulations of objects and their relationships by the learners) is crucial for intellectual development. During their active participation, information received physically and mentally is assimilated to the learner's current mental structures while accommodating (re-organising or adapting) his or her structures to the distinct characteristics of the data.Children's thinking ability are evolved to compensate for the interaction with the environment. This balance between self and environment was coined by Piaget(1964) as equilibration and described as essential for the development of potent dynamic mental structures applicable to various contents.

To show that science process skills and formal reasoning variables are correlated is primarily of academic interest. Of practical interest to educators is the influence one may have on the other. Padilla (1983) pointed out that if two variables are correlated, one may be influencing the other hence he called for an experimental study to determine this. This study is aimed at establishing if increasing the process skill abilities of students will have significant effect on their formal reasoning ability.

The process – based activities are designed and infused into learning tasks to see if it will have an influence on the subjects' formal reasoning ability. Watson (1972) pointed out that the suitability of a content is its ability to facilitate formal reasoning. The teaching of process skills is highly emphasized by science educators, however, there seems to be few related studies to ascertain its effectiveness in developing formal reasoning ability. This study is meant to establish if acquisition of science process skills has effect on students formal reasoning ability.

1.2 SCIENCE PROCESS SKILLS.

Science process skills are intellectual skills needed to learn concepts and broad principles used in making valid inductive inferences (Gagne',1970). The commission on science education of the American Association for the Advancement of Science (AAAS) has identified 11 process skills which are considered to be representative of problem solving activity. These process skills are categorised into two groups.

a. Basic process skills i.e. observing, measuring, inferring, predicting, classifying and collecting and recording.

b. Integrated process skills i.e. interpretation of data, controlling variables, defining operationally, formulating hypotheses and experimenting.

According to Gagne' (1970) the process skills are hierarchically organized with the ability to use each upper level process being dependent on the ability to use the simpler underlying process.

Finley (1983) identified the major feature of the process skills as;

i. each process is a specific intellectual skill used by all scientists and applicable to understand any phenomena.

ii. each process is an identifiable behaviour of scientists that can be learned by students.

iii. being generalizable (transferable) across content domains and contribute to rational thinking in every day life".

This study assumes that subjects are capable of acquiring these intellectual skills that scientists employ in scientific investigation through planned hands – on activities. Padilla et al (1983) established a high relationship between integrated process skills and formal reasoning ability and postulated that exposure to integrated process skills may have positive influence on the development of formal reasoning. The process – based activities involving the use of three integrated process skill (experimenting, hypothesizing and interpreting data) are designed and subjects are exposed to them for six weeks in this study. They are posttested at the end of the instruction to find out if there is improvement in their formal reasoning ability. The integrated process skills that the subjects were exposed to are:

1. Formulating questions and hypotheses:

Questions are formed on the basis of an attempt to evaluate situation. They point to specific problems to be solved. Hypotheses on the other hand, are based on the questions under investigation. Okebukola (1985) defined hypothesis as making wise guesses as tentative and unproven answers to questions raised. It is usually a statement that can be tested through experiment. In this study, subjects were led to formulate hypotheses and then design experiments to test them.

2. Experimentation:

This involves designing an investigation to find out the effect of independent variables on dependent variables. Failure to identify significant variables and control them affect results. In designing experiments, limitations of the method and apparatus

must be considered.

3. Interpreting data:

This is the act of deriving meaning from the data gathered thus providing answers to questions under investigation. At the simplest level, interpretation of data involves identifying changes in size, shape, position and judgment of validity and usefulness of data.

The development of formal reasoning and science process acquisition have been described as major goals of teaching science (Lee, 1993). This is because the two variables are known to correlate highly with achievement in Science. Norman (1997) reported that development of process skills and formal reasoning ability promote students' general achievement. Educators have also pointed out that formal reasoning is essential for students to undertake inquiry that involve the use of process skills.

Several studies have been conducted which dealt with students' acquisition of integrated process skills (Boyer and Linn 1998) One of the characteristics of these investigations is the implied correspondence between the integrated science process skills and intellectual development. For example, Linn and Thier (1975) examined the effect of SCIS on "the development of logic thinking measure which tested students' abilities to understand the role of compensating variables when a cart rolls down a ramp. In their rationale for expecting SCIS students to perform well on this task they state that SCIS students "engage in scientific processes". Yet neither these authors nor others cited above, made an explicit link between the constructs of integrated science process skills and many of the multiple aspects of formal operation thinking. Tobin and Capie (1981) found a significant inter correlation ($r = 0.60$) between formal reasoning ability and process skills achievement.

To show that process skills and formal reasoning are correlated suggests that the influence of one on the other can be determined. If two variables are correlated, one may be influencing the other, a follow up experimental study will determine this (Padilla et al, 1983). This study provides empirical information that will further shed light on the effect of process-based instruction on subjects' formal reasoning.

1.3 STATEMENT OF THE PROBLEM

Science process skills and formal reasoning ability, in students are essential in problem solving and have been shown to transfer to other curriculum areas (Zohar et al, 1994). The innovation of curricula like NISP and SEPA is based on the fact that formal reasoning and science process skills can be taught. Lee (1993) investigated the effects of science process skills training and reported that such training would promote the acquisition of science process skills. On the other hand, Baid and Borich (1985) investigated the correlation between science process skills and formal reasoning and reported that the two variables though different are significantly correlated. Correlational work is the first step in establishing a causal relationship. Padilla (1983) observed that if two variables are correlated, one may be influencing the other, therefore there is need for a follow up study to determine the influence of any of the two variables on the other. Good (1977) pointed out that exposure to a systematic science programme, which emphasizes integrated science processes, may promote cognitive development. This study is aimed at establishing if exposure of students to process skills instruction would have significant effects on their formal reasoning ability.

Specifically, the study sought to answer the following research questions:

1. Does process-based instruction have any significant effect on students formal reasoning ability?

2. Does science process-based instruction have any significant effect on students' achievement in the following formal schemata or schemas:

   (a) conservation

   (b) proportional reasoning

   (c) control of variables

   (d) correlational reasoning

   (e) combinatorial reasoning

   (f) probabilistic reasoning.

3. Do subjects in concrete operational and formal operational stages differ significantly in performance in solving science process skills problems?

4. Do boys and girls differ significantly in:

   (a) acquisition of formal reasoning ability?

   (b) ability to use conservation reasoning, proportional reasoning, control variables, correlational reasoning and combinatorial reasoning.

   (c) acquisition of science process skills?

1.4 NULL HYPOTHESES

The following null hypotheses are stated for testing:-

1. There is no significant difference in the formal reasoning ability of the subjects in the experimental and control groups after exposure to process-based instruction.

2. There is no significant difference in the pre and posttest mean scores of the subjects in the experimental group in the following skills.

   (a) conservation

   (b) proportional reasoning

   (c) control of variables

(d) correlational reasoning

(e) combinatorial reasoning

(f) probabilistic reasoning.

3. There is no significant difference in achievement between concrete and formal operational subjects in the experimental group in science process-skills ability after exposure to process-based instruction.

4. There is no significant difference in

(a) formal reasoning ability of the male and female subjects after exposure to process-based instruction.

(b) the posttest mean scores of the male and female subjects in the following formal reasoning components after exposure to process based inspection:

(a) conservation

(b) proportional reasoning

(c) control of variables

(d) correlational reasoning

(e) combinatorial reasoning

(f) probabilistic reasoning

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(c) the performance of male and female subjects in science process skills tasks after treatment.

1.5 THE PURPOSE OF THIS STUDY

The literature suggests that formal reasoning ability can only be acquired if right instructional medium is provided. The suitability of instructional method is determined by its viability in promoting the acquisition of formal reasoning and problem solving ability in learners. The purpose of this study therefore, was to establish, if exposure of secondary school students to process skills instruction would significantly improve their

reasoning ability. It is also to determine if acquisition of formal reasoning ability and science process skills if gender-related in any significant sense.

The study was also aimed at determining the prevalent mode of reasoning among secondary school students, which is a factor in determining the suitability of learning contents for students. Most of the chemistry concepts taught in secondary schools have been described as formal, hence can only be grasped conceptually by students that have from cognitive point of view, acquired formal reasoning.

1.6 THE NEED FOR THE STUDY

Formal reasoning ability is crucial for effective science instruction. This is because students' scores on formal reasoning ability have consistently shown appreciable correlation with achievement in science and other areas (Roadrangka, et al, 1983). It is on this basis that effectiveness of a programme in promoting learners' formal reasoning ability is used as criteria for selecting programmes or learning experiences to be included in curriculum. Several authors reported correlation between integrated process skills and formal reasoning (Padilla, 1977, Lee, 1983); indicating that the two variables interact with each other. However, little has been done to investigate this relationship despite strong logical similarities between the two abilities. Padilla et al. (1983) in their attempt to establish a relationship between these abilities merely correlated subjects scores on the two measures. There was, however, no treatment given to the subjects to establish if exposure to science process instruction increases students' reasoning ability. This study will help in establishing the relationship, if any, between these two abilities and also the effect of process skills instruction on students' formal reasoning. The findings from this study will provide empirical data on suitability of process – based instruction as a means of promoting formal reasoning.

Science educators have pointed out the need for science instruction that enhances the acquisition of science process skills and problem solving skills by learners. However, literature shows that teachers are ill–prepared in guiding process – based activities (Mari, 1994). Wideen (1977) reported that teachers stated more process skills objective after exposure to science process skills programme. The process-based activities designed may serve as model lessons plan for teachers who are ill–prepared to design such lessons.

Since curricula are generally designed for both male and female students, attempt is made in this study to determine if gender plays any significant role in the acquisition of science process skills. The results, it is hoped will aid teachers to plan lessons to take care of individual/gender differences in the teaching / learning of science.

Studies also show that science process skills are hardly assessed in Nigerian schools (Yashen, 1991). This may be that teachers are ill–prepared to design test items that assess students' understanding of process skills. The research instruments used in this study could serve as useful tools for teachers to adapt or adopt for use in assessing learners understanding of science ability.

1.7 DELIMITATION OF THE STUDY

The study was undertaken to identify the effect of process–based activities on formal reasoning. The process-based activities involved the use of three integrated process skills namely hypothesizing, experimenting and interpreting data. Some of the reasons that informed the decision to centre the activities on only three of the 11 process skills stated in section 1.2 include:

(a) ensuring that subjects acquire proficiency in the use of all the process skills chosen within the time available.

(b) the materials and chemicals available.

(c) the skills have been reported to correlate highly with formal reasoning.

Subjects used for the study were SSS II students randomly drawn from Schools in Sabon-gari Local Government of Kaduna State in Nigeria. SSS II students were chosen to avoid distracting the attention of the SSS III students who were about writing their final examinations. The SSS I students, on the other hand, were not chosen because they are considered to be relatively handicapped in the knowledge of the concepts on which the activities were based. Sabon Gari Local Government Area was chosen, because it is the closest Local Government area to the researcher where all categories of Schools: private schools, Government Secondary Schools, and Federal Government Colleges could be found. Other reasons that influenced the choice of the area for the study were; the consideration of gender factors availability of co-educational and single sex schools, the possibility of having a sufficiently large sample for meaningful generalization, the proximity and finances available to the researcher.

1.8 SUMMARY

The importance of formal reasoning in learning science cannot be over-emphasized. Studies, however, have revealed that majority of the students in secondary schools have not attained formal reasoning ability. This has stimulated concern by science educators to seek for ways of ensuring that students acquire formal reasoning ability. The process-based instruction seems a suitable method for facilitating the acquisition of formal reasoning. Five hypotheses will be tested to provide empirical data that will determine the suitability of the method in promoting acquisition of formal reasoning ability. Other variables like gender and concrete reasoning ability were considered.

CHAPTER TWO

LITERATURE REVIEW

2.1 INTRODUCTION

In this chapter, a review of pertinent literature is made in an attempt to put the present study in a proper perspective. The review is organized into the following sections;

2.2 Science process–based instruction

2.3 The meaning of formal reasoning

2.4 Importance of formal reasoning in science education

2.5 The effect of instruction on formal reasoning

2.6 Stages in Cognitive development

2.7.0 Related Literature

2.7.1 Related studies in Nigeria on acquisition of formal reasoning

2.7.2 Related studies, elsewhere in formal reasoning and science process skills acquisition

2.8 Implication of literature review for the present study

2.9 Summary.

2.2 SCIENCE PROCESS–BASED INSTRUCTION

This method of teaching originated in United States of America (USA) in 1960s. The method assumes that science is much more than an encyclopedia collection of facts and that children even in the primary grades, will derive much more from the study of science if they learn the behaviour of scientists. Brown (1979) pointed out that although behaviour of a scientist are complex, they have been classified into a number of process skills, some simple and some more complex. The acquisition of these intellectual activities of the scientist, the process skills, forms the goal of science instruction.

In this method of instruction, the ability to read and the mastery of subject content is not so essential as it is in many traditional curriculum. Thus, inquiry into science can begin as early as nursery school. Success does not depend on reading skills, but on process skills ability in science. Content is used to develop process skills and both teacher and students are actively involved in categorizing and synthesizing information from nature.

Because of the importance of science process skills in inquiry, they are described as scientific reasoning skills. German et al (1996) pointed out that classroom studies of scientific reasoning in science education have centred around the basic and integrated science process skills as key elements in inquiry. Gagne' (1970) described them as foundation for scientific inquiry.

The integrated science process skills form the core of hypothetico–deductive form of inquiry based, hand–on learning in which students use reasoning to construct knowledge by recognizing and stating problems, asking questions, in a manner that will allow them to pursue answers, formulating hypotheses, identifying variables, reaching conclusion concerning their observation and questions about natural phenomena and recognizing that these answers are both the final product and the starting point for further study. These skills enable students think logically, ask reasonable questions, seek appropriate answers and solve daily problems.

2.3 THE MEANING OF FORMAL REASONING.

Formal reasoning involves carrying out operations using symbols, and abstract ideas from the mind. It also involves the use of interpropositional operations and the exploration of all possibilities by subjecting the problem variables to a combinatorial analysis. According to Gage and Berlinger (1984), subjects at this stage can consider

logical possibilities for a given problem. This capability is not mere imagination but entails systematic exploration of logical alternatives. Wollman (1982) further stressed that subjects can make accurate comparison and deduction from information not concretely presented by thinking on his own. They can draw conclusion, offer interpretations and develop hypotheses.

Inhelder and Piaget (1958) divided formal operations into two broad classes, namely, propositional operations and formal–operational schemes. These categories of formal operations are regarded by Piaget as the immediate underlying genotypes that make the phenotypes of hypothetical– deductive reasoning, scientific reasoning and reflective abstraction possible. Flavel (1970) pointed out that propositional operations is oriented toward the possible and hypothetical and that one manifestation of this orientation is the tendency for those who have acquired formal reasoning to explore all possibilities by subjecting the problem variables to a combinatorial analysis. He further stressed, that the analysis gives him a cognitive picture of what the extant possibilities are for him to observe and experiment to determine which of these possibilities occurs as realities and from this information make logical deductions about the causal structure of the systems. This network of hypothetical possibilities which the formal "operational reasoner" has generated constitute what Piaget described as complete lattice structure that is behind formal reasoning.

On the other hand, formal operational schemes, the main focus of this study are less abstract and more highly specialized than propositional operations. According to Piaget, they are derived from propositional operations and are thought to be methods whereby propositional operations are applied to certain reasoning situations that occur with great regularity in the environment. Inhelder and Piaget (1958) defined them as latent potentiality of propositional operations that are elicited by certain common but

restricted situations in the environment. Brainerd (1978) pointed out that the difference between propositional operations and formal operational schemes lies in the degree of specialization. Formal operational schemes are adapted to the demand of certain forms of information from the environment, while the proportional operations are extremely general and equally applicable to all forms of information. Formal operational schemes can only be applied in specific reasoning situations like formulation of scientific laws as they are adapted to extracting the functional relationship such laws are concerned with.

This study determined the influence of process–based instruction on conservation and the other formal schemata discussed below:

i. Conservation

This referred to the ability to understand the features of physical concept in the face of transformations. To acquire conservation skill, an individual must be able to reverse operations, and understands transformations.

For example, a child would have to be aware that 2 + 4 + 3 and 4 + 2 + 3 etc will always add up to the same quantity no matter how it is presented. Similarly, he would need to achieve reversal of number such that he could solve any combination of the problem 2 x 6 = 12 or 12/6 = 2 or 12/2 = 6, all of which require knowledge of reversals. Decentering, another process linked with conservation involves the realization that the same fundamental quality be it volume, area, weight, space etc exists no matter how the dimensions might be altered. This is because the child's attention is no longer fixed on the dimension.

Piaget (1970) pointed out that children understand what he called reversibility rules ie inversion (Negation) and compensation (reciprocity) before they acquire the process of conservation. For example, children who understand the principle of inversion know that the transformation performed on an object (V) from an experimenter to change

it from V_1 to V_2 can also be carried out in the opposite direction V_2 to V_1. Further, they know that if the deformation were carried out in the opposite direction, then (V) could look exactly like it did when the test began. Compensation or reciprocity is acquired when subjects know that the experimenter's deformation produces more than one change in (V) and what is more, these various changes tend to compensate one another. That is, if the experimenter's deformation produces a certain feature of (V) (height, length, width etc), it also produces an equal and opposite change in some other features of (V). According to Piaget, children must be able to apply the principles of inversion and reciprocity as described above before they can conserve.

ii. Proportionality.

Proportionality in the broadest sense refers to subjects understanding of the fact that the ratio of two qualities (x/y) is equal to the ratio of the two other qualities (x^1/y^1). Inhelder and Piaget (1958) pointed out that the proportional scheme has two aspects, one logical or ordinal reasoning and the other mathematical. According to him, logical or ordinal reasoning develops before metrical or mathematical reasoning. Using the balance, for example, the subjects first by ordinal reasoning discovers that the greater the weight, the lower the arm and the farther from the line of equilibrium. This leads him to discover a linear function and to understand a first condition of equilibrium ie the quantity of weights at equal distances from the central pivot. Also by ordinal reasoning, he discovers that a single weight pulls the arm down more the father it is placed from the pivot. This leads him to discover a linear function and understands that equilibrium is attained for two equal weights provided they are at equidistant from the pivot, however, long the distance (l) may be. He finally by ordinal reasoning derives the hypothesis that when you begin with two equal weights at equal distances from the center, you maintain equilibrium by decreasing one weight but moving it further away or by increasing the

other weight and moving it closer to the center. It is only then that he grasps the simple metrical proportion, W/L = 2W/2L, but he discovers this by beginning with qualitative Proportion, that is that decreasing the weight and increasing the length is equivalent to increasing the weight and decreasing the length.

iii Control of variables.

Variables are factors that are known to independently affect a system. In every given situation, few or many variables might be responsible for an observation. An individual that has acquired formal reasoning ability is able to isolate all variables affecting the system and subject them to combinatorial analysis. Flavel (1970) pointed out that one manifestation of formal reasoning is the ability to explore all possibilities by subjecting the problem variables to a combinatorial analysis. This analysis provides a cognitive picture of what the extant possibilities are; the next steps are to observe and experiment to see which of these possibilities occurs as realities and from this information they are able to make logical deductions about the causal structure of the system.

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iv. Probability

This is the ratio that is expressing the chances that a certain even will occur. The concept of probability can only be comprehended when subjects understand what sort of events are probable (chance occurences) and those that are necessary. According to Inhelder and Piaget (1958), those that have attained the concepts are able to divide events in the world into two broad categories:

a. Things that must absolutely happen because they are governed by natural laws
b. Things that should only happen because they are not governed by any natural law.

He pointed out that the development of probability scheme consists of three global stages that correspond to pre-operational, concrete operational and formal

operational levels. Pre- operational subjects fail to grasp the distinction between events governed by natural law and those governed by chance. They tend to think that chance events may actually be governed by natural laws. Concrete operational subjects, however, are able to distinguish chance events from lawful ones. They are able to make this distinction by realizing that there are certain situations in which they cannot figure out a rule that allows them to make perfect predictions. However, they still have difficulty in distinguishing between events that are more and less likely to happen. The frequency principle that govern systems of chance events are not discovered until the formal operational stage. According to Piaget, this principle is only required in formal operational stage because the formulation of such statements calls for the application of the proportionality scheme which is a formal operational achievement.

v. Combinatorial reasoning.

