The Acquisition of the Six Formal Reasoning Abilities by Students in Kaduna State, Nigeria

By
Dr. Ahmed Bello
School of Science
Federal College of Education,
P.M.B 1041 Zaria, Nigeria.

belguruza@yahoo.com
+2348028406940

ACQUISITION OF THE SIX FORMAL REASONING ABILITIES BY STUDENTS IN KADUNA STATE, NIGERIA

Abstract
The study was carried out to determine the effects of learning cycle teaching strategy on students' acquisition of the six formal reasoning abilities. The population of the study consisted of 280 senior secondary school class three (SS III) Biology students from five private schools with adequate facilities in Sabon Gari Local Government Area, Kaduna State, Nigeria. Out of the five schools, one school was randomly selected as a study school, 41 subjects were randomly selected from the population of the study school and were pre and post tested using Group Assessment of Logical Thinking (GALT). GALT was used to measure the six reasoning abilities of the subjects. The group was taught genetic concepts using learning cycle teaching strategy. The data collected were analyzed using t-test statistics at 0.05 level of significance. One hypothesis was tested and the following findings were obtained; the subjects in the study group exhibited an impressive gains in formal reasoning ability after exposure to learning cycle teaching strategy; the subjects gained better in proportional, conservation and control of variables reasoning skills but they did not gain at all in correlational, combinatorial and probabilistic reasoning skills. This means that the strategy was not effective in promoting the acquisition of these reasoning skills.

Key words
Effects, learning cycle, acquisition, six formal reasoning abilities.

Introduction

Jean Piaget (1964) formulated theories concerning the mental process individuals use in dealing with problem situation. The mental process is referred to as "reasoning ability". He created the concept of stages of intellectual development in relation to reasoning ability an individual employed in solving problems. The stages are sensory-motor (0-2 yrs) which corresponds to nursery and primary years, concrete operational (7–15yrs) corresponds to nursery and primary years, concrete operational (7-15 yrs) corresponds to junior secondary school years and formal operational (11-15 yrs) corresponds to senior secondary school years as obtainable in Nigeria Educational system. Shayer and Adey (1981) found that Piagetian stages of intellectual development does not correspond neatly with the ages of physical maturity as suggested by Piaget. They found out that only about one-third of student age sixteen has reached the formal stage of cognitive operations. And, according to them majority of secondary age population; perharps even adults in post secondary age do not attain the formal operational stage.

Piaget (1964) explained that, in concrete operational stage, a person use concrete reasoning patterns in tackling problems. The reasoning patterns are applied to concrete objects or directly observable properties and simple relationships. He observed that, a person operating at concrete stage needs reference to familiar actions, objects and directly observable properties as well as step–by-step interaction with concrete objects in a lengthy procedure before he or she can understand the meaning of concepts and phenomenon. He theorized that, a formal reasoner uses formal reasoning abilities in tackling problems. When applying formal thought, an individual reasons without referring to concrete objects or directly observable properties. He or she uses logical and mathematical relationships rather than relying primarily on familiarity and experiences. Schneida and Renner (1980) point out that when classifying reasoning patterns, we sometimes meet examples of students' thinking that includes both concrete and formal elements in a response to a particular task. This type of reasoning, according to them, can perhaps best be termed 'transitional' with respect to that and similar tasks. Piaget (1964) have identified and categorised formal reasoning patterns into six categories; **Theoretical Reasoning:** applying multiple classification, conservation logic, serial ordering and other reasoning patterns to relationships and properties that are not directly observable; **Combinatorial Reasoning:** considering all conceivable combinations of tangible or abstract items; **Proportional Reasoning:** starting and interpreting functional relationships in mathematical forms; **Control of variables:** recognizing the necessity of an experimental design that controls all variables but except the one being investigated; Probability: this is the ratio that is expressing the chances that certain events will occur; **Correlational Reasoning:** this expresses a mutual relationship or connection in which one thing depends on another.