This is the kind of reasoning that is concerned with determining how many different ways a certain operation can be performed on a certain set of things. Flavel (1970) pointed out that combinatorial reasoning involves determining all the possible relations inherent in a problem so as to make sure that all can be tested for reality status, none over looked. It is a systematic way of isolating all the possible variables plus all possible combinations of these variables. According to Piaget and Inhelder (1977) combinatorial system is of prime importance in the extension and the re- enforcement of the power of thoughts. Once established, it enables the subjects to combine among themselves objects with objects or factors with factors or similarly ideas or propositions and consequently to reason about a given reality (a segment of physical reality, an explanation based on factors or a theory in the simple sense of a group of related proposition) by considering this reality no longer in its limited and concrete aspects but in terms of some or all of the possible combinations, that is one must at least be able to

conceive or imagine all possible hypothetical arrangement of set of objects. This ability, which is believed to be absent at the concrete operational stage is a direct consequence of proportional operations (Inhelder and Piaget, 1958).

vi. Correlation

This expresses a mutual relationship or connection in which one thing depends on another. Correlation could be described as follows;

a. *Perfect positive correlation – This is a term by term correspondence between the* values involved in case of serial ordering.

b. Perfect Negative correlation - This is an inverse correspondence between the values involved in a serial ordering.

c. Zero correlation – This expresses an equal distribution of the events stated by the prepositional conjunctions.

The distribution of events may not take any of the pattern outlined above. For example, the empirical distribution may be irregular due to chance interferences.

According to Inhelder and Piaget (1958), where this occurs, subjects who know nothing about mathematical probability are limited to the use of a logical schema. They have to guess at the corresponding numerical frequencies and simply compare the number of confirming cases to the number of non – confirming cases. If one of the sets is numerically superior to the other with a sufficiently observable margin, they conclude that there is a causal relationship, whether negative or positive and explain the minority cases by the interference of chance variables.

However. the notion of correlation can only be understood and applied by *subjects in formal operational stage. First, a correlation is sought only when a causal* relationship remains in part veiled by partial chance distribution, and in order to think of separating out this two sort of elements one has to distinguish the probable from the

determinate. Secondly, the search for correlation does require a combinatorial system, understanding of proportion and probability which are all formal schemas.

2.4 IMPORTANCE OF FORMAL REASONING IN SCIENCE EDUCATION

In central role of cognitive development and its relationship to other areas of life span development have captured and held the interest of researchers and educators particularly over the last decade or so (Karplus et al, 1980). The growing concern for adapting curricular contents, achievement goals, instructional methods, and evaluation strategies, to students level of cognitive development has led to great usage of research in the field of the influence of Piagetian concepts of concrete and formal operational thought upon science education (Lawson and Renner, 1978; Shayer, 1979).

Investigators have shown that full comprehension of some science concepts by students requires what Piaget defines as formal reasoning (Ingle and Shayer, 1971). For example, Herron (1975) suggests that certain chemical concepts are "formal" because they require formal reasoning patterns to understand whereas other concepts are "concrete" because they require concrete reasoning to comprehend.

According to Herron (1978), to increase comprehension of science, we must either assist students in their development of reasoning or we must learn to teach so that ideas of science are understood by students who remain at concrete operational level. Other researches have pointed out that certain concepts no matter how they are taught can not be comprehended by students at the concrete operational level. Gobdstein and Howe (1978) after use of some "hands – on" method to teach students some chemistry concepts, reported that concrete level students can not learn concepts which require advanced formal reasoning, no matter how the concepts are taught.

Formal reasoning is also known to affect the application of scientific concepts in novel situations. Staver and Halsted (1985) reported that formal reasoning enhanced the application of concepts. This is expected, as students can only apply concepts when they have fully comprehended them.

The ability to solve problems in science is also dependent on intellectual development. Gabel and Sherwood (1983) pointed out that two factors appear to be related to students problem solving ability are proportional reasoning ability and mathematic anxiety. Proportional reasoning ability is one of the Schemas that comprise the formal operational stage, which has been shown to be related to students success in chemistry, particularly their problem solving ability was dependent on students proportional reasoning ability. Lawson, et al. (1978) observed that understanding of proportional relationship as being embedded in numerous physical and biological concepts. Combinatorial reasoning is required for comprehension of mendelian genetics, while correlations represent the cornerstone of much of the descriptive investigative work of biologists and psychologists. In short, formal operational Schemas not only play a role in students understanding of important science content but also play a major part in the problem of scientific investigation.

The understanding of explanation concerning natural phenomena does require formal reasoning. Bass and Maddux (1982) pointed out that causal explanations exhibit formal operational reasoning ability in that they consist of implication statements chained together through transitive reasoning. Individuals who do not reason formally will have difficulty organizing explanations into memory in such a way that they can be reconstructed effectively. According to Inhelder and Piaget (1958), concrete operational subjects can deal with propositions and have an awareness of implications when reasoning rests upon direct observation and not upon assumption. Bass and Maddux

(1982) suggested that the teaching of explanation should not be suspended until students demonstrate formal reasoning capabilities. He stressed that concrete operational learners can likely follow step by step logic of an explanation when the external structure are supplied, but they probably will not integrate the various steps into a "structural whole" that enables the explanation to be restructured on demand.

It has also been hypothesized that students achievement in science is a function of repertoire of information schemata. Lawson (1983) however, argues, that the effect of cognitive development on achievement depends upon what the student is supposed to achieve. He emphasized that if the student is supposed to learn discipline specific facts and concepts, then the best predictor of his or her ability to do so should be number of discipline specific facts and concepts the students has already acquired. However, if the student is asked to think beyond specific fact or concept and perform certain operational transformations on them, then his or her repertoire of information schemata as reflected by Piagetian development level should be a predictor of performance. Other studies have shown that even the acquisition of discipline concepts depends on the cognitive stage of the learner. For example, Herron (1975) outlined the capabilities and limits of students who use concrete reasoning patterns. Such students can, for example " make inferences which are direct extrapolations from observations but they cannot make inferences which are twice removed from observations". He further suggests that certain chemical concepts are formal because they required formal reasoning pattern to understand whereas other concepts are "concrete" because they require only concrete reasoning to comprehend.

There seems to be general agreement by most science educators that formal reasoning is the central core of science education. This suggest the need for the development of a sound psychological theory and set of teaching principles to best promote the development of students formal reasoning ability.

2.5 THE EFFECT OF INSTRUCTION ON FORMAL REASONING.

The increased awareness of the need to adapt curricula to the developmental level of learners has motivated a search for reliable and valid measures of those levels (Lawson, 1978). Piaget tests of formal reasoning abound. These cognitive measures are essential for the teachers to identify learners into various cognitive levels in order to design instruction that will match individual cognitive abilities.

For the past three decades, researches have shown that large proportion of high school students and college freshmen are not able to apply abstract reasoning to concepts in science courses (Dunlop and Fazio, 1974; Bender and Millakofky, 1982). This has prompted the interest of researchers and educators particularly on how instructional strategies can be designed to match the cognitive level of learners and the various ways that can be employed to stimulate cognitive growth. Goodstein and Howe (1978) pointed out that if modern chemistry concepts are to be taught effectively to any but the brightest students, some way must be found to make the concept accessible to students who are not yet at formal operational level. Herron (1975) argues that many chemical concepts can be expressed at the concrete operational level and that this level should be used with learners who are themselves at this level. He suggests that students at the concrete level who are exposed to a formal reasoning should be provided with concrete props which model abstract concept. This will enable them acquire a surrogate concept that they can manipulate and that will assist the transition to the real concept at a later time.

Several investigators have sought to determine whether the use of manipulable materials lead to higher level of concept attainment for concrete/ or formal operational students. Sheehan (1970) found that use of concrete materials was more effective for both concrete and formal operational students. Goodstein and Howe (1978) reported that only the formal operational chemistry students benefited from the use of models in connection

with the study on stoichiometry. Gabel and Sherwood (1980) found that use of molecular models by students in chemistry classes over an entire school year increased achievement for both concrete and formal operational students.

Other studies however, do not lend support to the view that any subject may be successfully taught if concrete "hands-on" method are used. Gooodstein and Howe (1978) observed that three factors must be taken into account viz: the cognitive level of the learner, the conceptual level of the material and the method of instruction. They pointed out that if the conceptual level of the material to be learned is too high, "concrete" methods of instruction will not benefit the concrete level students or in other words, concrete level students cannot learn concepts which require advanced formal reasoning no matter how the concepts are taught.

Some educators have equally called for instructional method that promote the development of formal reasoning ability. This is because comprehension of some science concepts require formal reasoning ability, no matter how it is taught (Lawson, 1982). Various methods that aid cognitive development have been suggested Wollman (1982) pointed out that educators have long been calling for "hands – on" experiences for going from concrete to formal stage and basing instruction on what the learner already knows. Studies clearly revealed that performance can be significantly enhanced (Lawson, 1985). He further stressed that the extent to which the training transfers to novel problems and contexts and even to novel reasoning patterns depends upon the length and richness of the training and the extent to which learners are intellectually in control of their actions. In studies in which instruction is short-term and very teacher directed, improvements occur but are limited to trained tasks or very similar ones. When instruction is more diverse, long-term and less teacher directed the extent of improvement in any one area of formal reasoning may be less but improvement are more generalized i.e they exist across a wider

spectrum of formal reasoning. It seems that the pace of general development is regulated by the learners own internal regulatory mechanisms and the richness of the thought provoking environmental encounters. The process of equilibration /self-regulation then becomes one of the considerable pedagogical significance.

Though some studies have shown that cognitive development can be enhanced through appropriate instructional strategies, others indicate that not all subjects may benefit from such instruction. Piaget (1972) hypothesized that normal individuals vary in aptitude for formal reasoning, therefore, some individuals, even in favourable environments, will fail to attain formal reasoning. Lawson (1982) pointed out that low mental capacity, impulsivity and field dependent characteristics are hindrances to the acquisition of formal reasoning patterns.

It would appear that, although some students do not need our help and some may be beyond our help, the majority of the students can and should be assisted in their acquisition of formal reasoning patterns. The clear Education implication is that many courses in many disciplines, over an extensive period of time should more directly concern themselves with the development of formal reasoning. Lawson (1985) pointed out that many decisions must be made to arrive at approaches reasonable for specific grade levels and specific disciplines, yet the training studies are very encouraging as they suggest that such efforts would pay off handsomely in improved reasoning ability and improvement in general academic achievement.

2.6 STAGES IN COGNITIVE DEVELOPMENT.

Intelligence can be and has been studied through the cognitive processes that changes as young people mature. The primary deciples of the theory of cognitive development are Inhelder and Piaget (1958) whose theory on the growth of logical

thinking from childhood to adolescence stimulated extensive interest in cognitive development. They pointed out that intelligence develops not by virtue of maturation alone nor by learning alone, but as a result of the interaction of the child and his environment. They further proposed that cognitive development plays two essential roles. First, cognitions are organizing units that structure meanings and relations. Second, cognitions allow the individuals to adapt to environmental changes.

The adaptation mechanism according to them, include a balance between assimilation and accommodation process. In establishing a balance, an individual may modify his thoughts while at times it is appropriate to seek out information that confirms an existing perspective. Adams and Gullota (1991) observed that when one system dominates the other, then limited adativeness ness in cognitive growth and functioning occurs.

The cognitive development theory assumed that cognitions are transformed through an interaction between maturational mechanism and environmental experiences as the individual matures. It also postulates that a series of major sequential changes occur in how one understands the world and that at different stages of development, various kind of logical operations are available for processing information and understanding physical and social environment. Piaget (1958) proposed five stages in intellectual developments viz:

1. Sensori-motor stage (0 – 2 years)
2. Pre–conceptual stage (2 – 4 years)
3. Intuitive thought (4 – 7 years)
4. Concrete operations (7 – 11 years)
5. Formal operations (11 – 15 years)

The last two stages are relevant to this study as the subjects are in the age bracket

of 10 – 16 years. Adams and Gulotta (1991) pointed out that pupils at the ages of between 10 – 16 are operating in either of the two stages. The characteristics of pupils in these two stages are discussed below:

a. Concrete operational stage (7 – 11 years).

At this stage, a child can easily operate concrete objects in front of him to solve problems. Gage and Berlinger (1984) confirmed that the child becomes capable of various logical operations but only with concrete things. Adams and Gullotta (1991) further stressed that mental apparatus available limit cognition as children focus upon very concrete operations. They also understand that physical and social elements can be transformed into various shapes, sizes, ideas and so on and that certain mental operations can be reversed.

Another characteristic of children at this stage is the understanding of concepts of seriation. The child engages in the intellectual task of ordering more than two elements. For example, the child understands that if A < B and B < C then A < C. The thought of seriation of length emerges before seriation of weight, with the seriation of volume emerging at the end of the stage.

The concept of classification also emerges at this stage. Children now understand that mangoes and oranges are all fruits hence can perform logical operations of the addition of classes. They also come to know that there are multiple subclasses of a large class. Child (1977) confirmed that seeing relationship between groups and understanding similarity and subordination of classes are essential skills in concrete operational reasoning. The concrete operational child, however, finds it difficult to solve problems involving hypothetical settings and reasoning through completely verbal or highly complex information.

b. Formal operational thought (11 – 16 years)

Keys (1995) pointed out that at this stage, the child has entered the adolescence period which corresponds to the period of Junior Secondary School Education. The child is

capable of carrying out operations among symbols and abstract ideas from the mind can equally be perceived. The following characteristics may be exhibited by pupils :-

i. Hypothetic – deductive thinking: for example, they can formulate hypotheses as testable ideas in their mind.

ii. They can think in abstract, hence can distinguish both real and concrete from the abstract.

iii. They can control variable to isolate the one affecting the situation.

iv. They can engage in tasks on ratios, proportions and combinatorial logics.

v. They are reflective thinkers hence are capable of thinking back over series of mental operations and reflecting on them.

The process-based activities designed in the study, will provide learners the opportunity to employ some of these skills or abilities in solving problems. These activities require the use of formal thought processes to plan, collect and interpret data to provide solution to problems posed in the course of the activities. Learners are expected to develop in their formal thinking processes as they participate in these process – based activities.

2.7.0 RELATED LITERATURE

2.7.1 Related Studies in Nigeria on Acquisition of Formal Reasoning

Though there has been growing emphasis on the need to promote the acquisition of formal reasoning, however, there seems to be relatively few studies on cognitive development in Nigeria in relation to formal reasoning abilities.

Onocha and Okpala (1987) carried out a study to investigate the formal reasoning ability and age group of 600 preservice primary school teachers. The test of logical thinking developed by Tobin and Capie (1981) was adapted and used. Their results revealed that:

i. Slightly more than half of the preservice teachers (52%) were able to utilize formal

reasoning ability to solve problems presented in the TOLT.

ii. A large proportion of the pre – service teachers (72%) were unable to provide correct responses and justification for the items which attested probability reasoning mode.

iii. A great proportion of the preservice teachers (88%) provided correct responses and justification for items which addressed correlational reasoning mode.

iv. A greater proportion of the preservice teachers (72) were unable to use combinatorial reasoning to solve problems in the TOLT.

v. Most of the formal reasoners were either male or preservice teachers within the age bracket 28 – 36 years.

The results support the findings by Onocha, and Okpala (1986) which shows that a considerable number of preservice teachers in Australia demonstrated limitations in the use of formal reasoning ability. The researchers pointed out that the subjects may likely experience difficulty in planning and implementation of activity – centred investigation since formal reasoning pattern facilitates the ability to plan and implement science investigation. They may in addition, unable to identify deficiency in reasoning ability or promote its development in pupils.

Ehindero (1982) investigated the effects of certain ecocultural factors on operational thought among adolescents living in non – western cultures. The subjects consisted of non – schooled nomadic Fulanis and schooled agriculturalist. A total sample of 80 subjects whose ages ranged from 15 – 19 years was used. Four spatial tasks (tangrams, topological spatial relation, location of topological position, and co–ordinate reference system) and four operational tasks (proportionality, control of variables, combinatorial analysis and proportional logic) were administered. The results obtained support the hypothesis that individuals living in a very simple environment, who are nomadic and predominantly hunters, develop spatial skill that are adapted to the

ecological demands of their lives or in other words adapted to their profession. This supports Piaget (1972), observation that whether individuals reach formal reasoning or not depends on their profession and particularly on their socio-cultural systems. The percentage of the schooled subjects performing successfully on the Piagetian formal tasks is higher than that of the non – schooled subjects. This suggest that formal schooling would seem to provide the subjects with new cognitive processes, new abilities and new intellectual tools to handle tasks requiring hypothetico – deductive reasoning. The researcher observed that the science educator is faced with a concern for the development of formal thought among those individuals who would need such intellectual strategy for survival in their ecocultural environment.

Duyilemi (1987) determined the relationship between operational thought and achievement in taxonomic concepts in Biology. The subjects consisted of one hundred and twenty randomly selected fifth year students from three high schools in Ondo state. The ages of the subjects ranged from 14 – 19 years. The study made use of a post – test only static group design. Piagetian – styled instrument and a biology test were used to assess students levels of cognitive development and achievement in biology respectively. The t – test statistics and pearson –product correlational analysis were used to test hypotheses generated for the study. The results supports earlier findings, (Ehindero, 1979; 1980; Oni. 1982) that most high school students in Nigeria operate at the concrete level while less of them operate at the formal level. The study also show that cognitive development is involved in operational understanding of taxonomic concepts. Concrete operational students experienced more problems in these concepts than their formal operational colleagues. They call for more research by science teachers in developing countries especially Nigeria on operational thought.

Araoye (1991) investigated the relationship among self – concepts of thinking, thinking approaches and critical thinking skills of inservice science teachers. 100 subjects drawn from the population of science education students in Ahmadu Bello University, Zaria were used for the study. Group Assessment Logical Thinking (GALT) testing six reasoning mode – conservation, proportional reasoning, controlling variables, probabilities reasoning, correlational reasoning and combinatorial reasoning was administered. The study recalled that most of teachers were not critical thinkers. There was a significant relationship between thinking approaches and self – concepts of thinking among subjects. The researchers recommended that ways of improving students and teachers reasoning should be found. Popper (1970) also pointed out that critical thinking instructions should be given at all levels of schooling.

2.7.2 Related Studies, Elsewhere, In Formal Reasoning and Science Process Skills

Westbrook and Rogers (1994) carried out a research to test the hypothesis that descriptive learning cycles are neither sufficient to students to reason at a formal reasoning level nor to encourage facility with processes of scientific investigation. Subjects in the study were assigned to one of the three instructional groups: descriptive group (DE) question design group (QD) and hypothesis testing group (HT). Each group completed identical exploration and invention activities. Subjects in DE group followed instructions given on the laboratory sheets, organized the data tables and then repeated these processes in expansion phase activities. They were, however, not given opportunity to design experiments or to generate or test hypotheses. The QD group designed and conducted experiments to answer a question posed by the teacher. The HT group generated hypothesis concerning a problem, they designed and conducted experiments to test those hypotheses. The effects of the treatments were assessed in a pretest – posttest

format using Lawson's seven logic tasks, Test of integrated process skills and Lawson's revised class room test of scientific reasoning. Analysis of the data indicated that HT group exhibited a significant increase on the test of integrated process skills and formal reasoning ability.

Norman (1997) carried out a study to test Lawson (1992) law of multiple hypothesis theory which states that essence of scientific reasoning is the ability to initiate reasoning with more than one antecedent condition. This theory therefore predicts that a person with formal reasoning powers will tend to use conditional rather than biconditional logic and furthermore, that the context also plays a role in determining the type of logic used. Sixty eleventh and twelfth grade students were randomly selected for the study. The subjects were administered the Lawson classroom test of formal reasoning to determine their Piagetian developmental level. This test measures students ability to apply scientific and mathematical reasoning in solving problems, making predictions and in the general analysis of the situations. Two types of logic tasks were administered i.e the general logic tasks and the chemistry logic tasks. The percentage of responses in which students appropriately used conditional logic was compared for concrete, transitional and formal operational students. The peerson correlations follow the same general pattern as in Lawson (1992) study and broadly support the conclusion that more skilled reasoners are more apt to respond with a conditional pattern of reasoning.

Cavallo (1996) carried out a study to explore relationship among school students (N=199) meaningful learning orientation, reasoning ability and acquisition of meaningful understanding of genetics topics and ability to solve genetics problems. Students were tested before and after laboratory–based learning cycle genetics instruction. The tests were designed to measure students' interrelated understanding of genetics and their ability to solve and interpret problems using punnet square diagrams. Regression analyses

were conducted to examine the predictive influence of meaningful learning orientation, reasoning ability and the interaction of these variables on students performance on the different tests. There was no relationship between meaningful learning orientation and students understanding of punnet square diagrams as measured by mental model explanations of this topics. These findings contrasts results of previous studies (Cavallo,1991; Cavallo and Schafer, 1994). Reasoning ability was also not required for meaningful understanding of the punnet square diagram. One unexpected and interesting finding was that there was no relationship between meaningful learning orientation and reasoning ability. This finding suggests that students who had a more meaningful learning approach did not necessary have high reasoning ability. This may also suggest that meaningful learning and reasoning ability have distinct contribution to learning. However, meaningful learning and reasoning ability were both important for students successful genetics problem solving.

Zohar, Weiberger and Tamir (1994) determined in a study whether the Biology critical thinking (BCT) project contributes to the development of critical thinking skills in various biological and non – biological topics and how it affects students biological knowledge and classroom learning environments. 678 subjects were assigned randomly into two groups that studied the same seventh – grade biology text book. Only one group, the experimental completed the BCT activities. The results indicate that the students in the experimental group improved their critical thinking skills compared to their counterparts in the control group. Improved critical thinking skills were observed in a new biological context and non – biological everyday topics, suggesting generalization of thinking skills across domains. The experimental students scored significantly higher than the control on a knowledge test, suggesting that "knowledge of facts" is one educational goal and "learning to think as another, need not conflict, but rather can

interact with each other. Finally, the results shows that BCT involvement decreased the frequency of teachers – centred teaching and enhanced student centred more active learning. This suggests that student reasoning ability can be enhanced through instruction.

Schauble and Lahrer (1998) carried out a research to determine fifth grades reasoning on how gears move on a gear board and work in common place machines. Questions focused on transmission of motion, direction, plane and speed of turning and mechanical advantage. Several subjects believed that meshed gears turn in the same direction and in the same speed. Many subjects provided very incomplete explanation of transmission of motion. Most children confused mechanical advantage with speed. They discovered that as interview proceeded, several subjects generalized conceptions about transmission of motion into a rule about turning motion. They increasingly justified their ideas about gear speed by referring to ratio. Subjects reasoning became more general, formal and mathematical as problem complexity increased suggesting that mechanical forms of reasoning may develop when they provide a clear advantage over causal generalization.

Johnson and Lawson (1998) carried out a study to test the hypotheses that the best predictor of achievement in expository classes is domain – specific prior knowledge while the best predictor in inquiry classes is reasoning ability. Students enrolled in a non – majors community college biology course were pre-tested to determine reasoning ability and prior knowledge. After a semester of either expository or inquiry instruction, students took a comprehensive final examination. Reasoning ability but not prior knowledge or number of previous biology courses accounted for a significant amount of variance in final examination score in both instructional methods and with semester examination and quiz scores in inquiry classes. This suggests that reasoning ability limits

achievement more than prior knowledge among these biology students, whether they are enrolled in expository or inquiry classes. Reasoning ability explained more of the variance in final examination scores for students enrolled in expository classes (18.8%) than in inquiry classes (7.%). The reason for this is not clear, but significant improvements in reasoning were found in the inquiry but not in the expository classes. These improvements were accompanied by significant differences in achievement in the inquiry classes. Perhaps the reasoning improvement facilitated the better and more equal achievement for students in the inquiry classes thus reducing the correlation between initial reasoning ability and final achievement.

German (1994) used path analysis to test a hypothesized structural model of direct and indirect causal effects of student variables on science process skills. The model was tested twice using data collected at the beginning and the end of the school year from 67 9^{th} and 10^{th} grade biology students who lived in rural Franco – American community in new England. Each student variable was found to have significant effects, accounting for approximately 80% of the variance in science process skills achievement. Academic ability, biology knowledge, and language preference had direct significant effects. There was a significant mediated effect by cognitive development, parents education and attitude toward science in school. The variables of cognitive development and academic ability had the greatest total effects on science process skills. This suggests a positive relationship between reasoning ability and acquisition of science process skills.

Zarour and Gholam (1981) carried out a research to assess the level of intellectual development of male and female students preparing to enroll in the somophore class of the American University of Berut, Labanon and to compare this level with their performance in achievement tests in Mathematics, Biology, Chemistry and Physics. A Formal Thinking Test (FTT) was administered to 135 male and 75 female students in

secondary schools and higher institutions. The sex factor was found to be significant in favour of the males.

There was also a high correlation between the scores on FTT and scores on each of the mathematics, Physics and Chemistry. The chemistry and physics questions were loaded with questions reflecting quantitative reasoning and applications. The mathematics selection was a combination of quantitative ability and achievement in a freshman level calculus and analytical geogmetry course. The relatively high correlations between the scores on this test and scores on each of the Mathematics, Physics, and Chemistry, tests may suggest a common factor between Piagetian tasks and tests which emphasized quantitative ability, reasoning and applications.

Glass (1981) examined the relationship between cognitive skill measured and understanding the heterotrophy hypothesis. The subjects after exposure for twelve weeks to Biology content which emphasized the development of heterotrophy hypothesis were then treated with Islands Puzzle test, controlling variables tasks and achievement test. The findings from the study after a multiple regression exercise show that certain cognitive skills are necessary for successful understanding of the heterotrophy hypothesis. These skills as measured by Islands Puzzle test and controlling variables tasks are skills of data interpretation, identification of assumptions and hypothesis and controlling of variables. This suggests that the level of cognitive development determines learners understanding of heterotrophy hypothesis.

Lawson (1980) determined the relationship among level of intellectual development, cognitive style and grades in college Biology. The subjects level of intellectual development was assessed on the first day of the class and examination of the grades were awarded on the basis of an average of three semester examinations and final examinations. The results of the study show that formal reasoning and field independence

are significantly correlated. Person product – moment correlation coefficients were also calculated among developmental level, cognitive style and commulative examination scores. Scores on the Piagetian demonstration test correlated significantly with cumulative examination scores and with scores on the cognitive style test. The result implies that some college students are indeed operating at concrete operational level and that responses to Piagetian -- styled "physical science" test items such as those used in the study do in large part meaningfully predict level of intellectual functioning within the Biological sciences.

Lee (1983) tested the following hypothesis:

i. There are significant differences in cognitive development, science process skills, and attitude toward science of preservice teachers with different science backgrounds through the ages

ii. There are significant correlations among cognitive development, science process skills, and attitude toward science.

Subjects were randomly selected among students majoring in science and non science major in different levels and divided into four different groups. A Chinese version of the Group Assessment of Logical Thinking (GALT), Test of Integrated Process Skills and a scientific attitude questionnaire were administered. The cognitive development and science process skills of group I and III students, with more science courses grades 10 – 12 were significantly higher than those of students with less science courses. Cognitive development, science process skill, and attitude towards science were also significantly correlated. Research findings imply that these non – science majors performed poorer than students at the same age in cognitive development and in science process skills.

Ward (1981) evaluated the effectiveness of the longeot test in classifying subjects

into concrete and formal operational reasoners. The test was found to be reliable and the classification made using the Piagetian tasks. The test works well for determining the developmental level of large number of students and the knowledge gained from making these classification can be used to designed instruction.

Maloney (1983) carried a study to find out the relation if any between students' ability to solve simple ratio tasks i.e their proportional reasoning patterns and their rule-governed behaviour with the balance beam. One hundred and eight subjects from different science courses composed the sample used in the study. The Lawson classroom test of formal operations and Fuller proportionality task were administered to the subjects. A statistically significant difference was found between the proportionality tasks scores of the subjects using the most sophisticated rule and the next lower rules. The data also indicate a relation between subjects proportionality reasoning ability as expressed on the tasks administered and the strategy they will employ on the balance beam. The fact that subjects employed set rules in an attempt to analyze the behaviour of the balance beam, suggest that they came with set strategies. However, only a fair segment of this population was already in possession of the correct strategy i.e those with high proportional reasoning ability.

Lawson (1985) carried a research to determine if formal reasoning is required to balance even simple one – step equations. A sample of science students was tested to determine level of intellectual development, mental capacity and degree of field dependence-field independence. Students were given instruction in using trial and error to balance equations. As predicted, a post test revealed significant correlations between developmental level and equation balancing ability for both simple and complex equation but not with simple equations.

Lawson (1983) determined the role of developmental level, disembedding ability,

mental capacity, prior knowledge and beliefs on science achievement. Subjects were pre-tested to determine level of intellectual development, ability to disembed relevant information from irrelevant background, size of working memory, amount of prior knowledge of evolution and natural selection and beliefs in evolution or special creation. Following the assessment of the learners variable, some biological concepts were taught in a series of five lessons. At the end of the lessons, students were pre-tested to determine the extent to which they achieved the concepts presented. Disembedding ability, prior knowledge and beliefs in evolution were found to be significantly related to overall achievement, while developmental level and mental capacity were not. However, developmental level was found to be best predictor of performance on computational item, while belief in evolution and prior knowledge were found to be best predictor of performance on the essay items. This shows that cognitive variables influences different aspects of science achievement.

Sunal and Sunal (1985) carried out study to investigate the implications of cognitive development of preservice teachers as it relate to their classroom teaching performance. Ninety-one seniors involved in a field oriented teacher education programmes were given classroom responsibilities, which included teaching a science unit. Formal thinking abilities were assessed using two types of developmental level tasks, performance on traditional type Piagetian tasks and recognition of formal thought approaches in solving educational tasks. Professional behaviours were tested using observational ratings of classroom instructional and planning activities. Subjects assessed as formal operational (30% sample) had significantly higher facility in performing model classroom teaching behaviours than transitional or concrete subjects.

Staver and Halsted (1985) determined the effect of reasoning, use of models during testing and sex type on post test achievement in chemical bonding under

controlled instruction. Eighty-four high schools students taking chemistry were randomly assigned within their classes to models and non-models groups for posttest. Reasoning ability was assessed by the Piagetian Logical Operation Test (PLOT) prior to instruction. The subjects received the same instruction on chemical bonding, which included teacher demonstrations of concepts with three-dimensional molecular models, interpersed teacher questions during the introduction and development of the concepts. Results indicate that reasoning accounted for significant portion of the variance in total score. Use of models and sex type did not account for significant portion of the variance on total scores or any section of the posttest.

Bass and Maddux (1982) examined the effects of operational levels of learners on causal explanations they recall after instruction. It was hypothesized in the study that individuals who do not reason formally would have difficulty in learning explanations presented in instructions. To test this hypothesis, the effect of levels of operational thought on explanation which ninth grade college physical science students reconstructed after instruction was investigated. Subjects in the study were classified though Piagetian tests as concrete or formal operational. Both concrete and formal subjects were successful in recalling explanation requiring the chaining of two implication statements. Formal operational subjects perform significantly better than concrete operational subjects in three of the four tests of the reconstruction of complex explanation. The study show that formal reasoning is at the heart of understanding science.

Bender and Milakofsky (1982) carried out an investigation to relate cognitive functioning to other measures of aptitude and performance and described the weakest areas of Piagetian development for college students. Cognitive performance on Piagetian tasks was related to Scholastic Aptitude Test (SAT), and performance in both college chemistry lecture and laboratory classes. Scores on Piagetian tasks correlated highly with

scores in SAT. Performance on proportional reasoning correlated with course achievement. This shows that formal reasoning influences achievement in science.

Howe and Durr (1982) analysed chemistry curriculum to determine the level of cognitive demand of the various aspects of the selected topic. Piagetian levels of thinking of subjects were initially assessed by the group tests, a unit on the mole was formally taught and guidelines were used to estimate the level of cognitive operations required by each concept and problem type in the unit. Results of a 23 item test were used to compare the estimated level of cognitive demand of each test item with the Piagetian cognitive level of pupils who were able to answer the item correctly. It was found that pupils' cognitive level was positively associated with overall unit test score and with present success on all test items.

Howe and Durr (1982) tested the effectiveness with secondary chemistry students of an instructional strategies based on the use of manipulatable material combined with planned peer interaction. A post test only, control group was used. Students enrolled in a chemistry course were randomly assigned to experimental/control group. Assessment of cognitive level preceeded treatment which consisted of instruction in two units of the prescribed state chemistry syllabus. Both affective and cognitive out comes were more positive in experimental group.

Farrel and Farmer (1985) investigated the understanding of proportion by a selected group of college–bound adolescents. Gender–related differences and the influence of course experience were also studied in relation to first order direct proportional reasoning and multiple proportional reasoning. Nine hundred and one subjects were administered the Tall – short task as a test of first order direct proportional reasoning. From 474 subjects classified as successful, a random sample of 128 subjects were administered the projection of shadow task. An analysis of the transcripts of

responses showed that feedback and second trials were essential for success for most 68% of these successful subjects. In addition, this selected sub- sample generally used a multiplicative strategy and still could not overcome the inability effect of focusing on direct proportions. There are significant gender differences in favour of male subjects, in first order direct proportion reasoning but there were no gender differences in multiple proportion reasoning. Prior course experience in maths and science were each significantly related to first–order direct proportion reasoning but there was no significant relationship between either of these variables and multiple proportion reasoning.

Gabel and Sherwood (1983) constructed a study to determine whether certain instructional strategies were superior to other in teaching high school chemistry students problem solving. The effectiveness of instructional strategies for teaching problem solving to students of various proportional reasoning ability, verbal and visual preference and mathematics anxiety were compressed in this aptitude by treatment interaction study. Results show that problem solving is dependent on students proportional reasoning ability.

Lawson et al. (1978) sought answers to the following questions among others.

1. Does the ability to reason according to the common rules of proportional logic develop gradually during the secondary school years?
2. Does the use of the formal operational schemata of proportions, probabilities and correlation develop gradually during the secondary years?

Subjects spanning the entire age range of adolescent – roughly the ages of 11.5 to 20.0 years were administered a seven item pencil and paper test during their regularly scheduled classes. Five questions required use of formal operational schemata of proportions, probability and correlation, while two of the items required the use of the common rules of prepositional logic. The study reveals that propositional logic and

formal schemata are not part of the same structural unity of mental operations proposed by Piaget. However, the finding that the formal schemata of proportions, correlation and probability do in fact develop during adolescence suggests the possibility of some developmental link among them. A plausible hypothesis is that this group of related concepts is in fact what constitute formal thought.

Lawson (1978) developed an instrument for which will measure concrete and formal operational reasoning. The instrument consists of 15 items. Each item involved some demonstration using some physical materials and or/ apparatus. The classroom test was administered to a total of 513 students enrolled in eighth, ninth and tenth grade classes in a Junior and senior high schools. The test reveals that 35.3% responded at concrete level, 49% responded as transitional to formal operational, while 15% responded at formal operational. The test was intended for use by teachers interested in determining the developmental level of reasoning.

Goodstein and Howe (1978) tested the hypothesis that instructional methods in which learners use concrete models and exemplars of a concept will lead to a better understanding by students at both the concrete and formal operational levels of cognitive development. The piagetian level of logical thinking of all students was assessed and all of them received instruction in stoichiometry for approximately six weeks. The two teachers who participated in the study each taught one experimental and one control group. Students in the experimental group use concrete models to develop the idea that the weight ratio of single atoms of different elements is the same as the weight ratio of models of the same elements. The fact that concrete operational students do not profit from the use of concrete models and examples suggest that in learning three factors must be taken into account: the cognitive level of the learners, the conceptual level of the material to be learned, and the method of instruction. In this case, the conceptual level of

the material to be learned was apparently too high for all but the advanced formal level students. It can be inferred that concrete level students cannot learn concepts which required advanced formal operational thinking no matter how the concepts are taugh and that learning of formal operational concepts can be enhanced for formal operational students by use of concrete models during the learning process.

Blake and Nordland (1978) determined the effectiveness of the semester's instruction in science and mathematics using an inquiry-based methodology, in facilitating cognitive development on freshman college students. A Solomon four group design was employed in preference to the more conventional pretest - post test control group design in order to control for possible interaction between pretests and treatment. The two treatment groups were given inquiries – based instruction and didactic instruction. In the space of one semester, inquiry – based teaching of a mathematics – science course did not promote cognitive growth in the subjects in comparison with expository teaching approach.

Tobin and Capie (1982) established the relationship between formal reasoning ability, locus of control, academic and integrated process skill achievement. Twelve pupils from each of the thirteen middle science classes participated in the study. Measures were obtained for each pupil on nine engagement modes. Two engagement measures, attending and generalizing, together with formal reasoning ability were related to process skill achievement and retention. Formal thinking ability was the strongest predictor of process skill achievement and retention, accounting for approximately 36% of the variance in each case. Formal reasoning ability and locus of control were each correlated with specific engagement modes. Formal reasoning ability was positively related with rules of generalizing and comprehending. Locus of control was significantly related with rates of attending and total engagement.

Keys (1995) investigated scientific reasoning skills used by students in a naturalistic collaboration writing context and changes in students reasoning discourse over time. Three ninth grade general science classes taught by one teacher participated in a collaborative writing intervention. Report guidelines were designed by the teachers and the researcher to assist the students with their writing. An interpretive research design was used to study the conventions of three target student pairs in depth. Eleven distinct, yet integrated scientific reasoning skills used to support report composition emerged from the data. One of the target pairs improved their reasoning discourse over time by discussing conceptual meanings more fully and bringing specific information into their conversation. The study also revealed that all target students used reasoning skills to assess prior models of scientific phenomena and to generate new models for scientific phenomena.

Lawson et al. (1975) compared performance of 35 disadvantaged high school students (ages 14.0 – 17.7 years) on the conservation of number substance, continuous quantity, length, area, weight, volume using clay, volume using cylinders, bending rods and pendulum tasks with reading ability as measured by the sequential test of Educational progress reading test. Total task correlated with total reading score at 0.70 (0.78 correlated for attenuation). Correlations with the formal tasks were higher than those with the concrete tasks. For example, conservation of substance correlated at 0.36 with reading total, while the bending rods correlated at 0.70 and the pendulum at 0.73. These substantial correlations with reading ability serve as evidence on the validity of the formal task as measures of general intellectual development.

Capin and Kuhn (1979) examined the ability of 50 adults female shoppers in supermarket to determine which of the two bottles of schilling garlic powder was a better

buy. Only 32% of the shoppers were able to use proportional reasoning to determine the correct choice when the ratio was simple one (2:3). Only 20% were correct when the ratio was more complex. Capin and Kuhn claimed that the results do not contradict the notion that performance is enhanced when the problem context is familiar. Yet, they pointed out that the results indicated that formal reasoning among adults is far from universal even under favourable assessment conditions. They concluded that a significant variability in level of reasoning does exist among the adult population and that this variability has considerable practical implications. Mathematics and science teachers should take considerable note of this result as proportions are "taught" (but obviously not learned) in many mathematics classes, and are "used" (but obviously not successfully) in many science classes.

Hardy–Brown (1979) classified 30 college subjects into concrete, transitional and formal level based upon performance on a paper and pencil test of formal reasoning which included versions of the chemical combinations and bending rods tasks and two items involving ratio and proportions. In individual clinical interviews, the subjects then read two poems and were asked to interpret their meanings. A two level scheme based primarily on subjects ability to marshal individual clues to arrive at a logical synthesis of meaning was used. Chi–square analyses showed the task and poems classifications to be significantly related. As predicted, the concrete thinkers were generally classified at the lowest level of literary comprehension while the formal thinkers were generally classified at the highest level. Hardy–Brown concluded that the formal operations described by Inhelder and Piaget (1958) do represent a system of thought which is of central importance in an individual's effort to master, comprehend, or produce mature thinking in poetic discourse.

Renner and Paske (1977) compared two forms of the semester physics instruction for non–science majors under graduate student. The "concrete" mode of instruction followed the learning cycle approach while the "formal" mode followed the traditional lecture/demonstration approach. Students in both groups were pre – and post tested with measures of formal reasoning and the Watson–Glaser critical thinking Appraisal. Post testing also included an attitude survey and a content examination. Three sections were taught by the concrete mode while one section was taught by formal mode. The concrete instruction sections performed consistently better than the formal section on the content examination and were generally pleased with the instruction, while the formal was generally dissatisfied with its instruction. Greater gains and fewer losses were made on the Watson Glaser by the concrete sections. They also showed greater gains on the formal tasks from the low to high concrete level and high concrete to low formal levels, however, the formal sections showed greater gains from the low to high formal level. This result suggests that inquiry oriented instruction is more effective at producing reasoning gains for concrete students but for students with some expertise in formal reasoning, further progress is better attained by traditional methods.