The acquisition of the six formal reasoning ability by students has been observed by Lawson (1995) to be the key to the understanding of Science Concepts and Students' achievement in Science. Researches and studies have shown that most concepts in science are formal in nature (Gyuse, 1990). Their understanding requires formal reasoning ability (Gyuse, 1990). This means that, formal reasoners are most likely to understand scientific concepts and perform better in science. Gyuse (1990) observed and pointed out that, from psychological standpoint, there seem to exist a definite relationship between what learners are expected to learn and the intellectual level of the learners. Disparity between these two could be expected to lead to difficulties in comprehension, retention and application of what is learnt. She further pointed out that learning is most likely to occur when activities are matched to a child's way of thinking and at the same time also challenge that way of thinking. Thus, she argue that children learn more effectively and enjoyable when their learning experiences are matched to their capabilities.

The work of Lawson (1995), Gyuse (1990) and Mari (2001) have shown that majority of secondary school students operate at concrete level very few operate at formal level. Ironically, the works indicates that majority of secondary school science curricular demands formal reasoning and very few demands concrete reasoning. This clearly shows the mismatch between secondary school students reasoning ability and the reasoning demand of their science curricula. It means then, there is the need to choose an appropriate Science teaching strategy(s) that would addressed the mismatch and promote the acquisition of the six formal reasoning ability.

Several science teaching strategies could be used to promote the acquisition of the six formal reasoning abilities in students. One of such strategy is the learning cycle science teaching strategy developed by Karplus, in 1979. The cycle is divided into three stages or phases purposely designed to promote the acquisition of formal reasoning ability and understanding of science concept in students by concretizing the teaching and learning process. The three phases of learning cycle teaching strategy provides a variety of activities in which students use reasoning pattern to explore, examine, modify and relate concept to additional examples or tackle problems. These activities may promote cognitive gains and make concept learning more meaningful (Karplus, 1979).

Literature reviewed suggests that, there is little or no evidence of study conducted in Nigeria on Students acquisition of the six formal reasoning ability using learning cycle teaching strategy. The question is; can learning cycle teaching strategy promote the acquisition of the six formal reasoning abilities in Nigerian Secondary School Students? To have answer to this question, this study therefore, investigated the effects of the learning cycle teaching strategy on science students acquisition of the six formal reasoning abilities in Kaduna state, Nigeria.

Objectives of the Study

The Objectives of the study is to investigate the effect of Learning Cycle teaching strategy in promoting the acquisition of the six formal reasoning abilities among Secondary school Biology students, in Kaduna state, Nigeria.

Research Questions

Is there any significant difference between the pre and post-test mean scores of students' taught using learning cycle teaching strategy in the six formal reasoning ability?

Hypothesis

There is no significant difference in the pre and post test mean scores of students' taught using learning cycle teaching strategy in the following reasoning skills.

a) conservation
b) proportional reasoning
c) control of variables.
d) correlational reasoning
e) combinatorial reasoning
f) probabilistic reasoning

Research Design and Methodology

This study adopted the quasi-experimental research design involving pre and posttest (Kerlinger 1973). The study group was pre-tested to determine the level of the six formal reasoning abilities using Group Assessment of Logical Thinking (GALT). After the administration of the pre test, the study group was taught genetic concepts as obtainable in SSIII curriculum using learning cycle teaching strategies for thirteen weeks. At the end of the instruction, the study group was post-tested using the same instruments. The posttest was used to determine the effect of the treatment given (learning cycle) to the study group.