Schneider and Renner (1980) compared two methods of teaching physical science concepts to ninth grade students over one semester period. One method, labelled formal instruction, followed a traditional pattern of lecture, motion pictures, filmstrips, text book readings, questions and problems, supervised study and demonstrations. The second method, labeled concrete instruction, followed the exploration – invention – discovery learning cycles where emphasis Is placed on relatively open exploration, student data collection and teacher guidance. Results show that concrete operational method was inferior to the formal method in content achievement in both immediate and delayed post tests. It was also superior in promoting formal reasoning as attested by a battery of formal

tasks. The superiority of the concrete instruction group persisted on the delayed posttest three months later. It may be argued that this superiority does not reflect a real difference in reasoning ability as the concrete instruction subjects interacted with manipulative material while the formal group did not. Because the formal tasks involved the manipulation of materials the group difference could be attributed simply to gains in students confidence with manipulatives. However, this argument is weakened considerably by the finding that the concrete instruction group also evidenced greater gains on a manipulative test of IQ (the short form test of academic aptitude). This therefore support the hypothesis that the learning cycle approach to teaching due presumably to its ability to intellectually stimulate and challenge students reasoning processes, can not only improve their understanding of science content but can affect general advances in reasoning ability and academic aptitude as well.

Padilla et al (1983) carried out a study to examine integrated process skill and formal thinking abilities of middle and high school students and determine the relationship, if any, between the two. A relationship was thought to exist since both sets of skills strongly emphasized conducting fair experiments as well as other abilities. Pencil and paper measures of formal operational and integrated process skill achievement were given to almost 500 grade 7 – 12 students. The results show a strong correlation between achievement on two measures (r=073) and all subtest of both measures. Factor analysis data corroborate the correlational evidence. They inferred that process skill teaching might influence formal reasoning ability. They also call for a follow up study to determine this.

2.8 IMPLICATION OF LITERATURE REVIEW FOR THE PRESENT STUDY.

The literature reviewed suggests that students need to acquire formal reasoning in

order to understand and apply science concepts Duyilemi (1987) reported that cognitive development is involved in the operational understanding of taxonomic concepts as concrete operational students experienced more problems in understanding the concepts than their formal operational colleagues. The results of Duyilemi's study support findings by Goodstein and Howe (1978) that students who operate at concrete level can not learn concepts which require advanced formal operational reasoning, no matter how the concepts are taught. The researchers recommended that teachers should seek for ways of improving learners formal reasoning ability. This study is aimed at establishing if science process – based activities can be effective in improving subjects formal reasoning ability.

A relationship between integrated process skill and formal operational abilities has been hypothesized by several scholars, for example (Padilla, 1979). Padilla et al. (1983) showed that science process skill ability is strongly associated with formal reasoning and is, therefore a likely factor that has direct influence on it. They observed that the work that remains is to determine in an experimental study if increasing the process skill abilities of students will increase students formal reasoning. The Literature does not seem to show that much effort has been made in this direction. This contributed to stimulate this study.

A study by Araoye (1991) revealed a significant gender differences in subjects critical thinking in favour of male subjects. The differences in reasoning might be as a result of methods of teaching that have negative influence or are unsuitable in promoting reasoning ability in females. Mari (1994) reported that female subjects perform better than their male counterparts in process skills of interpretation of data, experimenting and hypothesizing. This process – based teaching may be an effective way of remedying female subjects deficiency in formal reasoning.

The literature revealed quite a number of instruments used in measuring subjects formal reasoning ability. These include the individually administered Piagetian tasks that involved demonstration using some physical materials and or apparatus (Lawson, 1978). Others consist of paper and pencil examinations (Raven, 1973; Capie, 1982). While individually administered Piagetian tasks are the most widely used method for making these determinations, they suffer from the problem of being extremely time consuming to administer (Ward et al., 1981). They also require trained interviewer inter-rater reliability checks to assure consistent check scoring. For these reasons, many researchers have been working at developing and evaluating more objective measures of formal reasoning ability. One of such instruments is group assessment of logical thinking (GALT) by Roadranka et al.(1982) which is being adopted for this study. Thus, the literature has been valuable in the attempt to appropriately situate this study contextually. It has also been useful as a guide in the choice of instrument used in this study.

2.9 SUMMARY

Some of the studies reviewed show that subjects perform alarmingly low in formal reasoning tasks (Lawson, 1978; Araoye, 1991; Oni, 1982). The literature also revealed that formal reasoning could be acquired through purposeful instruction (Jones, 1983). Campbell (1977) compared the effectiveness of the learning cycle approach to conducting physics laboratory activities plus the personalized system of instruction (PSI) to the more traditional lecture – laboratory – recitation method of college freshman physics teaching. The learning cycle and PSI approach were significantly better than the traditional approach in promoting the development of formal reasoning. Lawson and Switgen (1982) reported that some subjects described as field dependent failed to improve in their formal reasoning abilities after instruction. Lawson (1982) also pointed

out that the extent to which training transfers to novel problems and contexts and even to novel reasoning patterns depends upon the length and richness of the training and the extent to which children are intellectually in control of their own actions. Science process-based instruction involve the use of hands–on activities and affords learners opportunity to independently acquire knowledge by the use of science process skills. This method appears to fulfill the conditions outlined by Lawson above and may be effective in promoting formal reasoning patterns that are transferable to novel situations by all categories of learners. The current study was aimed at establishing the effectiveness of science process-based instruction in promoting formal reasoning.

CHAPTER THREE

METHODOLOGY

3.1 INTRODUCTION.

The main purpose of this study was to determine the effect of process-based instruction on formal reasoning ability. To achieve this goal, data were collected using two instruments. In this chapter, the description of the research design, population and the procedure for analysing the data collected are discussed.

3.2 DESIGN OF THE STUDY

Pretest–posttest matched-group experimental control design was used (Kerlinger (1973). The pretest was administered to the subjects before they were exposed to the treatment i.e science process–based instruction. Both the experimental and the control groups were taught the selected chemistry content through lecture method. The experimental group in addition, was given process–based instruction in which they designed experiments, stated hypotheses, collected and interpreted data. At the end of the treatment, a posttest was administered to both the experimental and the control groups to evaluate the effectiveness of the treatment in promoting formal reasoning in subjects. The pre- and posttests that were administered were the same, even though the items were shuffled at the posttest stage to limit the effects of "test-wiseness". The design could be represented as follows:

$Q_1\ X_1\ O_1$

$Q_2\ X_2\ O_2$

X_1 traditional instructional method

X_2 process-based instructional strategy

Q_1 and Q_2 – pretest measurements

O_1 and O_2 posttest measurement

3.3 THE POPULATION.

The population of this study was all SS II students in Sabon Gari Local Government Area of Kaduna state. There were ten of them. The schools comprised co–educational and single-sex schools owned by government and private organizations. One of the schools was a male school, three were female schools, while six were co–educational institutions. Table 3.1 shows the schools in the population

Table 3.1 Senior Secondary Schools in Sabon Gari Local Government Area.

S/ No	Name of school	Type of school	No of students		Total
			Male	Female	
1	Government Secondary School – Bomo (GSSB)	All boys	368	-	368
2	Government Girl's Secondary School – Samaru (GGSS)	All girls	-	200	200
3	Demonstration Secondary School – ABU Zaria. (DSS)	Co – education	120	80	200
4	Federal Government Girl's Secondary School – Zaria (FGGS)	All girls	300	-	300
5	Government Secondary School – Basawa (GSSBA)	Co – education	200	106	306
6	Government Secondary School – Chindict Barracks (GSSC)	Co – education	220	149	369
7	Government Girl's Secondary School – Dogon Bauchi (GGSSD)	All girls	-	316	316
8	Commercial College – Zaria (CCZ)	Co – education	100	180	280
9	Therbow Secondary School – Zaria (TSS)	Co – education	124	76	200
10	God's Time Secondary School – Samaru (GTS)	Co – education	110	90	200
Total	-	-	1242	1608	2850

3.4 SAMPLES AND SAMPLING PROCEDURE

To select the sample, initially six schools were randomly selected from the schools listed in Table 3.1. The following schools: Demonstration Secondary School, God's Time Secondary School, Bomo Secondary School, Therbow Secondary School, Commercial College and Federal Government Girl's School, all located in Sabon Gari local government area of Kaduna state, were selected. To select the schools that were used as experimental and control groups, the mean scores were tested using t – test to choose a pair of schools that had no significant difference in their mean scores in formal reasoning ability test. Demonstration and Therbow Secondary schools were selected, being a pair of schools that had no such significant difference. Demonstration Secondary School was randomly assigned as experimental group and Therbow as control group. In each of the sample schools, an arm of a science class was randomly selected for the study. There were forty students in the class that was used as the experimental group and thirty eight students in the class selected as control group. However, two (2) subjects in the experimental group could not complete the course. The choice of a class to serve as experimental group was to allow easy control of the students and provide room for maximum interaction between the students and the researcher. A class of forty subjects was considered as an adequate representation of a normal population based on the recommendation by Kerlinger (1973), that 30 subjects randomly sampled can serve as a fair representation of a normal population in an experimental study. The choice of two separate schools was to avoid interaction between the two groups through sharing of ideas which would otherwise lead to reduction in the effect of treatment. The results of the pretests administered to both the experimental and control group is shown in Appendix 4.

3.5 INSTRUMENTATION.

The two instruments that are adopted for use in this study are Group Assessment of Logical Thinking (GALT) and Test of Practical Skills (TOPS).

A. Group Assessment of logical thinking.

This test was developed by Road-Rangka et al. (1982) and has a reported reliability coefficient of 0.85. The instrument consists of 12 questions testing six reasoning abilities or schemata, namely;

a. Conservation

b. Proportional reasoning

c. Controlling variables

d. Probabilistic reasoning

e. Correlational reasoning

f. Combinatorial reasoning.

Items 1 and 2 deal with conservational ability, 3 and 4 test proportional reasoning, 5 and 6 controlling variables, 7 and 8 Probabilistic reasoning, 9 and 10 correlational reasoning, and lastly, 11 and 12 test combinational ability. Examples of some tasks used to test some specific schemata described as formal reasoning ability are given below.

a. Conservation tasks

A picture of two balls of clay placed on balance pan was given. Subjects were required to infer with suitable reason, if the weight of the two balls will remain the same when one of them is flattened.

b. Proportional tasks

Subjects were provided with a picture of a small glass, a small jar and a large jar. They were asked, "if it takes 15 small glasses of water or nine large glasses of water to fill the large jar and 10 small glasses of water to fill the small jar, how many large glasses of water does it take to fill the same small jar?" They were also required to provide reason(s) for their answers.

c. Correlation

A picture of 16 fat mice with black tails, 6 fat mice with white tails and 6 thin mice with white tails and two thin mice with black tails was printed on the test booklet. Subjects were told that these mice represented a sample of mice captured by a farmer from a part of his field. They were asked whether they thought there was a relationship between the size of the mice and the colour of their tails.

In questions 1 – 10, subjects were required to give reasons for their responses. This was to avoid guess work and to ensure that subjects made their judgments based on reasons. Every item was followed with three alternative answers and four reasons for the subjects to choose the most suitable answers and reasons. As these reasons could only be abstracted, subjects who made right responses with suitable reasons might be operating at the level of formal reasoning. For items 11 and 12, questions were posed and subjects were required to give possible combinations.

The Piagetian type paper-and-pencil test was chosen in preference to Piagetian clinical method for the fact that the clinical method is difficult to administer, subjective in judgment and inadequate to cope with measurement of large scale (Ahlawat and Bilch, 1982).

The reasons for choosing GALT in preference to other paper-and-pencil tests are:

a. It was developed keeping in mind the real spirit of Piagetian concept of developmental stages of logical learning.

b. It has stood the test of time and proved useful in a variety of research studies in several countries (Blake, 1980).

c. It employs several items to measure each one of the operational concepts so as to provide a reliable assessment of each concept.

d. It is easy to administer and does not require more than a normal instructional period of time.

e. The test has a suitable reliability coefficient of 0.85.

f. The test deals more with level of acquisition of scientific concepts and less on acquisition of language.

B. Test of Practical Skills (TOPS)

This instrument was developed by Ajagun (1998) and has a reported reliability coefficient of 0.79. The instrument is meant to measure the level of acquisition of science process skills by chemistry students in secondary schools. The instrument is a paper-and-pencil test of subjects' ability to interpret scientific operations and processes, the ability to follow, understand and judge the soundness of scientific operations and processes.

The instrument consisted of five items that require short answer and completion formats in which students perform activities and record their results in blank spaces provided. The test items were validated by school teachers and lecturers at both Ahmadu Bello University, Zaria and the King's College, London, some of whom were experts in assessment. The assessments determined whether or not

i. An item measures the process skill for which it was designed by categorizing the test items using the process skills in a table of specification designed in the

course.

ii. The language is simple and comprehensive.

Items that were judged as appropriate by at least 80% of the assessors where selected and proportionately distributed into test forms. This procedure ensured balance between the test forms with respect to the skills and sub-skills measured.

3.6 SCORING PROCEDURE

The mode of scoring by Siegel (1989) in which a correct response and a reason are tied to score, was adopted. For the first ten questions, responses and correct reasons were tied together to score. For example, where there was correct response with wrong reason or vice versa, the item was not scored. The questions were multiple choice items, hence this measure was taken to check guess work by the subjects. However, items 11 and 12 were scored differently. For item 11, marks were given to responses which showed a pattern and have not more than one error, while item 12, is scored if there was pattern and not more than 2 errors or omissions. Subjects were required in items 11 and 12 to independently, work out the pattern. The numbers of arrangements required to produce a pattern are more in questions 12 hence subjects were not penalised when they made two omissions. This mode was adopted based on the observation by Siegel (1989) that a formal thinker always seek reasons on which to base their judgment and actions. This is a good attribute of a scientist as Araoye (1991) pointed out that a good scientist should be able to cite criteria for making judgment.

Subjects responses in TOPS were scored using a marking scheme drawn out by Ajagun (1998). Each correct response was scored a mark. The two graphs in the questionnaire were scored 7 marks each and the scores were distributed as follows:

i. Choice of graph–bar or line graph, 1mark

ii. Correct labelling of axes, 2marks

Axes correct but no label, 1mark

Incorrect axes, zero

iii. All points correctly plotted, 2marks.

Some of the points correctly plotted, 1mark

All points wrongly plotted, zero

Best straight line, 1mark

3.7 TREATMENT

GALT was used as the pre and posttest. It was administered to the subjects during the first week the researcher went to each of the two schools. This was done before the experimental group was exposed to science process-based instruction. The subjects were classified into concrete and formal operationers based on their scores in the pretest. Araoye (1991) mode of classification in which subjects who scored between 0 and 5 are termed as concrete reasoners, while those that scored between 6 and 12 are termed as formal reasoners, was adopted. The method was based on the standard or norm established for the test.

After the subjects were pre-tested, they were exposed to process-based instructions for three hours a week for six weeks. There were two lessons of one hour thirty minutes each week. In the process-based instruction, subjects are exposed to some activities that involved hypotheses formulation, design of experiments and data interpretation. The goal of the instruction was to facilitate the acquisition of scientific skills in subjects to enable them function as scientists. The activities were designed to allow students work independently, following series of instructions as guidelines to assist them to successfully formulate hypotheses, design experiments, interpret data and proffer

conclusions or generalizations that are of scientific interest.

All the activities were designed by the researcher following the pattern by Butler et al (1988), but for activity 4 and 5 that were adapted from the series of activities designed by Butler et al. (see Appendix 5). The activities were infused into topics like neutralization reaction, determination of purity of liquids through boiling point, qualitative analysis and rates of reaction. However, the goal was not to teach the chemistry concepts but to assist subjects acquire scientific skills. All the activities were meant to provide the learners the opportunity to learn how to formulate hypotheses, design experiments and interpret data. Both the experimental and control groups were taught the topic Acids, Bases and Salts. The subjects in the experimental group, in addition, were exposed to some activities that facilitated the acquisition of science process skills. For example, subjects were given this process-based activity to solve;

"You are provided with solution labelled A1, A2 and A3. They are 1M hydrochloric acid, 2M hydrochloric acid and 1M sodium hydroxide solution but are not in this order. You are to devise a method to identify these solutions using only a thermometer, a measuring cylinder and a beaker". The activity required that subjects would have learnt that *neutralization reactions produce heat or enthalpy of neutralization.* Subjects were provided with reagents and allowed to state a hypothesis and design an experiment to test this hypothesis. They were required to give a detailed procedure of the experimental design and reasons they arrived at the procedure. Subjects note books were then marked and their procedures were discussed and appraised in the class. Various ways of improving upon the designs were also provided. Interaction among the subjects in the experimental group was not allowed during the activity so that they were provided with the ample opportunity to individually reason out their solutions to problems posed.

However, the researcher provided assistance to subjects who had not fully understood the concepts the activity were based on by explicitly explaining such concepts. For maximum interaction between the researcher and the subjects, a class of forty subjects served as experimental group.

3.8 PROCEDURE FOR DATA ANALYSIS.

The data collected was used to test the hypotheses stated in section 1.7. Each of the hypotheses is restated below along with description of the statistical tool to be used for testing each.

Ho_1 There is no significant difference in the formal reasoning ability of subjects in the experimental and control group after exposure to process–based instruction.

Using the GALT posttest scores of the experimental and control group, a t – test statistics was used to test for any significant difference in the mean scores of the experimental and control groups.

Ho_2 There is no significant difference in the ability of the subjects to use probabilistic reasoning, combinatorial reasoning, proportional reasoning, correlational reasoning, ability to control variables, and conservation after exposure to science process–based instruction.

A t–test statistics was used to test for any significant difference in the mean scores of the subjects in each of the schemata before and after they have received treatment.

Ho_3 There is no significant difference in achievement between subjects in concrete and the formal operational stage in science process skills after treatment.

A t–test statistics was used to test any significant difference in the mean scores of those subjects at the concrete operational stage and the formal operators who received treatment.

Ho_4 There is no significant difference in:

(a) formal reasoning ability of the male and female subjects after exposure to process-based instruction.

(b) the posttest mean scores of the male and female subjects in the following formal reasoning components:

(i) conservation

(ii) proportional reasoning

(iii) control of variables

(iv) correlational reasoning

(v) combinatorial reasoning

(vi) probabilistic reasoning

(c) the performance of male and female subjects in science process skills tasks after treatment.

A t-test statistics was used to test for any significant difference in the mean scores of the male and female subjects in the variables after treatment.

3.9 SUMMARY

In this chapter, the research population and sample were described. The research instrument, the scoring procedures and statistical techniques used were also discussed. After the subjects have received treatment, their mean scores in GALT and TOPS were tested to provide answers to the research questions stated in chapter one.

A t–test statistics was adopted to test the hypotheses. In the next chapter, the analysis of data is presented and discussed.

CHAPTER FOUR

PRESENTATION AND DISCUSSION OF THE RESULTS.

4.1. INTRODUCTION

The purpose of this study was to determine the effect of process–based instruction on acquisition of formal reasoning ability among secondary school students. The results obtained from the analysis of data collected and the discussion of the results are presented in this chapter.

4.2 THE RESULTS

General assessment of logical thinking test, which measured six logical operations, was used to measure the level of the cognitive development of the subjects. The results are presented in Table 4.01

Table 4.01: Distribution of scores on the reasoning ability test among the subjects in the experimental group before treatment. (N = 38)

Reasoning ability group	Number of subjects at each reasoning level		Total
	Male	Female	
Concrete level (scores 0 – 5)	14	14	28
Formal level (scores 6 – 12)	8	2	10
Total	22	16	38

According to classification of Staver and Halsted (1985) used, the results in Table 4.01show that only 10 students (26%) were functioning at formal operational level, while 28 students (74%) were operating at concrete operational stage. This shows that few of the subjects had attained formal reasoning ability level.