Population for the Study

The population of the study consisted of all the senior secondary class three (SSIII) biology students in the five coeducational private secondary schools with adequate facilities in Sabon Gari Local Government Area, Kaduna State, Nigeria. The total students' population was 280 which comprised 187 boys, 93 girls distributed among five secondary schools in the category. Both private and public secondary schools in Nigeria use the same curriculum for teaching and learning. They equally sit for the same public examinations. The population for the study is presented in table 1

Table I: Private Schools with Adequate facilities in Sabon Gari LGEA

S/N	Names of School	Boys	Girls	Total
1.	Therbow School, GRA Zaria	49	45	94
2.	Great Hallmark, GRA Zaria	40	62	102
3.	Premier Secondary School, GRA Zaria	12	10	22
4.	Abuhurayrah College, GRA QRTS Zaria	29	38	67
5.	Demonstration Secondary School, A.B.U. Zaria	187	93	280

Source: Sabon Gari LGEA (2009)

Sample and Sampling Procedure

The private secondary schools in Sabon Gari Local Government Area were divided into three categories based on their exclusive similarities. Those schools that have adequate infrastructures, instructional facilities, qualitative teachers and student's enrolment effective selective mechanism were categorized into category 'A'. Those with fairly adequate facilities were categorized into 'B' while those with inadequate facilities were categorized into 'C'. The category 'A' schools, was purposely chosen for the study. This is because the schools in this category have adequate infrastructure, instructional facilities, qualitative teachers and good students' selective mechanism. These qualities make it reasonable to assume that students in this category might have some reasonable number of students functioning at the formal reasoning abilities. One school (Therbow) from category 'A' was randomly selected as a study school. Therbow school had only two classes (A and B) of SSII Biology students. In order to get one class that will constitute the study group, SS III 'A' was randomly selected as a study group.

In order to control other variables that might influence the formal reasoning ability along the period of the study of the participants, a survey of the teaching methods used by teachers in teaching subjects in the study group was carried out. It was found that teachers used lecture/explaining methods in teaching their subjects. In the case of science subjects, the lecturing/explaining method is sometimes followed by practical sessions in which studests are expected to follow a given instruction to arrive at already established facts. This methodn of teaching has been found not to promote formal reasoning ability (Karplus, 1979). This finding made the researcher to seek the cooperation of the teachers teaching the study group not to change their method of teaching for the entire period of the study. Which they did. The distribution of subjects used for the study is given in table 2:

Table 2: Distribution of Subjects in the study group.

		No of students			
Name of school	**Type of school**	**Male**	**Female**	**Total**	**Group**
Therbow Secondary School Zaria	Co-educational	21	20	41	Experimental

Instrumentation

Group Assessment of Logical Thinking (GALT) was used for the study.

This instrument was used to measure the six reasoning abilities of the study subjects. It was adopted as it was used in 1993 from Roadranka, Yeany & Padilla (1983). It's reliability was re-established with a calculated (r) of 0.79.

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 deals with conservational ability, 3 and 4 test proportional reasoning, 5 and 6 test controlling variables, 7 and 8 test Probabilistic reasoning 9 and 10 test correlational reasoning and lastly 11 and 12 test combinational ability.

In question 1- 10, subjects were required to give reasons for their responses. This is to avoid guess work and to ensure that subjects make judgment based on reasons. Every item was followed with three alternative answers and four reasons for the subjects to choose the most suitable answer and reason. As these reasons could only be abstracted, subjects who make right responses with suitable reasons might have acquired formal reasoning. For items 11 and 12, questions were posed and subjects were required to give possible combinations.

GALT was scored adopting the mode of scoring by Siegel (1989) in which a correct responses and reasons are tied to score. When there is a correct response with wrong reason or vice versa, the item was not scored. However, item 11 and 12 were scored differently. For item 11, marks were given to responses which show a pattern and not more than one error. While item 12 was scored if there is a pattern and not more than two errors or omissions. This is because the number of arrangements required to produce a pattern are more in question 12. This mode was adopted based on the observation by Siegel (1989) that formal thinkers always seek reasons on which to base their judgement and actions. A correct response and reason earns one mark. Correct pattern with one error or two errors earns a mark for question 11 and 12 respectively. A respondent can score a maximum of 12 marks and a minimum of zero mark for a test.

Administration of Treatment

The study group was taught basic genetic concepts as obtainable in West African Examination Council (WAEC) and National Examination Council (NECO) syllabus using Learning Cycle instructional strategy by the researcher. Thirteen lessons, each lasting 40 minutes were conducted over a period of thirteen weeks for the group.