Table 4.02: Distribution of the subjects' score on reasoning ability test in experimental group after treatment. (N = 38)

Reasoning ability group	Number of subjects at each reasoning level		Total
	Male	Female	
Concrete level (scores 0 – 5)	8	6	14
Formal level (scores 6 – 12)	14	10	24
Total	22	16	38

From the results in Table 4.02, 24 students (63%) were operating at the formal operational level, while 14 students (37%) were operating at the concrete operational level after administration of treatment. 14 students have moved from the concrete operational level to formal stage because of the training. This is an indication that the process–based instruction was effective in improving the reasoning ability of the subjects.

Table 4.03: Distribution of the scores of the subjects in reasoning ability test of the control group before instruction. (N = 38)

Reasoning ability group	Number of subjects at each reasoning level		Total
	Male	Female	
Concrete level (scores 0 – 5)	13	15	28
Formal level (scores 6 – 12)	9	1	10
Total	22	16	38

The results in Table 4.03 show that 10 students (26%) were operating at the formal operational level, while 28 students (74%) were operating at concrete operational level before instruction started. The results indicated a very low performance in Piagetian formal tasks.

Table 4.04 Distribution of the scores of the subjects in reasoning ability test of the control group after instruction (N = 38).

Reasoning ability group	Number of subjects at each reasoning level		Total
	Male	Female	
Concrete level (scores 0 – 5)	10	14	24
Formal level (scores 6 – 12)	12	2	14
Total	22	16	38

The results in Table 4.04 show that 14 students in the control group were operating at the formal level after instruction. That shows that 4 students (1%) of the subjects attained formal reasoning after instruction. It is an indication that the mode of instruction adopted in schools can either promote or hinder the acquisition of formal reasoning ability.

Table 4.05 Mean scores and standard deviation of the subject in the subscales of the experimental group before treatment. (N = 38)

Reasoning mode	$\bar{X}$	SD
Conservation	0.52	0.83
Proportional reasoning	0.50	0.80
Control of variables	0.21	0.47
Correlational reasoning	0.32	0.66
Combinatorial reasoning	0.63	0.82
Probabilistic reasoning	0.58	0.79

The results in Table 4.05 show that the experimental group recorded the highest mean score in combinatorial reasoning. The lowest mean score of 0.21 was obtained in control of variables. The results differ from those obtained by Araoye (1991) in which the highest mean score she reported was in conservation and the lowest in correlational reasoning. The result in table 4.05 also shows that the subjects had higher mean scores in all the schemata considered than the preservice science teachers reported by Araoye except in conservation. The subjects of this study being children of university staff and

from a well-equipped secondary school in terms of facilities, might have been exposed to an environment that stimulates cognitive development.

Table 4.06 Mean scores and standard deviations of the reasoning ability test of the experimental group after treatment.

Reasoning mode	MALE (N = 22)		FEMALE (N = 22)	
	$\bar{X}$	SD	$\bar{X}$	SD
Conservation	0.82	0.80	0.50	0.73
Proportional reasoning	1.00	1.02	1.00	0.82
Control of variables	0.36	0.73	0.63	0.72
Correlational reasoning	1.18	0.85	0.50	0.63
Combinatorial reasoning	1	0.82	1.00	0.82
Probabilistic reasoning	0.55	0.80	0.63	0.81

Table 4.06 shows that the male and female subjects had same mean scores in proportional and combinatorial reasoning. The male subjects had higher mean scores in conservation and correlational reasoning, while the female subjects were better in probabilistic reasoning and control of variables.

Table 4.07 Mean scores and standard deviation of the experimental group on the subscales of reasoning ability test after treatment (N = 38).

Reasoning mode	$\bar{X}$	SD
Conservation	0.74	0.76
Proportional reasoning	1.05	0.90
Control of variables	0.47	0.73
Correlational reasoning	0.47	0.60
Combinatorial reasoning	0.16	0.82
Probabilistic reasoning	0.53	0.73

The results in Table 4.07 revealed that the mean score of 1.05 in proportional reasoning as the highest, the score of 0.47 in both control of variables and correlational reasoning as the lowest. From the results in Tables 4.05 and 4.07, it can be deduced that

the subjects showed relatively low gains in correlational reasoning. These results agree with the observation of Lawson (1982), that correlational reasoning is a complex skill that requires rich instruction over a long period of time for appreciable increase in performances in the tasks involving it.

4.3 TESTING THE STATED HYPOTHESES.

The results of the analysis of posttest scores of the control and experimental groups are presented below:

4.3.1 The effects of process based instruction on formal reasoning.

The null hypothesis tested was stated thus:

Ho_1 there is no significant difference in the formal reasoning ability of the subjects in the experimental and control groups after exposure to process–based instruction.

t – test statistics was used to determine if there was any significant difference in the mean scores of the experimental and control groups in reasoning ability after exposure to science process–based instruction.

Table 4.08(a) Comparison of the mean scores of experimental and control groups in logical thinking after exposure to science process–based instruction.

Group	N	$\bar{X}$	SD	df	t- value	P
Experimental group	38	4.45	2.19			
				74	1.81*	0.074
Control group	38	3.58	1.98			

* = Significant at $P \leq 0.05$; t - critical = 1.671

The results in Table 4.08(a) show that there is significant difference at 0.05 confidence level between the mean scores of the experimental and control groups in logical ability, in favour of the experimental group after exposure to treatment. This

indicates that science process–based instruction as potentially effective in increasing subjects' reasoning ability. The null hypothesis was therefore rejected. The results support the observation of Lawson (1985), that performance on formal reasoning tasks can be significantly enhanced if the right instructional medium is provided.

Table 4.08(b) Comparison of the mean score of he control group before and after instruction.

Group	N	$\bar{X}$	SD	df	t- Value	P
Control group after instruction	38	3.58	1.98	34	0.12*	0.47
Control group before instruction	38	3.53	1.96			

* = Not Significant at 0.05; t – critical = 1.67

The results in Table 4.08(b) indicate that there was no significant increase in the performance of the control group in formal reasoning tasks after instruction. This shows that the lecture method may not be effective in enhancing the acquisition of science process skills in the subjects. This supports the observation by Lawson (1983) that some instructional methods are not effective in promoting the acquisition of formal reasoning ability in students.

4.3.2 The effect of science process skills instruction on the acquisition of formal reasoning schemata.

The question being addressed is the effect of treatment on acquisition of formal reasoning schemata. The following null hypothesis was tested:

Ho_2 There is no significant difference in the pre and posttest mean scores of the subjects in the experimental group in the following skills.

a. Conservational reasoning

b. Proportional reasoning

c. Control of variables

d. Correlational reasoning

e. Combinatorial reasoning

f. Probabilistic reasoning.

Table 4.09(a) comparison between the mean scores for the subjects in tasks involving conservation before and after treatment.

Group	N	$\bar{X}$	SD	df	t- Value	P
Experimental group before Treatment	38	0.53	0.83			
				74	1.15*	0.25
Experimental group after treatment	38	0.74	0.76			

* = Not Significant at $P \leq 0.05$ level $t - critical = 1.67$.

The results (Table 4.09(a)) indicate that the treatment did not result in any significant increase in the performance of subjects in conservation, even the treatment led to an increase in the mean score of the subjects in conservation tasks after treatment compared to pre–treatment mean score. This may suggest that the subjects have reached an advanced level in conservation reasoning ability hence further advancement requires intensive and longer treatment to give rise to significant gains in this ability. Secondly, the conservation reasoning ability may be more associated with basic science skills as it requires the ability to conserve variables like weight, volume, density etc, which requires some activities in measurement. Since the treatment was based on integrated science processes, conservation reasoning ability, which appears the most likely to be influenced, tended not to be significantly improved after treatment.

Table 4.09(b) Comparison of the mean scores of the subjects in the experimental group in proportional reasoning before and after treatment.

Group	N	$\bar{X}$	SD	df	t- Value	P
Experimental group before Treatment	38	0.50	0.80	74	2.87*	0.0059
Experimental group after treatment	38	1.05	0.90			

* = Significant at $P \leq 0.05$ level t – critical = 1.67.

The results (Table 4.09b) show that the experimental subjects' performance in proportional reasoning increased significantly in the course of the experimental intervention. This shows that process–based instruction is effective in promoting the acquisition of probabilistic reasoning.

Table 4.09(c) Comparison of the experimental group mean scores in the control of variables before and after treatment.

Group	N	$\bar{X}$	SD	df	t- Value	P
Experimental group before Treatment	38	0.21	0.47	74	1.81*	0.065
Experimental group after treatment	38	0.47	0.73			

* = Significant at $P \leq 0.05$; t- critical = 1.67.

The results (Table 4.09c) show a significant difference in the subjects' performance in the control of variables as a result of the treatment, i.e. science process-based instruction. This is probably expected, as the ability to identify and control variables has been described to be a skill required in planning and conducting experiment (Padilla, 1983).

Table 4.09(d) Comparison of the performance of the experimental group in correlational reasoning before and after treatment.

Group	N	$\bar{X}$	SD	df	t- Value	P
Experimental Group before treatment	38	0.31	0.66			
				74	1.09*	0.28
Experimental group after treatment	38	0.47	0.60			

* = Not significant at $P \leq 0.05$; - critical = 1.67

The results (Table 4.09(d)) show that the experimental subjects performance did not show a significant difference after treatment. Nous and Raven (1973) observed that correlational reasoning requires complex mental operation hence instruction may be more effective for students who have acquired the pre – requisites skills for correlational reasoning. Lawson (1983) had predicted that probability reasoning and proportional reasoning are prerequisites to correlational reasoning. Since at the inception of the treatment, subjects have not yet acquired these prerequisites skills, it may logically follow that the subjects would require longer time of treatment to bring about significant gains in their correlational reasoning ability.

Table 4.09(c): Comparison of the mean scores of the subjects in combinatorial reasoning before and after treatment.

Group	N	$\bar{X}$	SD	df	t- value	P
Experimental group before Treatment	38	0.63	0.87			
				74	2.79*	0.066
Experimental group after treatment	38	1.16	0.82			

* = Significant at $P \leq 0.05$; t-critical = 1.67

The results (Table 4.09(e)) show a significant difference in the performance of the experimental subjects in tasks requiring combinatorial reasoning before and after treatment. This implies that science process based instruction is effective in increasing subjects'

performance in tasks requiring combinatorial reasoning. This is ordinarily expected, as the planning of experiments requires some logical combination of relevant variables.

Table 4.09(f) Comparison of the mean scores of the experimental subjects in probability tasks before and after treatment.

Group	N	$\bar{X}$	SD	df	t-value	P
Experimental group before treatment	38	0.53	0.79			
				74	0.30*	0.76
Experimental group after treatment	38	0.58	0.73			

* = Not significant at $P \leq 0.05$; t – critical = 1.67

Table 4.09(f) reveals that there is no significant difference in the mean scores of the experimental subjects in tasks involving probability reasoning before and after treatment. The fact that correlational, probability and conservation schemata were significantly increased may be explained based on arguments by Lawson et al (1978) that these skills are not acquired through direct or short term teaching. They further stressed that these skills are acquired as consequence of gradual process of equilibration. This implies that the curriculum designed to promote the acquisition of these reasoning skills should provide opportunities for equilibration to take place i.e. allows the cognitive structure to change to accommodate or provide anchorage for new information.

Table 4.10 The t – test value for the differences between the mean score of the control group in conservation, control of variables, probability, proportional, correlational, combinatorial and probabilistic reasoning after instruction.

Schemata	N	Df	t– value	P
Conservation	38	36	0.14*	0.89
Proportional reasoning	38	36	0.14*	0.89
Control of variable	38	36	0.39*	0.69
Correlational reasoning	38	36	0.37*	0.71
Combinational reasoning	38	36	0.58*	0.56
Probability reasoning	38	36	0.16*	0.87

* = Not significant at 0.05; t- critical = 1.67.

The results in Table 4.10 shows that there is no significant increase in the performances of the control group in all the six schemata tested. This is an indication that the lecture method does not seem to be effective in enhancing the acquisition of formal reasoning ability in the subjects as did the science process instructional strategy in most of the schemata.

4.3.3 The effect of science process instruction on acquisition of science process skills.

The third question deals with the effects of science process – based instruction on acquisition of science process skills. The following null hypothesis was tested.

$H0_3$: There is no significant difference in achievement between experimental subjects in concrete and formal operational stages in science process skills ability after exposure to science process – based instruction.

t – test statistics was used to determine if there is significant difference in the mean scores of the concrete and formal operational subjects in reasoning ability test after exposure to treatment i.e. for subjects in the experimental group.

Table 4.11 Comparison of the mean scores of the concrete operational and formal operational subjects in science process skills tasks for the experimental group before treatment.

Group	N	$\bar{X}$	SD	df	t– Value	P
Concrete	26	10.23	2.97			
				36	4.35*	0.000
Formal	16	14.83	3.16			

* = Significant at $P \leq 0.05$; t – critical = 1.68

The results in Table 4.11 show that there is significant difference in the performance of the formal and concrete operational subjects in science process skills tasks after treatment. This may be attributed to the use of hands-on activities that enable those at the concrete operational level to make inferences based on observed phenomena. These tended to make the processes of making such inferences less abstract and more meaningful to the concrete operational learners. Secondly, subjects who were concrete reasoners, might have acquired more experiences or formal reasoning ability in the course of the process–based instruction, which tended to have enhanced their performance. Lawson (1982) observed that greater amount of experience and greater information processing makes concrete operational subjects more responsive to instruction on formal reasoning. He explained that such concrete operational subjects have greater store of experience with which to assimilate the instruction, perhaps a larger mental capacity or perhaps in the classroom setting they are simply more motivated.

Table 4.12. Comparison between the mean scores of the concrete and formal operational subjects in science process skills tasks for the experimental group after treatment.

Group	N	$\bar{X}$	SD	df	t– Value	P
Concrete	26	23.46	2.03			
				36	0.56*	0.55
Formal	12	24.00	3.33			

* = Not Significant at $P \leq 0.05$ t – critical = 1.68

The results in Table 4.12 show that there is no significant difference in the performance of the formal and concrete operational subjects in science process skills tasks after treatment. This may be attributed to the use of hands–on activities that enable those at the concrete operational level to make inferences based on observed phenomena. These tended to make the process of making such inferences less abstract and more meaningful to the concrete operational learners. Secondly, subjects who were concrete reasoners, might have acquired more experience or formal reasoning ability in the course of the process–based instruction, which tended to have enhanced their performance. Lawson (1982) observed that greater amount of experience and greater information processing makes concrete operational subjects more responsive to instruction on formal reasoning. He explained that such concrete operational subjects have greater store of experience with which to assimilate the instruction, perhaps a larger mental capacity or perhaps in the classroom setting they are simply more motivated.

4.3.4 Effect of gender on acquisition of reasoning ability.

A comparison of the male and female subjects in the experimental group in reasoning ability was considered here.

The null hypothesis tested was stated thus:

Ho_4 There is no significant difference in

(a) formal reasoning ability of the male and female subjects after exposure to process-based instruction.

(b) the posttest mean scores of the male and female subjects in the following formal reasoning components:

(i) conservation

(ii) proportional reasoning

(iii) control of variables

(iv) correlational reasoning

(v) combinatorial reasoning

(vi) probabilistic reasoning

(:) the performance of male and female subjects in science process skills tasks after treatment.

/\. The question addressed here is whether gender constituted a factor in the acquisition of formal reasoning.

t – test statistics was used to determine the significant of the observed difference l etween the mean scores of the male and the female subjects in reasoning ability after t eatment.

Table 4.13: Comparison of the mean scores of the male and female subjects in the experimental groups in reasoning ability before treatment.

Group	N	$\bar{X}$	SD	Df	t- Value	P
Male	22	4.27	1.96			
				36	3.37*	0.0018
Female	16	2.50	0.89			

* = Significant at P≤ 0.05 level t - critical = 1.68

The results in Table 4.13 show a significant difference in the mean scores of the two groups. This indicates a significant difference in the reasoning ability of the boys and the girls. This tends also to show that reasoning is gender – related, being more in favour of boys, at least before treatment was administered in this study.

out that the gender differences observed in some reasoning modes were in favour of males. This is probably expected, as in Nigerian cultural setting, because females are less adventurous compared to the males, hence, they (the females) are not all the time confronted with situations where they are required to take crucial decisions that require reflective reasoning. Keating and Clark (1980) observed that interpersonal reasoning through a dilemma format (i.e. dilemma format involves an individual to think out a solution to a dilemma) promoted formal reasoning in individuals, though not as effective as the use of physical tasks. As cultural practices may not allow women to pass through such vigorous dilemmas as males do, their reasoning ability may not develop as that of their males counterparts.

Table 4.16 Comparison of the mean scores of the male and female subjects in the control group after instruction.

Group	N	$\overline{X}$	SD	Df	t- Value	P
Male	22	4.55	2.06			
				36	3.70*	0.001
Female	16	2.38	1.03			

* = Significant at $P \leq 0.05$; t – critical = 1.68

The results in Table 4.16 indicate that the male subjects also performed significantly better than the female subjects in the post test. The mean score of the male subjects by inspection (compare Table 4.15 and Table 4.16) shows a slight increase over the female subjects. This may indicate that the lecture mode of teaching in schools tends to stimulate reasoning in male more than in the female subjects. Levy (1980) stated that males' superior performance of cognitive tasks is due to their ability to extract spatial and logical relationships independently of the contextual components of the tasks. This ability helps them to cope with the rather abstract scientific concepts even when concepts are

explained through mathematical and quantitative treatment. Girls, on the other hand are less analytical and they tend to elucidate the meaning of a concept from connotative content as specified, for example by social context. They also possess the ability to form associations between conceptually, seemingly unrelated ideas. These pattern of reasoning which are many characteristics, but none the less confined to girls, are usually neglected in the sciences class; hence, their holders are never rewarded by teachers.

(B) The posttest mean scores of the male and female subjects in formal reasoning schemata

The question addressed here is whether gender constitutes a significant factor in the subjects' ability to use the following components of reasoning effectively, namely;

a. Conservation

b. Proportional reasoning

c. Control of variables

d. Correlational reasoning

e. Combinational reasoning

f. Probabilistic reasoning

Tables 4.17(a) comparison of the posttest mean scores of the male and female subjects in conservation after treatment.

Group	N	$\bar{X}$	SD	df	t-value	P
Male	23	0.83	0.39			
				46	1.26*	0.22
Female	24	0.50	0.78			

* Not significant at P 0.05 level t critical 1.68

Table 4.17(b) comparison of the pre-test means scores of male and female subjects in the experimental group on proportional reasoning

Group	N	$\bar{X}$	SD	df	t-value	P
Male	22	1.00	1.07			
				36	0.00*	1.00
Female	16	1.00	0.82			

* Not significant at P< 0.05 level t – critical = 1.68

The results in Table 4.17(a) and 4.17(b) indicate that the male and female subjects do not differ significantly in performance after instruction. This shows that the female subjects have been able to match the performance of their male counterparts in proportional logic by the end of the treatment.

Table 4.17(c): Comparison of male and female subjects' post-test mean scores in the control of variables after treatment.

Group	N	$\bar{X}$	SD	df	t-value	P
Male	22	0.36	0.73			
				36	1.07	0.28
Female	16	0.65	0.25			

Not Significant at P< 0.05 level t – critical = 1.68

The result of the t – test analysis in Table 4.17(c) revealed no significant difference in the subjects' ability to control variables after exposure to treatment. Though, there is no significant difference in performance, the mean score of the female subjects is higher than that of the males. This is an indication that the female subjects tended to have benefited more from the treatment than their male counterpart.

Table 4.17(d): Comparison of the post-test mean scores of the male and female subject in correlational reasoning after treatment.

Group	N	X	SD	DF	t-Value	P
Male	22	1.18	0.85			
				36	2.70*	0.011
Female	16	0.5	0.63			

Significant at P< 0.05 level t-critical 1.68

The results in Table 4.17(d) show that the male subjects performed significantly better than the female subjects. This observation is an additional empirical evidence that correlational reasoning is a very complex skill that can only be acquired when the prerequisite skills required for its development have been formed. The female subjects performed significantly lower than the male subjects at the beginning of instruction, thus, the treatment period might have been too short for the prerequisite skills to develop and assimilation takes place for the correlation skill to be established.

Table 4.17(e): Comparison of the mean scores of the male and female subjects in combinatorial reasoning after treatment.