The stages involved in learning cycle teaching strategies used in this study are illustrated below:

Step I: Concept Exploration phase (Development of concept)

The teacher engages the students in the following concept exploration phase activities;

a) presentation of initial physical and or mental tasks which students are not accustomed to; cannot use their existing reasoning patterns in tackling the tasks, consequently, creating initial difficulties in trying to handle the tasks.

b) Involvement of students in active physical/mental activities where they create and debate their results and reflect upon implications and explanations.

c) Involvement of students in group activities where they freely compare and contrast activities, results, explanations etc.

d) Involvement of students in activities that provides a wide variety of scientific investigation approaches.

e) Presentation of tasks and challenges to students where unexpected events will occur and questions will be raised that cannot be answered by looking in textbooks or laboratory manuals.

The Primary purpose of the exploration phase is to allow the students experience, create and discover the concept(s) to be learned by exposing the students to both physical and mental activities related to the concepts without naming or telling them about the concept.

Step II: Concept Introduction phase

The teacher name and explains the students' identified concept(s) using a variety of teaching methods based on the experiences gained by the students in the exploration phase. The teacher establishes a discussion environment where he or she asks students to report and interpret their findings and encourage them to formulate statements on the concept (s) or main idea in their own words.

Step III: Concept application phase

The teacher provides variety of different activities from those of exploration phase in which the students apply the new concept(S) or reasoning pattern to additional examples in order to extend the range of applicability of the new concept (s). The purpose of the application activities is to provide students with experience that help them organize the concepts they have constructed and /learned with other ideas that relate to the concept (s).

Results

The results obtained are presented in tables 3 to 6

Table 3: Distribution of Scores on the Reasoning Ability Test Among the Subjects in the Study Group Before Treatment (N = 41).

Reasoning ability group	Number of subject each reasoning level		Total
	Male	Female	
Concrete level (scores 0-5)	17	18	35
Formal level (scores 6-12)	4	2	6
Total	**21**	**20**	**41**

Using the classification of Staver & Halsted (1985), the results in table 3 shows that, 35 students (85%) were functioning at concrete operational level and only 6 students (15%) were functioning at formal operational stage in the experimental group before treatment.

Table 4: Distribution of Scores on Reasoning Ability Test in Study Group After Treatment (N=41)

Reasoning ability group	Number of subject each reasoning level		Total
	Male	Female	
Concrete level (Scores 0-5)	8	10	18
Formal level (Scores 6-12)	13	10	23
Total	**21**	**20**	**41**

Table 4 shows that 18 students (44%) were operating at the concrete operational level, while 23 students (56%) were operating at formal operational level after administration of treatment. An impressive number of 17 students representing 49% out of 35 concrete reasoners have moved from concrete operational level to formal level because of the training/treatment given.

Table 4 reveals that 44% and 56% of the subjects in the study group were functioning at concrete and formal reasoning level respectively after treatment. It also indicated that an impressive number of students' (17, representing 49%) have moved from concrete operational level to formal level because of the treatment given. This indicates that the learning Cycle instructional strategy was effective in improving the reasoning ability of the subjects in the study group.

Table 5: Mean Scores and Standard Deviation of the Subjects in the Six Reasoning Ability Subscales of the Study Group Before Treatment (N=41).

Reasoning mode	$\bar{X}$	SD
Conservation	0.29	0.46
Proportional reasoning	0.49	0.64
Control of variables	0.32	0.61
Correlational reasoning	0.66	0.76
Combinatorial reasoning	0.10	0.30
Probabilistic reasoning	0.90	0.54

Table 5 shows that the study group recorded the highest mean score in probabilistic reasoning of 0.90. The lowest mean score of 0.10 was obtained in combinatorial reasoning.