Group	N	X	SD	df	t-value	P
Male	22	1.00	0.82			
				36	0.00*	1.00
Female	16	1.00	0.82			

* Not Significant at P< 0.05 level t- critical 1.68

From the results in Table 4.17(e), it can be seen that there is no significant difference in the comparison of the mean scores of the male and female subjects in combinatorial reasoning.

Table 4.17(i): Comparison of the mean scores of the male and female subjects in probabilistic reasoning after the onset.

Group	N	X	SD	df	t- Value	P
Male	27	10.55	0.520			
				56	0.30[ns]	0.76
Female	16	0.67	0.51			

[ns] Not significant at P 0.05 level t critical 1.68

The results in Table 4.17(i) shows that there is no significant difference in the performance of the male and female subjects in probabilistic reasoning.

c The last aspect of Ho_3 was to address the effect of gender on acquisition of science process skills.

Table 4.18: Comparison of the mean scores of the male and female subjects of the experimental group before treatment.

Group	N	X	SD	df	t- Value	P
Male	27	11.63	5.63			
				56	0.08[ns]	0.93
Female	16	11.75	5.90			

[ns] Not Significant at P 0.05 level t critical 1.68

The results in Table 4.18(a) indicated that there is no significant difference in the performance of the male and female subjects in science process skills tasks before treatment.

Table 4.19: Comparison of the mean scores of the male and female subjects of the experimental group in science process skills tasks after treatment.

Group	N	$\bar{X}$	SD	df	t- Value	P
Male	22	23.00	3.18			
				36	1.69	0.10
Female	16	24.44	1.50			

* Significant at P 0.05 level t critical 1.68

The results in Table 4.19 shows that the female subjects in the experimental group performed significantly better than male subjects in process based tasks after treatment. This supports the observation by Shuaibu and Ameh (1982) and Mari (1994) that the performance of girls in tasks involving science process skills is generally superior to that of boys. It also suggests that female subjects benefited more than their male counterparts in the process based instruction in this study.

Table 4.20: Comparison of the mean scores of the male and female subjects in the control group in science process skills tasks after instruction.

Group	N	$\bar{X}$	SD	df	t- Value	P
Male	22	12.36	4.30			
				36	0.88*	0.36
Female	16	13.50	3.35			

* Not Significant at P 0.05 level t critical 1.68

Table 4.21: Comparison of the mean scores of the male and female subjects in the control group in science process skills tasks.

Group	N	$\bar{X}$	SD	df	t- Value	P
Male	22	11.29	3.15			
				36	0.34*	0.73
Female	16	11.69	4.11			

* Not Significant at P 0.05 level t critical 1.68

The results in Table 4.20 and 4.21 show that the performance of the male and female subjects in the control group did not differ significantly before and after treatment

indicating that the gain observed in the experimental group was due to the treatment. These results support the findings of Ajagun (1998) in which she observed that the performance of the female subjects in urban school was not significantly different from their male counterpart. However, the mean score of the female subjects by inspection, was higher than that of the male subjects, an indication that the female subjects were slightly, but not significantly superior to their male counterparts.

4.4 DISCUSSION OF THE RESULTS

The data generated from the administration of the instruments, i.e. GALT and TOPS were analyzed according to the demand of the hypotheses stated and the design of the study as reported in chapter 3. The analysis was carried out using the SPSS statistical package. The discussion of the results and the summary of the findings are as follows:

Ho1: There is no significant difference in the formal reasoning ability of the subjects in the experimental and control groups after exposure to process based instruction.

The experimental group performed significantly better than the control group (t [81] $p < 0.05$) in their post test scores. This shows that the process based instruction is effective in enhancing the acquisition of formal reasoning in subjects under study. This result supports the observation by Lawson (1985a) that subjects' formal reasoning ability can be enhanced through effective instruction. Other studies by Jones (1983) and Lawson (1985) have also shown that time spent on teaching pre service teachers' process skill results in gains in their logical reasoning. The suitability of science process skills as means of promoting reasoning ability may be attributed to the nature of the instruction which is less teacher directed, but more learner centered, and thus, provides a variety of activities for the subjects to control their own actions in the process of learning. Subjects

are allowed to independently state hypotheses, plan experimental design to test them, carry out the experiments, identify and control variables, collect data and interpret them, think out possible sources of error and ways of appropriately modifying the experimental design. All these require intellectual exercise, which did positively affect the subjects' reasoning ability. The relatively poor performance of the subjects in the control group in formal reasoning ability is an indication that the lecture method adopted in teaching science by science teachers is not quite effective in promoting formal reasoning in students in the secondary schools. This is supported by the observation of Lawson (1978) that subjects do not acquire formal reasoning ability unless concerted efforts are made to identify and use instructional strategies that promotes its development.

Ho2 There is no significant difference in the pre and post test mean scores of the subjects in the experimental group in the following skills.

a. Conservation
b. Proportional reasoning
c. Control of variables
d. Correlational reasoning
e. Combinational reasoning
f. Probabilistic reasoning

T – test statistics was used to test for possible significant differences in the pretest and postest scores of the subjects in all the schema. The results showed that the subjects' postest mean scores was significantly better than the pre test mean scores in the schemas of proportional reasoning, control of variables, and combinational reasoning. There was no significant increase in performance in conservational, correlational, and probabilistic reasoning. However, the subjects showed gains in correlational, conservational and probabilistic reasoning which is an indication that the process based instruction could be

used to enhance the acquisition of all the schemas involved. The subjects' insignificant improvement in performance in correlational and probabilistic reasoning may be attributed to the fact that the acquisition of these skills requires the attainment of some pre-requisite skills. For example, the ability to solve correlational and probabilistic tasks requires the use of skills like proportion and control of variables. This entails that these pre requisite skills must be acquired first before there is significant improvement in the ability to solve tasks involving probabilistic and correlational reasoning.

The subjects' insignificant improvement in performance in conservation skill may be attributed to the fact that the skill is more associated with basic science process skills as it requires ability to conserve variable like weight, volume, density etc which requires some activities in measurement. In the current study, all the activities were based on integrated science process skills. Hence, the conservation skills which appear to be the most likely to be enhanced tended not to be significantly improved after treatment.

Ho$_{10}$: There is no significant difference in achievement between concrete and formal proportional subjects in the experimental groups in science process skills ability after exposure to process based instruction.

The results in Table 4.12 show no significant difference in the performance of the formal and concrete operational subjects in science process skills tasks after treatment. The pretest results (Table 4.11), however, show a significant difference in performance between the concrete and formal operational subjects in favour of formal operational subjects. The posttest means scores of both the formal and concrete operational subjects are higher than the pretest scores. This is an indication that both concrete and formal subjects show a significant improvement in science process skills tasks as a result of the treatment. The process based instruction is therefore effective in stimulating cognitive growth in both concrete and formal operators.

The findings that formal operational subjects did not perform significantly better than the concrete operational subjects, contrary to expectation is attributable to the use of hands on activities that enable those at concrete operational level to make inferences based on observed phenomena. These tended to make the process of making such inferences less abstract and more meaningful to the concrete operational learners. Secondly, subjects who were operating at concrete operational stage, might have acquired more experiences or formal reasoning ability which tended to have enhanced their performance. This claim can be substantiated by the result (Table 4.07) which showed that 37% of the subjects attained formal reasoning at the end of the treatment. Thirdly, subjects at the average age of 16 years could have acquired a reasonable measure of experience or perhaps a large mental capacity with which to assimilate the instruction or perhaps they were simply more motivated than the formal operational subjects.

Ho4 There is no significant difference in;

(a) formal reasoning ability of the male and female subjects after exposure to process-based instruction

(b) the posttest mean scores of the male and female subjects in the following formal reasoning components;

(i) conservation

(ii) proportional reasoning

(iii) control of variables

(iv) correlational reasoning

(v) combinatorial reasoning

(vi) probabilistic reasoning

(c) the performance of male and female subjects in science process skills tasks after treatment.

(a) There is no significant difference in the formal reasoning ability of the male and female subjects after exposure to process based instruction.

The t – test analysis of the posttest ($\alpha = 0.05$; $P = 0.05$) scores of the subjects (Table 4.13) revealed no significant difference in formal reasoning ability between the male and female subjects. However, the pre – test scores analysis revealed a significant difference in performance in favour of male subjects. This shows that the female subjects were able to bridge the gap at the end of the treatment. Though, both the male and female subjects showed gains in their formal reasoning ability following treatment, the female subjects tended to have benefited more from the treatment. The results suggest that process based instruction is gender related in favour of female subjects. Several studies for example Shuaibu and Anieh (1987), Mari (1993) and Ajaegu (1998), revealed superiority in performances of female students over their male counterparts in tasks involving science process skills. Generally, gender differences in cognitive abilities are attributed to either psycho-social factors (Shuaibu and Anieh, 1982; New comb et al, 1983) or psychological factors (Levy, 1980). Levy (1980) stated that the males' superior performance in cognitive tasks in some instances is due to their ability to extract spatial and logical relationships independently of the contextual components of the tasks. The females, according to him are less analytical and they tend to elucidate the meaning of a concept from connotative content as specified. These patterns of reasoning, which are more characteristic, but nonetheless confined to girls are usually neglected in the science classrooms and so teachers never reward their holders. The process based instruction tend to provide remedy in reasoning ability of female students by providing very rich activities and concrete materials which lowers the level of abstraction hence, enable female subjects make inferences which are direct extrapolation from observed phenomena. The results then, showed that gender plays an important role in the

acquisition of formal reasoning by students.

(b) There is no significant difference in the pooled mean scores of the male and female subjects in the following formal reasoning components;

a. Conservation

b. Proportional reasoning

c. Control of variables

d. Correlational reasoning

e. Combinatorial reasoning

f. Probabilistic reasoning

The results in Table 4.17(a) – 4.17(f) showed that there was no significant difference in the performance of the male and female subjects in all the schemas, except the schema of correlational reasoning, in which the male subjects performed significantly better than the female subjects. The treatment administered seem to have helped in removing male/female differences in all the schemata except correlational reasoning in which the male subjects' superiority over the female subjects persisted even after treatment. This may be another evidence that the correlational reasoning is a complex skill, which can only be attained when the prerequisites skills are formed. Thus, the treatment was long enough to allow for the acquisition of the pre-requisite skills, but was not long enough for the subjects to significantly improve their performance in correlational task.

(c) Male and female subjects exposed to science process based instruction do not differ significantly in their performance in science process skills tasks.

The results in Table 4.19 show that the female subjects in the experimental group performed significantly better than the male subjects in process skills tasks after treatment. This is an indication that science process based instruction promote the

acquisition of science process skills in female more than in male subjects. In a similar study, Shuaibu and Ameh (1987) attributed this gender difference in favour of girls to sex roles in the formative years of children. They opined that girls were severely limited in experiences requiring manipulative and mathematical skills. They further stressed that in Nigeria and in the African traditional setting generally, females are expected to "use their eyes and ears, not their mouths". The science process skills, according to Shuaibu and Ameh (1987), are more intuitive and dependent on some level of internalization of observed data; hence, girls tend to excel in them more than boys do.

CHAPTER FIVE

SUMMARY, CONCLUSION AND RECOMMENDATIONS

5.1 INTRODUCTION

In this chapter, the summary of the procedure for data collection and the findings from the study are presented. The conclusions, and recommendations arising from the findings are also outlined.

5.2 SUMMARY

This study was designed to investigate the effect of a process based instruction on formal reasoning ability. In addition, the researcher examined the interactions between gender, cognitive stage of the subjects and process based instruction on one hand, and the effect of process – based instruction on the learning outcomes of the subjects.

A total of 76 subjects (38 in experimental group and 38 in control group) were used for the study. The experimental group was exposed to process based instruction for six weeks. The pretest and posttest scores of the experimental and control groups were analyzed to test hypotheses stated in chapter one.

The t-test statistics was used for testing the stated hypotheses. A confidence limit of 0.05 level was adopted for retaining or rejecting the hypotheses. The analysis of the pretest results on reasoning ability test, revealed low level of formal reasoning among the subjects. The distribution of the scores showed that a high proportion of the subjects were operating at the concrete operational stage of Piaget's classification and that only 26% of the subjects had attained the level of abstract reasoning. Since the subjects had an average chronological age of 16 years, they were, theoretically expected to be proficient in using formal reasoning modes to solve problems.

5.3 SUMMARY OF THE RESULTS

The summary of the results and findings of the study are presented below.

5.3.1 Results

The pretest scores show that the experimental group performed significantly better than the control group in formal reasoning tasks. This is an indication that the process based instruction was effective in promoting the acquisition of formal reasoning ability in the subjects.

The results also showed that both the male and female subjects made some gains in their mean scores on formal reasoning tasks following treatment. However, the female subjects achieved higher gains in their mean scores compared to their male counterparts. This was an indication that the female subjects benefited more from the process - based instruction i.e. the treatment compared to their male counterparts.

The results also showed that both the concrete and formal operational subjects showed increased performance in science process skill tasks following treatment. However, the treatment tended to be more beneficial to the subjects at the concrete operational level than those at the formal operational stage. The posttest scores of the experimental group showed an appreciable gains in their mean scores measuring the various schemas compared to pretest mean scores at the end of treatment. However, it was found that the increase was statistically significant in the schemas of proportional reasoning, control of variables and combinational reasoning only.

Similarly, the results also showed that the performances of the male and female subjects were not significantly different in all the schemas after treatment except in the schema of correlational reasoning in which the male subjects performed significantly better than the female subjects.

In another gender related variable examined, i.e. the effect of gender on process skills acquisition, the female subjects performed significantly better than the male subjects in process skills tasks after treatment.

5.3.2 Findings

The following findings were obtained:

1. The experimental group performed significantly better than the control group in formal reasoning tasks after treatment.
2. Science process based instruction was found to be gender related in favour of girls.
3. The initial gap between the female and male subjects in formal reasoning ability was bridged in all the schemas (conservation, control of variables, proportional reasoning, probabilistic reasoning, combinatorial reasoning) except in correlational reasoning.
4. Science process skill instruction was found to be more effective in promoting the acquisition of science process skills in female than in their male counterparts.
5. Though the subjects showed an appreciable increase in their mean scores in post test over the pretests in all the schemas, however, the difference in the mean scores was only significant in the schemas of combinatorial reasoning, proportional reasoning and control of variables.
6. Though both the concrete and formal operational subjects benefited from the treatment, the concrete operational subjects seemed to have benefited more than their formal operational counterparts.

5.4 CONCLUSION

Based on the results obtained from this study, the following conclusions can be made:

The analysis of the results show that 32% of the experimental subjects acquired formal

reasoning ability because of the training. This is an indication that process-based instruction is effective in improving the reasoning ability of the subject. This also show that the traditional lecture method commonly used for instruction in schools is not quite suitable for promoting the acquisition of formal reasoning ability.

The study revealed a gender related difference in reasoning ability. Since formal reasoning is essential in the learning of scientific concepts, this may explain why female students generally perform poorly in science.

The male and female subjects did not show any significant difference in piagetian tasks after treatment. This shows that process-based instruction is more effective in promoting acquisition of formal reasoning in male than in female subjects. This may imply that process based instruction can be used as an effective instructional tool for eliminating gender related differences in reasoning ability and also a step towards enhancing female students performance in science learning.

The experimental group performed significantly better than the control group in formal reasoning tasks after treatment. This shows that formal reasoning could be acquired through appropriate training. This is also an indication that improbable teaching methods may be responsible for students' inability to acquire formal reasoning ability in the secondary schools.

The concrete operational subjects showed greater gains in formal reasoning than the formal operational subjects when process – based instruction was used. This suggests that process based instruction is effective in promoting reasoning gains for concrete operational students. As this study has shown that most of the senior secondary school students are operating at concrete operational level, the mode of instruction should be predominantly concrete laboratory experiences that would aid transition from concrete to formal level of reasoning.

The study revealed that female subjects are superior to male subjects in achievement in science process skills tasks. This is an indication that this mode of teaching could enhance the acquisition of science process skills and achievement in science among the female students.

5.5. RECOMMENDATIONS

Based on the findings of this study, the following recommendations are made:

1. Since the level of students' reasoning affects the learning of science concepts, there is therefore the need for science teachers to systematically and periodically assess or determine the reasoning ability of their students. One way of doing this is by the use of Group Assessment of Logical Thinking (GALT). This is with a view to adapting curricular contents, achievement goals, instructional methods and educational strategies to match students' level of cognitive development. Teachers could also use GALT to monitor the effects of their instructional mode on students' acquisition of formal reasoning ability.
2. The science process based instruction tend to have stimulated higher reasoning gains in the female subjects than the male subjects. There is, therefore, the need to use science process based instruction in the early years in secondary school as a means to reduce if not totally eliminate, the male/female difference in reasoning ability.
3. The study also revealed gender-related differences in the acquisition of science process skill (between boys and girls, in favour of girls. One implication of this is that boys are seen as superior over girls in science and technical courses. Also, the method of evaluation in Nigerian schools is predominantly content based, hence, would make it difficult for teachers to identify and remedy for this deficiency in boys. As this study has shown, instructional methods tend to be gender related, there is the need to

use a variety of methods in science teaching to ensure that both boys and girls are provided with ample opportunity that help them to develop conceptually and thus, enhance understanding of science lessons.

4. The finding in this study that shows the existence of a wide range of students' performance on GALT, in which some students successfully used proportional, probabilistic and correlational reasoning while a significant fraction of the subjects could not, calls for an urgent need for teachers to identify the cognitive characteristics of their students prior to and during instruction periods. GALT could be used as a suitable instrument to gain such knowledge as a guide for provision of individual remedial treatment where the need arises.

5. Science teachers should not expose students to activities that involve the use of correlational reasoning until in SSS III or higher level when proportional and probabilistic reasoning which are pre requisites for correlational reasoning are relatively well established in the students' repertoire.

6. Science teachers should be encouraged to regularly and routinely attend workshops on how to organize and direct process-based instruction.

7. All faculties of education in Nigerian universities should be encouraged to design programmes that will equip pre service teachers with skills for use in science process based instruction and in organizing science process based activities. This is because teachers teach the way they are taught and or trained.

5.6. LIMITATIONS OF THE STUDY.

This study, arising from time and other logistic constraints, suffered from some limitations that the author could do little to avoid or forestall. The major ones were the following:

1. The process based instruction used in the study was limited to three science process skills, namely experimenting, interpretation of data and hypotheses formulation. The time constraint could not permit the use of all the process skills. The findings cannot therefore be generalized to the other skills that were not included in the study.
2. The average age of the sample used for the study was 16 years, hence, the concrete subjects in the sample might have a greater repertoire of experiences than concrete subjects at lower age. If the findings of this study are to be generalized to the students at the lower chronological age, then, it must be done with some caution.

5.7 SUGGESTIONS FOR FURTHER STUDIES

1. A further study could be carried out to collect data on several classes with larger sample sizes and each class analyzed separately to observe any developmental differences, which may exist across various age levels. Such study would help to broaden an understanding of the interrelationships which might exist among students cognitive structures vis - a - vis their age type.
2. This study can be replicated in rural schools to determine if there are differences in the cognitive development between students in the schools located in the rural areas and those located in the urban areas.
3. There is the need to extend the study over a period of two to four years to determine the sustenance or otherwise of the effects of process based instruction in promoting cognitive gains in students. This will also help to establish if long period of exposure to process based instruction will help to eliminate or remedy female students deficiency in the use of correlational reasoning.
4. The findings of the study seem to suggest deficiencies in the subjects' ability to use formal reasoning. Studies should be carried out, focusing particularly on identifying the nature of the difficulties and possible remedial procedures.

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APPENDIX I

To test hypotheses using t-test statistics, the following assumptions were made:

1. That the samples are random samples from a normal distribution.

2. That normal population distribution have equal variances.

Following the demand of the first assumption, samples will be selected randomly as described in section 3.4. Thus, the normality of the distribution is assumed.

To satisfy the demand of the second assumption, the size of the samples to be compared will be kept the same. Walepole (1974) pointed out that t – test can be used to compare the differences of the means of the two samples which the estimated population variances differ significantly, if the two samples are of the same size (N1 = N2). The number of the subjects in form SII and SI was kept the same and also the male and female subjects. This means that t – test can still be used for comparing the means even if the **population variances differ significantly**

Appendix 2

TEST OF SCIENCE PROCESS SKILLS (TOPSS) CHEMISTRY TEST 1

ATTEMPT ALL QUESTIONS

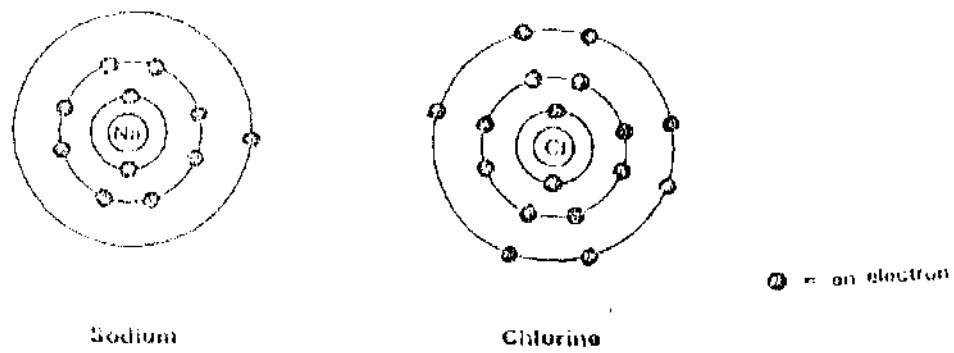
ALL ANSWERS MUST BE WRITTEN ON

THE QUESTION PAPER.

DO NOT START UNTIL YOU ARE

TOLD TO DO SO

1. The diagram shows the structure of sodium and chlorine atoms



a State three similarities between the structure of the atoms.

i_____

_____

ii _____

_____

iii. _____

_____

b State two differences between the structure of the atoms.

i _____

_____

ii _____

_____

2. The table shows some properties of elements in the second and third periods of the periodic Table.

(a) Moving from left to right across period

2(i.e. from Li to F) what pattern is shown by changes in

(i) The radius of the atom

(ii) The melting points of the atoms?

(iii) The *boiling points of* atoms?

(b) Moving from to down the groups e.g. from Li to Na, describe the pattern shown changes in

(i) The radius of the atoms

(ii) The boiling points of the atoms.

(iii) The melting points of the atoms.

3 While investigating the effect of temperature on reaction rates, a student obtained the following results.

Experiment	Mass of zinc (g)	Temperature (°C)	Time taken to dissolve in HCl (s)	State of Zinc
A	2.0	5	400	Zinc foil
B	2.0	15	200	do
C	2.0	25	100	do
D	2.0	35	50	-do-
E	2.0	45	25	-do-
F	2.0	15	5	Zinc powder

a. In which experiment was the reaction rate fastest ? Ans. ____

b. If 2g of zinc foil took 40 seconds to dissolve completely in the acid, what is the temperature of the reaction ?

Answer ____

c. In one sentence, state the effect of temperature on the reaction of zinc and HCl.

4. In an investigation into the reaction of lithium with water, a student obtained the following results :

Reaction time (s)	0	10	20	30	40	50	60
Volume of hydrogen (cm^3)	0	24	39	48	53	55	55

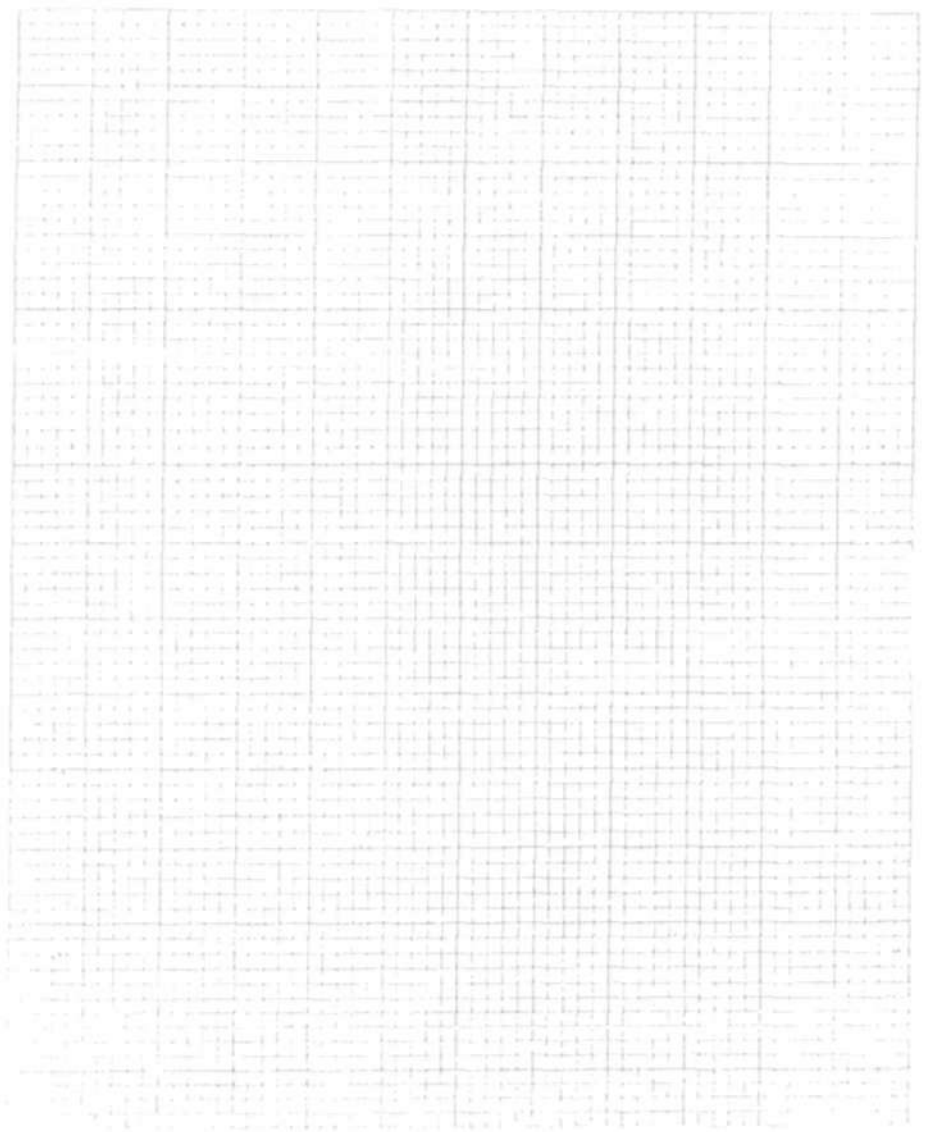
Name	Numberof carbon atoms/ molecule.	Formula	Boiling point. °C	Stateat room temp.
Methane	1	CH4	- 160	gas
Ethane	2	C_2H_6	- 90	gas
Propane	3	C_3H_8	- 40	gas
Butane	4	C_4H_{10}	0	gas
Pentane	5	C_5H_{12}	35	
Hexane	6	C_6H_{14}	70	liquid
Heptane	7	C_7H_{16}	100	liquid

a. Complete the gap in the last column of the table.

b. Plot a graph of the above information.

c. Use your graph to predict the boiling point of octane ; an alkane with eight carbon atoms. Answer _____.

a. Plot a graph of these results.



b. The volume of hydrogen liberated in the first half of the reactiontimeis_____

c. The volume of gas liberated in 46 seconds is _____.

5. Crude oil, a major source of revenue in Nigeria is a mixture of a family of chemicals called alkanes. The table shows some of the properties of the first seven members of the alkane family.

Name	Number of carbon atoms/ molecule	Formula	Boiling point °C	State at room temp.
Methane	1	CH_4	- 160	gas
Ethane	2	C_2H_6	- 90	gas
Propane	3	C_3H_8	- 40	gas
Butane	4	C_4H_{10}	0	gas
Pentane	5	C_5H_{12}	35	
Hexane	6	C_6H_{14}	70	liquid
Heptane	7	C_7H_{16}	100	liquid

a Complete the gap in the last column of the table.

b Plot a graph of the above information.

c Use your graph to predict the boiling point of octane, an alkane with eight carbon atoms. Answer .....

APPENDIX 3

GROUP ASSESSMENT OF LOGICAL THINKING(GALT)

Directions

Directions.

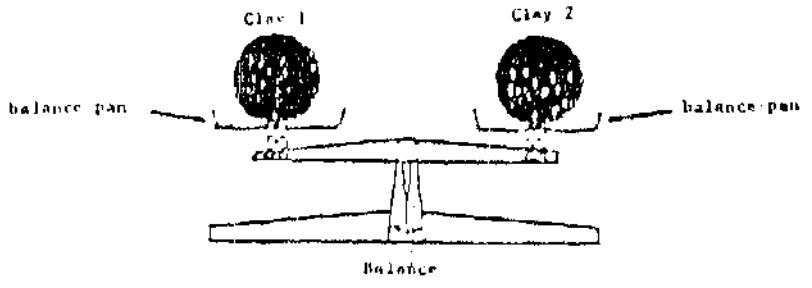
The purpose of the questions in this booklet is to find out how logically you think. Your reasons for choosing an answer is as important as the answer itself.

Answer Every Question

In answering each question, go through the following steps:

1. Read the question carefully
2. Record you answer in the space provided on the answer sheet.
3. Read the set of possible reasons and carefully select the reason which best matches your thinking.
4. Record your reason in the space provided on the Answer Sheet.

Tom has two balls of clay. They are the same size and shape. When he places them on the balance, they weigh the same.



The balls of clay are removed from the balance pans. Clay 2 is flattened like a pancake.



WHICH OF THESE STATEMENTS IS TRUE?

a. The pancake-shaped clay weighs more.

b. The two pieces weigh the same.

c. The ball weighs more.

REASON

1. You did not add or take away any clay.

2. When clay 2 was flattened like a pancake, it had a greater area.

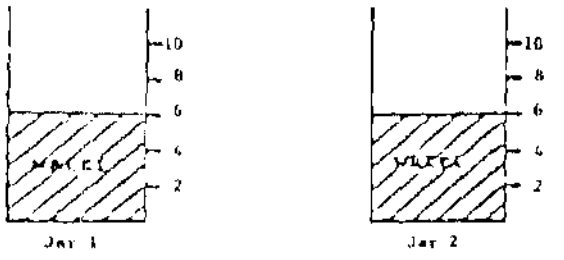
3. When something is flattened, it loses weight.

4. Because of its density, the round ball had more clay in it.

Metal Weights

120

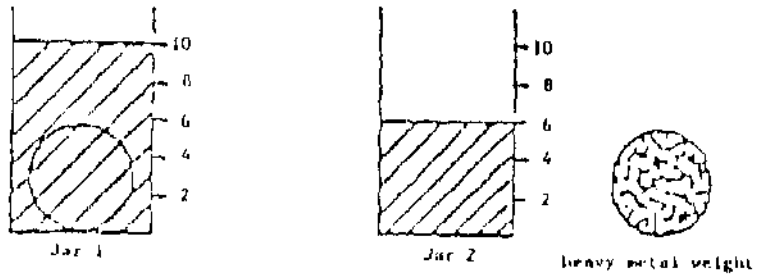
Linn has two jars. They are the same size and shape. Each is filled with the same amount of water.



She also has two metal weights of the same volume. One weight is light. The other is heavy.



She lowers the light weight into jar 1. The water level in the jar rises nd looks like this:



F THE HEAVY WEIGHT IS LOWERED INTO JAR 2, WHAT WILL HAPPEN?

a. The water will rise to a higher level than in jar 1.
b. The water will rise to a lower level than in jar 1.
c. The water will rise to the same level as in jar 1.

EASON

1. The weights are the same size so they will take up equal amounts of space.
2. The heavier the metal weight, the higher the water will rise.
3. The heavy metal weight has more pressure, therefore the water will rise lower.
4. The heavier the metal weight, the lower the water will rise.

The drawing shows two glasses, a small one and a large one. It also shows two jars, a small one and a large one.



It takes 15 small glasses of water or 9 large glasses of water to fill the large jar. It takes 10 small glasses of water to fill the small jar.

HOW MANY LARGE GLASSES OF WATER DOES IT TAKE TO FILL THE SAME SMALL JAR?

a. 4

b. 5

c. 6

d. other

REASON

1. It takes five less small glasses of water to fill the small jar. So it will take five less large glasses of water to fill the same jar.

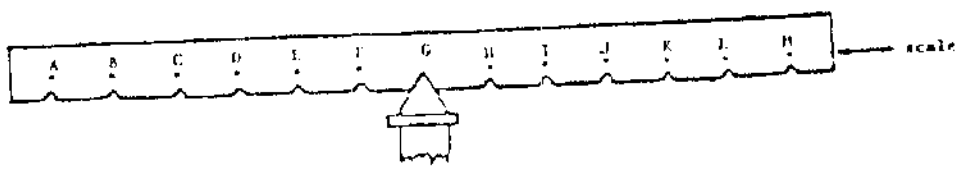
2. The ratio of small to large glasses will always be 5 to 3.

3. The small glass is half size of the large glass. So it will take about half the number of small glasses of water to fill up the same small jar.

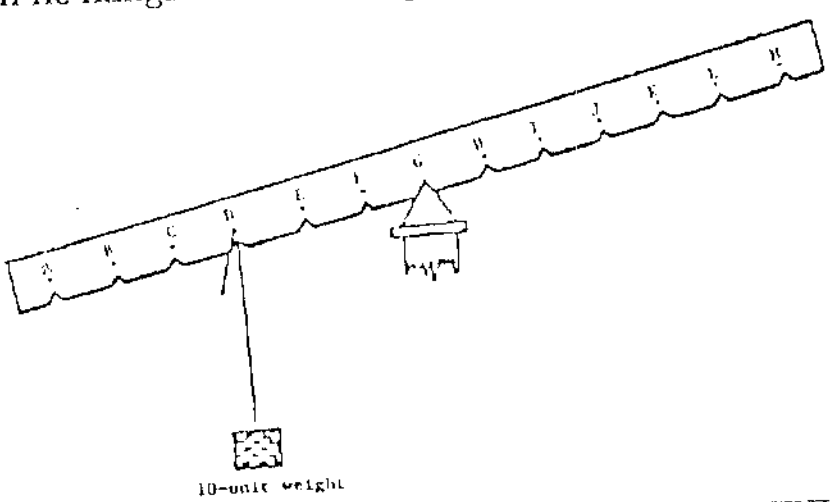
4. There is no way of predicting.

Scale # 1 122

Joe has a scale like the one below.



When he hangs a 10-unit weight at point D, the scale looks like this:



HERE WOULD HE HANG A 5-UNIT WEIGHT TO MAKE THE SCALE
ALANCE AGAIN?

a. at point J

b. between K and L

c. at point L

d. between L and M

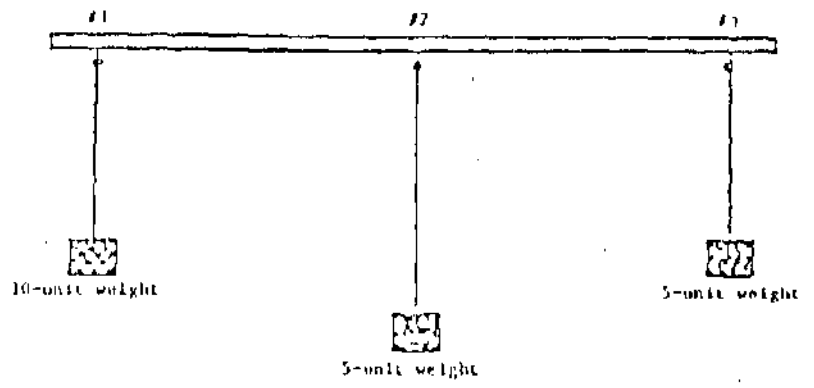
e. at point M

EASON

1. It is half the weight so it should be put at twice the distance.
2. The same distance as 10-unit weight, but in the opposite direction.
3. Hang the 5-unit weight further out, to make up its being smaller.
4. All the way at the end gives more power to make the scale balance.
5. The lighter the weight, the further out it should be hung.

Pendulum Length 123 113

Three strings are hung from a bar. String #1 and #3 are of equal leng h. ring #2 is longer. Charlie attaches a 5-unit weight at the end of string #2 id at the end of #3. A 10-unit weight is attached at the end of string #1. ich string with a weight can be swung.



Charlie wants to find out if the length of the string has an effect on the ount of time it takes the string to swing back and forth.

ICH STRING AND WEIGHT WOULD HE USE FOR HIS EXPERIMENT?

a. string #1 and #2

b. string #1 and #3

c. string #2 and #3

d. string #1, #2, and #3

e. string #2 only

ASON

1. The length of the strings should be the same. The weights should be different.

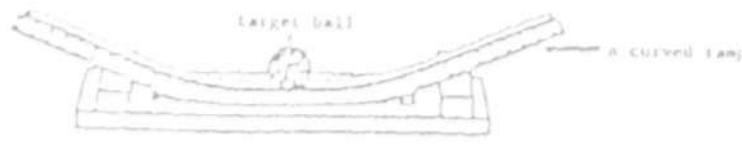
2. Different lengths with different weights should be tested.

3. All strings and their weights should be tested against all others.

4. Only the longest string should be tested. The experiment is concerned with length not weight.

5. Everything needs to be the same except the length so you can tell if length makes a difference.

Eddie has a curved ramp. At the bottom of the ramp there is one ball alled the target ball.



There are two other balls, a heavy and a light one. He can roll one ball own the ramp and hit the target ball. This causes the target ball to move up he other side of the ramp. He can roll the balls from two different points, a w point and a high point.



Eddie released the light ball from the low point. It rolled down the mp. It hit and pushed the target ball up the other side of the ramp.



He wants to find out if the point a ball is released from makes a Terence in how far the target goes.

O TEST THIS WHICH BALL WOULD HE NOW RELEASE FROM THE HIGH OINT?

a. the heavy ball
b. the light ball

EASON

1. He started with the light ball he should finish with it.
2. He used the light ball the first time. The next time he should use the heavy ball.
3. The heavy ball would have more force to hit the target ball farther.
4. The light ball would have to be released from the high point in order to make a fair comparison.
5. The same ball must be used as the weight of the ball does not count.

Squares and Diamonds #1

In a cloth sack, there are

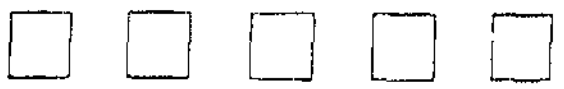
474792



3 spotted wooden squares



4 black wooden squares



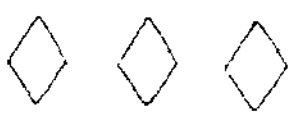
5 white wooden squares



4 spotted wooden diamonds



2 black wooden diamonds



3 white wooden diamonds

All of the square pieces are the same size and shape. The diamond pieces are also the same size and shape. One piece is pulled out of the sack. WHAT ARE THE CHANCES THAT IT IS A SPOTTED PIECE?

a. 1 out of 3
b. 1 out of 4
c. 1 out of 7
d. 1 out of 21
e. other

REASON

1. There are twenty-one pieces in the cloth sack. One spotted piece must be chosen from these.
2. One spotted piece needs to be selected from a total of seven spotted pieces.
3. Seven of the twenty-one pieces are spotted pieces.
4. There are three sets in the cloth sack. One of them is spotted.
5. 1/4 of the square pieces and 4/9 of the diamond pieces are spotted.

Squares and Diamonds #2

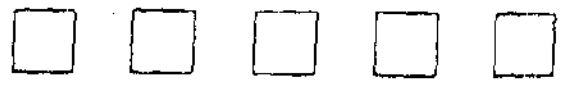
In a cloth sack, there are



3 spotted wooden squares



4 black wooden squares



5 white wooden squares



4 spotted wooden diamonds



2 black wooden diamonds



3 white wooden diamonds

All of the square pieces are the same size and shape. The diamond pieces are also the same size and shape. Reach in and take the first piece you touch.

WHAT ARE THE CHANCES OF PULLING OUT A SPOTTED DIAMOND OR A WHITE DIAMOND?

a. 1 out of 3
b. 1 out of 9
c. 1 out of 21
d. 9 out of 21
e. other

REASON

1. Seven of the twenty-one pieces are spotted or white diamonds.
2. 4/7 of the spotted and 3/8 of the white are diamonds.
3. Nine of the twenty-one pieces are diamonds.
4. One diamond piece needs to be selected from a total of twenty-one pieces in the cloth sack.
5. There are 9 diamond pieces in the cloth sack. One piece must be chosen from these.