Table 6: Mean Scores and Standard Deviation of the Subjects in the six Reasoning Ability Subscales of the Study Group after Treatment (N=41)

Reasoning mode	$\bar{X}$	SD
Conservation	0.54	0.55
Proportional reasoning	1.12	0.84
Control of variables	1.02	0.85
Correlational reasoning	0.56	0.67
Combinatorial reasoning	0.10	0.30
Probabilistic reasoning	0.85	0.53

The result in Table 6 shows that the highest scores of 1.12 and 1.02 was recorded in proportional reasoning and control of variables while the lowest scores of 0.10 and 0.54 were recorded in combinatorial and conservation reasoning. From the results in table 5 and 6, it can be deduced that the subjects in the study group showed high gains in proportional reasoning and control of variables and low gains in combinatorial reasoning and conservation. These results agree with the observation of Lawson (1995), that combinatorial reasoning is a complex skill that requires instruction over a along period of time for appreciable increase in performance in the tasks involving it.

Hypotheses Testing

There is no significant difference in the pre and post test mean scores of students' taught using learning cycle teaching strategy in the following formal reasoning skills;

(a) Conservation
(b) Proportional reasoning
(c) Control of variables
(d) Correletional reasoning
(e) Combinatorial reasoning
(f) Probabilistic reasoning

To test the hypothesis, the pre-test reasoning ability mean scores in the six reasoning skills of the study group were compared with their post-test mean scores using t-test statistics to determine if there were any significant differences in the mean scores. The results are presented in Tables 7 to 12

Table 7: t-test Analysis of Pre and Post-test Mean Scores of the Study Group in the Acquisition of Conservation Reasoning Skill.

Test	N	$\bar{X}$	SD	SE	DF	t-cal	t-crit	P-value
Pre	41	0.30	0.46	0.07	80	3.01	1.99	0.003*
Post	41	0.51	0.55	0.09				

***significant at P $\leq$ 0.05**

From Table 7, the calculated t-value is 3.01, which is greater than the t-value critical of 1.99 and P= 0.003 is less than P= 0.05. The null hypothesis was rejected. This means that the treatment resulted in significant increase in the performance of the subjects in conservational reasoning ability of the experimental group after exposure to learning cycle teaching strategy.

Table 8: t-test Analysis of Pre and Post-test Mean Scores of the Study Group in the Acquisition of Proportional Reasoning Skill.

Test	N	$\bar{X}$	SD	SE	DF	t-cal	t-crit	P-value
Pre	41	0.49	0.64	0.10	80	3.84	1.99	0.000*
Post	41	1.12	0.84	0.13				

***significant at P $\leq$ 0.05**

Table 8 shows that the calculated t-value 3.84 is greater than the t-value critical of 1.99 and at P≤ 0.05. The null hypothesis was rejected. This means that the treatment given resulted in significant increase in the performance of the subjects in proportional reasoning skill.

Table 9: t-test Analysis of Pre and Post-test Mean Scores of the Study Group in the Acquisition of Control of Variable Reasoning Skill.

Test	N	$\bar{X}$	SD	SE	DF	t-cal	t-crit	P-value
Pre	41	0.32	0.61	0.10	80	4.33	1.99	0.00*
Post	41	1.02	0.86	0.13				

***significant at P ≤ 0.05**

Table 9 shows that the calculated t-value of 4.33 is greater than the critical value of 1.99 and P≤ 0.05. The null hypothesis was rejected, which means that the treatment given resulted in significant increase in the performance of the subjects in the control of variable reasoning skills.

Table 10: t-test Analysis of Pre and Post-test Mean Scores of the Study Group in the Acquisition of Correlational Reasoning Skill

Test	N	$\bar{x}$	SD	SE	DF	t-cal	t-crit	P-value
Pre	41	0.66	0.76	0.12	80	0.62	1.99	0.54*
Post	41	0.56	0.67	0.11				

not significant at P ≤ 0.05

From table 10, the calculated t-value of 0.62 is less than the critical value of 1.99 and P value of 0.54 is greater than 0.05. The null hypothesis was accepted, which means that the experimental subjects did not show any significant different in their acquisition of correlational reasoning skill after treatment.