...ersity Library
...ern Illinois University

The Mice

A farmer observed the mice that live in his field. He found that the mice were either fat or thin. Also, the mice had either black tails or white tails.

This made him wonder if there might be a relation between the size of a mouse and the color of its tail. So he decided to capture all of the mice in one part of his field and observe them. The mice that he captured are shown below.

DO YOU THINK THERE IS A RELATION BETWEEN THE SIZE OF THE MICE AND THE COLOR OF THEIR TAILS (THAT IS, IS ONE SIZE OF MOUSE MORE LIKELY TO HAVE A CERTAIN COLOR TAIL AND VICE VERSA)?

a. Yes

b. No

REASON

1. 8/11 of the fat mice have black tails and 3/4 of the thin mice have white tails.

2. Fat and thin mice can have either a black or a white tail.

3. Not all fat mice have black tails. Not all thin mice have white tails.

4. 18 mice have black tails and 12 have white tails.

5. 22 mice are fat and 8 mice are thin.



Some of the fish below are big and some are small. Also some of the fish have wide stripes on their sides. Others have narrow stripes.

IS THERE A RELATIONSHIP BETWEEN THE SIZE OF THE FISH AND THE KIND OF STRIPES IT HAS (THAT IS, IS ONE SIZE.OF FISH MORE LIKELY TO HAVE A CERTAIN TYPE OF STRIPES AND VICE VERSA)?

a. Yes

b. No

REASON

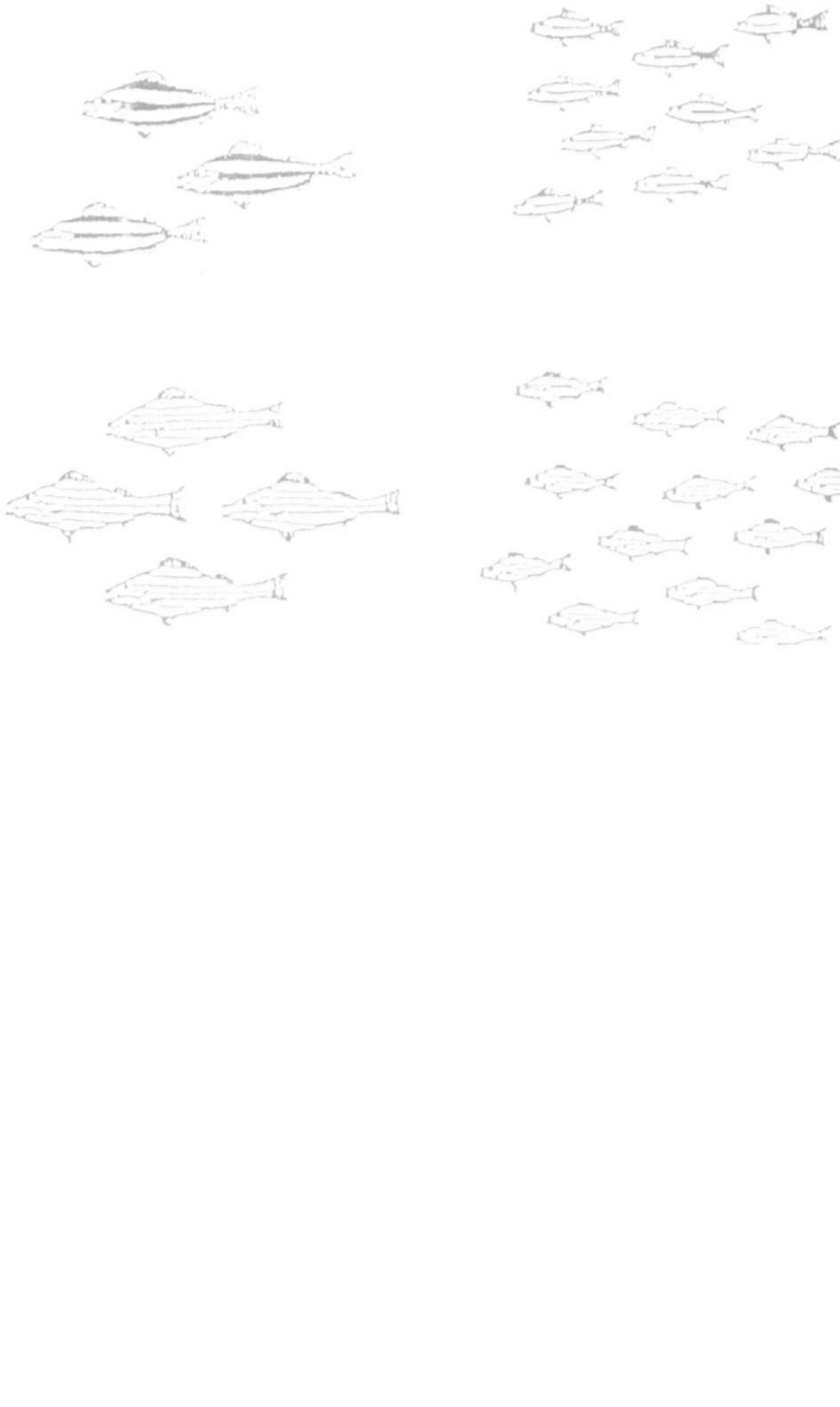
1. Big and small fish can have either wide or narrow stripes.

2. 3/7 of the big fish and 9/21 of the small fish have wide stripes.

3. 7 fish are big and 21 are small.

4. Not all big fish have wide stripes and not all small fish have narrow stripes.

5. 12/28 of fish have wide stripes and 16/28 of fish have narrow stripes.



The Dance

After supper, some students decide to go dancing. There are three boys: ALBERT (A), BOB (B), and CHARLES (C), and three girls: LOUISE (L), MARY (M), and NANCY (N).

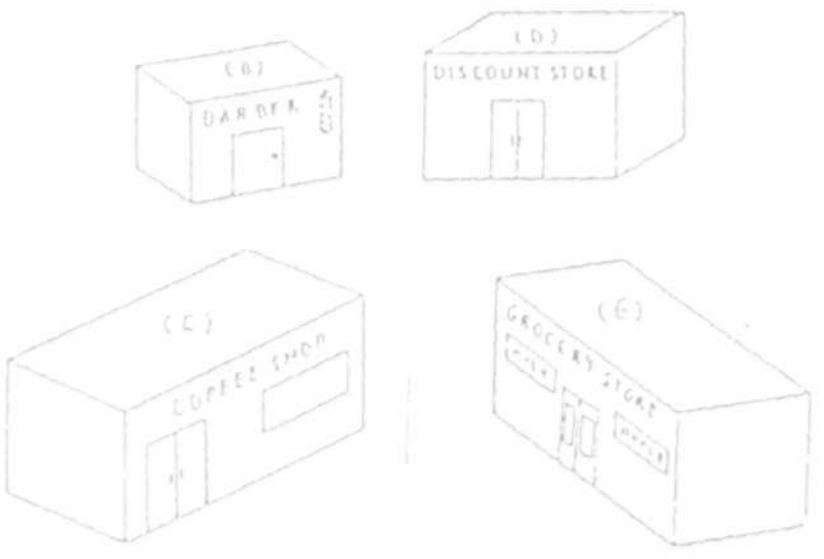


ALBERT (A) BOB (B) CHARLES (C) LOUISE (L) MARY (M) NANCY (N)

One possible pair of dance partners is A-L, which means ALBERT and LOUISE.

LIST ALL OTHER POSSIBLE COUPLES OF DANCERS. BOYS DO NOT DANCE WITH BOYS, AND GIRLS DO NOT DANCE WITH GIRLS.

In a new shopping center, 4 stores are going to be placed on the ground floor. A BARBER SHOP (B), a DISCOUNT STORE (D), a GROCERY STORE (G), and a COFFEE SHOP (C) want to locate there.



One possible way that the stores could be arranged in the 4 locations is BDGC. Which means the BARBER SHOP first, the DISCOUNT STORE next, then the GROCERY STORE and the COFFEE SHOP last.

LIST ALL THE OTHER POSSIBLE WAYS THAT THE STORES CAN BE LINED UP IN THE FOUR LOCATIONS.

APPENDIX 4 t-VALUE OF ALL THE PAIR OF SCHOOLS MATCHED.

NOS	PAIR OF SCHOOLS	MEAN DIFFERENCE	t	P
1.	DSS and GTS	0.14	0.34	0.4636
2.	DSS and GSSB	0.22	1.54	0.0708
3.	DSS and TSS	0.01	0.06	0.9842
4.	DSS and CCZ	0.20	1.39	0.3439
5.	DSS and FGGS	0.13	0.77	0.4374
6.	GTS and GSSB	0.16	0.89	0.5194
7.	GTS and TSS	0.18	1.64	0.2267
8.	GTS and CCZ	0.3	0.95	0.5739
9.	GTS and FGGS	0.17	0.90	0.1626
10.	GSSB and TSS	0.37	.63	0.0351
11.	GSSB and CCZ	0.11	0.92	0.5526
12.	GSSB and FGGS	0.16	0.89	0.5193
13.	TSS and CCZ	0.17	1.58	0.0775
14.	TSS and FGGS	0.14	0.79	0.4574
15.	CCZ and FGGS	0.16	0.74	0.4354

APPENDIX 5

ACTIVITY 1

A is a 1.0 mol dm^{-3} HCl (monobasic) solution.

B is 1.0 mol dm^{-3} NaOH solution

Using a measuring cylinder, pour $25m^3$ of solution B into the plastic cup provided and measure the stead temperature. Rise the thermometer, use a $50cm^3$ measuring cylinder to measure $25cm^3$ of solution A and record its temperature.

Carefully add solution A to B, stir with the thermometer and record the highest temperature.

	Experiment I	Experiment II	Experiment III
Temperature of A/°C			
Temperature of B/°C			
Highest temperature /°C			
Mean initial temp/°C			
Temperature rise/°C			

EXPERIMENT 2

Thoroughly rinse out the plastic cup ad repeat the experiment using $25cm^3$ of solution B ad 50 cm^3 of solution A.

EXPERIMENT 3

Thoroughly rinse out the plastic cup and repeat the experiment using $50cm^3$ of solution B and $25cm^3$ of solution A.

a. Complete the table of results by calculating the mean initial temperature of solution A and B for each of the three experiments. When calculating the mean initial temperatures for experiments 2 and 3, ignore the fact that the values mixed are unequal.

Fill in the corresponding rises in temperature.

b. Calculate the amount of heat involved in experiment 2.

(Assume that 4.35J are required to raise the temperature of $1cm^3$ of solution by 1.0°C)

C is 1.0mol dm^{-3} acid which is either monobasic with the formula HY or dibasic with the formula H_2Y

D. is 1.0 mol dm^{-3} NaOH solution.

i. Thoroughly rinse out the plastic cup and repeat the experiment in activity 1 using $25cm^3$ of solution D and $50cm^3$ of solution C.

ii. Thoroughly rinse out the plastic cup and repeat the experiment using $50cm^3$ of solution D and of $25cm^3$ solution C

   a. What is the basicity of the acid based on your results. Give reasons for your answer.

   b. What amount of heat do you think will be evolved if you mix $25cm^3$ each of solution C and D (give reasons for your answer)

c. What amount of heat do you think will be evolved if you mix 25cm^3 of solution G and 25cm^3 of solution D.
d. What amount of heat do you think will be evolved if you mix of 20cm^3 solution C and of 50cm^3 solution D.

ACTIVITY 3

SECTION A. Carry out the following tests and record your observations.

1. Take about 1cm^3 of $Pb(NO_3)_2$ solution in a test tube and add dil HCl dropwise until in excess.
2. Take about of 1cm^3 NaI solution in a test tube and add $AgNO_3$ solution dropwise un il in excess.
3. Take about of 1cm^3 of NaCl solution in a test tube and add $AgNO_3$ solution dropwise until in excess.
4. Take about of Na_2SO_4 solution and add $BaCl_2$ solution dropwise until in excess.

SECTION B. You are provided with four solutions labeled A, B, C, ad D, they are aequeous *solutions of NaI, NaCl, $Pb(NO_3)$ Na_2SO_4, but they are not in this order. E, F, G,* are aqueous solution HCl, $AgNO_3$, BaCl respectively. Describe how you would, based on your observations in section A use solutions E, F, G, as reagents to identify solutions A, B, C, and D.

Carry out the tests according to the procedure you have outlined.

SECTION C. H, I, J are IMHCl, 2MHCl, CL, and 1M NaOH solutions but not in that order.

Describe how you will use only measuring cylinder, thermometer and a beaker to identify H, I and J.

HOME WORK

Outline a method by which the concentration of HCl solution could be established by using 1M NaOH solution and a thermometer, rather than indicator.

ACTIVITY 5

1. James and Adamu were getting ready to wash a car, however, Adamu noticed that the water was too hot. He suggested a way to lower the temperature.
2. They decided they will mix some cold water in with the hot water. They were curious about how much cold water to add and they raised this question: when hot and cold water are mixed together, is there any way to know ahead of time what the temperature of the *mixture will be?*

3. The teacher leads the student to rephrase the question, using the word affect or effect. Questions like "How does the amount of rain affect the growth of corn? Or what is the effect of an inch of rain on the growth of my crop?" were used to guide students.

4. The question is therefore rephrased as "How will the mixing of two equal amounts of water that have different temperatures affect the temperature of the water after they are mixed together?

5. The teacher leads the students to identify the variables to be tested and experimental controls i.e. size of containers, type of containers, amount of water; mix two volumes of warm water, mix two volumes of cold water etc.

6. The teacher then lead students to state a hypothesis to answer the question stated in 4 above i.e. If two equal amounts of water that have different temperatures are mixed together, the temperature of the resulting mixture will be in he middle

7. The teacher asks students to write a procedure that could test this hypothesis.

8. James and Adamu wrote the following procedure. Read their entire procedure carefully and note that James and Adamu did each part of their procedure only once.

9. Perform James' and Adamu's experiment:

    i. Mark 3 cups, one with A, one with B and one with C.
    ii. Mark cups A and B with a line 4cm from the bottom
    iii. Get two containers, one filled with warm water and the other filled with cold water.

PART ONE

i. Pour the warm water into cups A and B up to 4cm line.
ii. Measure the temperature of the water in cups A and B. Record the temperatures in a data table.
iii. Pour the water in cups A and B into cup C.
iv. Measure the temperature of the water in cup C. Record the temperature in a data table.

PART TWO

i. Pour the cold water into cups A and B up to the 4cm line.
ii. Measure the temperature of the water in cups A and B. Record the temperatures in a data table.
iii. Pour the water in cups A and B into cup C.
iv. Measure the temperature of the water in cup C. Record the temperature in a data table.
v. Discard the water in sink before going on to part III.

PART THREE

i. Pour the warm water into cup A, up to the 4cm line, pour the cold water into cup B up to 4cm line.
ii. Measure the temperature of the water in cups A and B. Record the temperatures in a data table.
iii. Pour the water in cups A and B into cup C.
iv. Measure the temperature of the water in cup C. Record the temperature in a data table.
v. Discard the water in sink.

10. Analyze the results by comparing the before – mixing and after – mixing temperatures of Part I, Part II and III.
11. Suppose this procedure were repeated many times and similar data were obtained. Write a possible conclusion from this experiment regarding the hypothesis that was stated above.
12. What evidence is there for this conclusion?

ACTIVITY TWO

1. A is a solution of lead (II) nitrate
B is a solution of aluminium sulphate.
C is a solution of copper II chloride

i. Take 1cm3 of solution A and add dil HCl drop wise until in excess.
ii. Repeat the activity with solution B and C.
iii. Take 1cm3 of solution A and add sodium hydroxide drop wise until excess.
iv. Repeat activity III with solution B and C.

2. Solution D contains Aluminium Sulpate, copper II chloride and lead II nitrate.
Describe how you will separate the compounds using dil hydrochloric and ammonia solution ad sodium hydroxide.

ACTIVITY SEVEN

RATE, PURITY, CONCENTRATION.

SECTION A

INSTRUCTION

1. Measure 1g of sample A into a plastic cup, add 20cm3 of 1m HCl and start the clock.
2. Keep swirling the mixture and watching until the magnesium disappears. Stop the clock and then label the solutions as solution A.
3. Measure 1 g of sample B into another plastic cup ad add 20cm3 of 1M HCl and start the clock.
4. Keep swirling the mixture and watching until all the substance disappears. Stop the clock and then label the solution as solution B.
5. Measure 1g of sample A into another plastic cup. Add 20cm3 of 2M HCl and start the clock. Keep swirling the mixture and watching until all the magnesium disappears. Stop the clock.
6. Repeat experiment 5 using 3M HCl.

QUESTIONS

1. Construct a table ad record the results of the experiment.
2. Do you think sample A ad B are the same? Give reasons for your answer.
3. In which of the HCl solutions does sample A reacts faster? Explain why the sample reacts faster in one of the solutions.

SECTION B

INSTRUCTION.

1. Take a spatula full of sample A in a test tube and add about 1cm3 of 1M HCl and use a glowing splint to identify the gas giving off.
2. Repeat experiment (1) using sample B.
3. Take about 1cm3 of solution obtained when sample A reacts with 1M of HCl and add NaOH in drops until in excess. Filter the content and then add dil HCl to the filtrate in drops until in excess.
4. Take about 1cm3 of solution obtained when sample B reacts with 1M of HCl and add NaOH in drops until in excess. Filter the content and then add dil HCl in drops until in excess.

QUESTIONS

1. Name the gas that was evolved in experiment 1 and 2.
2. Identify sample A and B based on your observations.
3. Do you think sample A and B are the same? Give reasons.
4. If you want to produce a large quantity of gas A, which of the HCl solutions will you use? Give reasons.
5. How long will it take for 2g of magnesium to dissolve in 2M HCl solution.

Acting Fourteen

The total amount of energy used each year in the world is so huge that it is not convenient to measure it in joules or Kilojoules. Instead we can use 'bdoe' which stands for 'barrels per day of oil equivalent'. This is the number of barrels of oil you would have to use each day to give the same amount of energy.

Usage of energy resources in 1985 (millions of bdoe) (world, excluding USSR, Eastern Europe and china)

	Oil	Gas	Coal	Electricity	Other
Transport	21.7	-	0.1	-	0.1
Industry	7.0	7.1	5.8	5.6	0.3
Domestic	6.8	6.1	0.9	5.5	0.2
Electricity generation	3.8	3.6	12.8	-	14.2
Chemical	5.4	0.6	0.8	-	-

World energy consumption (millions of bdoe)

	1965	9175	9185
Oil	30.9	55.2	57.6
Gas	11.1	20.9	29.2
Coal	26.7	30.1	39.9
Other	6.1	11.1	18.7

Known world reserves of oil ad gas at end of 1985

Oil 700 thousand million barrels
Gas 512 thousand million barrels (equivalent)

QUESTIONS

1. What is the major use for oil?
2. What is the major use for coal?
3. What is the major energy source for generating electricity?
4. Which fossil fuel is the main supplier of chemical feedstocks?
5. Which sector (transport, industry, etc) used most energy in 1985?
6. Work out the total amount of energy used in the whole world in 19865, 1975 and 1985. Draw a bar chart to show this.

7. For 1985, work out the percentage of the total energy used which came from oil, coal, gas, etc. Draw a pie chart to show this.
8. In 1985, 57.6 million barrels of oil were used each day. How many barrels were used in the whole year?
9. There are about 700 thousand million barrels of oil left in the Earth that we know about. How long would this last if we carry on using it at the same rate as in 1985?
10. Work out how long the known reserves of gas would last at 1985 consumption rates.

APPENDIX 6

The pretest scores of the subjects were used to estimate reliability of the GALT and Tops using odd-even split half technique. The reliability co-efficient of the GALT and Tops were 0.79 and 0.82 respectively.

APPENDIX 7 140

The t-test value for the differences between mean score of the male and female subjects in experimental group before treatment.

Schemata	N 36	df	t-value	P
Conservation		36	1.87	0.060
Proportional reasoning		36	1.69	0.081
Control of variables		36	1.50	0.90
Correlation reasoning		36	2.85	0.004
Combination reasoning		36	1.58	0.82
Probability reasoning		36	2.53	0.002