Table 11: t-test Analysis of Pre and Post-test Mean Scores of the Study Group in the Acquisition of Combinatorial Reasoning Skill

Test	N	$\bar{x}$	SD	SE	DF	t-cal	t-crit	P-value
Pre	41	0.10	0.30	0.05	80	0.00	1.99	0.65*
Post	41	0.10	0.30	0.05				

not significant at P ≤ 0.05

Table 11 shows that t-value calculated of 0.00 is less than t-value critical of 1.99 and P value of 0.65 is greater than 0.05. This means that the treatment given to the subjects did not result in any significant increase in the performance of the subjects in combinatorial reasoning. The null hypothesis was accepted.

Table 12: t-test Analysis of Pre and Post-test Mean Scores of the Study Group in the Acquisition of Probabilistic Reasoning Skill

Test	N	$\bar{x}$	SD	SE	DF	t-cal	t-crit	P-value
Pre	41	0.90	0.59	0.08	80	0.41	1.99	0.68*
Post	41	0.85	0.53	0.08				

*not significant at P ≤ 0.05

Table 12 reveals that there is no significant difference in the mean scores of the experimental subjects in tasks involving probabilistic reasoning skill before and after treatment. The null hypothesis was accepted. This means that the treatment given does not result in any significant gain in probabilistic reasoning skill.

Discussions

Answers to Research Questions and Results of Hypothesis Testing

Table 3 reveals that 85% of the subjects in study group were functioning at the concrete level and only 15% were functioning at the formal level before treatment.

The pre-test and post-test mean scores of the subjects in the study group were compared using t-test statistic to test for possible significant differences. The results shows that the subjects post-test mean scores was significantly better then the pre-test mean scores in reasoning skills of conservation, proportional reasoning and control of variables. There was no significant increase in performance in correlational, combinatorial and probabilistic reasoning. The subjects insignificant improvement in performance in correlational, combinatorial and probabilistic reasoning may be attributed to the fact that according to Mari (2001), the acquisition of these skills, requires pre-requisite skills of conservation, proportional reasoning and control of variables. This means that, before subjects can solve tasks involving correlational, combinatorial and probabilistic reasoning, they have to acquire the skills of conservation, proportional reasoning and control of variables this requires longer time to achieve.

Findings

The findings from the study are as follows;

1. The subjects in the study group exhibited an impressive gain in formal reasoning ability after exposure to learning cycle teaching strategy. Seventeen (17) students representing 49% acquired formal reasoning ability out of the 35 concrete reasoners.
2. The subjects gained better in proportional, conservation and control of variables reasoning skills but they did not gain at all in correlational, combinatorial and probabilistic reasoning skills after exposure to learning cycle instructional strategy. This means that the strategy was not effective in promoting the acquisition of these reasoning skills.
3. The study group recorded the highest mean scores in proportional and control of variables reasoning skills and lowest score in combinatorial and conservation reasoning skill after treatment.
4. There was significant difference between the pre and the post-test mean scores of the study group in the acquisition of conservation, proportional and control of variables reasoning skills after exposure to learning cycle teaching strategy.

5. There was no significant difference between the pre and post-test mean scores of the study group in the acquisition of co-relational, combinatorial and probabilistic reasoning skills after exposure to learning cycle teaching strategy.

Conclusion and Implications

Based on the results and the findings from this study, the following conclusions can be made;

a) Most of the subjects in the study group whose average age was found to be 16 years were operating at concrete stage of reasoning. Very few were operating at formal reasoning stage. This contradicts the assumption that most students at age 16 years have acquired formal reasoning.

b) It is expected that the learning cycle teaching strategy would significantly enhance the acquisition of the six formal reasoning skills. However, the study has shown that the strategy only promoted the acquisition of conservational, proportional and control of variables formal reasoning skills. It did not promote the acquisition of correlation, combinational and probabilistic reasoning skills.

Recommendations

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

a) Findings from this study have shown that students of average age of 16 years exhibit very low level of formal reasoning ability, this means that there is the critical need for science teachers to determine the reasoning ability of students before commencing science teaching especially at senior secondary school level.

b) Other strategies or perhaps longer period of the use of learning cycle teaching strategy should be encouraged to enhance students' acquisition of correlational, combinatorial and probabilistic reasoning skills.

c) Majority of secondary school students operate at concrete reasoning level and greater percentage of their curricular demands formal reasoning. The need for teaching method(s) that promote formal reasoning is necessary.

d) Since majority of secondary school students operate at concrete reasoning level and greater percentage of secondary school science curricula demands formal reasoning, this means that, there is the critical need for science teaching methods that promote the acquisition of formal reasoning ability in students. There is also the need for science teachers to use relevant and appropriate teaching aids to concretize the teaching and learning of those formal science concepts that could assist students in understanding them.

Limitations of the Study

The study have the following limitations.

1. The subjects used for the study all came from private co-educational schools with adequate facilities. Federal, State, and private schools with fairly and inadequate facilities were not used. The findings cannot therefore be generalized to Federal, State and private schools with fairly and inadequate facilities.
2. The study was conducted only in Kaduna state and only in Sabon Gari Local government Area. The findings cannot be therefore generalized to other states and other local government areas of Kaduna state of Nigeria.
3. The development and execution of learning cycle teaching strategy activities is a very difficult task. It requires time, materials, competency among others. Time and other constraints could not permit the development and execution of learning cycle activities on genetic concepts as expected.
4. It was practically impossible to control all other variables that might influence the formal reasoning ability along the period of the study of the participants.

REFERENCES (Alternative 1)

Gyuse, E. Y. (1990) Cognitive Reasoning Pattern of Senior Secondary School Students in Relation to The conceptual Demands of their Chemistry Curriculum: Unpublished Ph.D. Thesis Dept. of Curriculum Studies, University of Jos, Nigeria.

Karplus, Robert. " *Science Teaching and the Development of Reasoning".* Paper presented at General Science Workshop, the Regents of University of California Berkeley, 1979.

Kerlinger, F. N. (1973) Foundation of Behavioral Research. Holt, Richard and Wiston, London.

Lawson, A.E. (1995). *Science Teaching and the Development of Thinking*. Belmont, CA: Ward worth.

Mari, J.S. (2001). The effect of process skills instruction on formal reasoning ability among senior secondary school students in Kaduna State Unpublished PhD Thesis. Faculty of Education, A.B.U., Zaria, Nigeria.

Piaget, J. (1964). Development and Learning. *Journal of Research in Science Teaching*

(2) 12-18.

Roadranka, V. Yeany, R.H. & Padilla, M.J. (1983). The construction and validation of GALT. A paper presented at the annual meeting of the National Association of Research in Science Teaching.
Dallas Texas.

Schneider, L.S. & Renner, J.W. (1980). *Concrete and formal teaching. Journal of Research in Science Teaching,* 29, 1101-1115

Shayer, M. & Adey, P (1981). *Towards a Science of Science Teaching*. London: Heinemann Educational Books.

Siegel, H. (1989). The rationality of science critical thinking and science education. Synthese: *An International Journal of Epistemology, Methodology and Philosophy of Science.* Khuwer Academic Publishers Aordrecht, Boston, London. Vol. 80 (1) 9 – 41.

REFERENCES (Alternative 2)

Karplus, Robert. “ *Science Teaching and the Development of Reasoning”.* Paper presented at General Science Workshop, the Regents of University of California Berkeley, 1979.

Kerlinger, F. N. (1973) Foundation of Behavioral Research. Holt, Richard and Wiston, London.

Lawson, A.E. (1995). *Science Teaching and the Development of Thinking*. Belmont, CA: Ward worth.

Piaget, J. (1964). Development and Learning. *Journal of Research in Science Teaching* (2) 12-18.

Roadranka, V. Yeany, R.H. & Padilla, M.J. (1983). The construction and validation of GALT. A paper presented at the annual meeting of the National Association of Research in Science Teaching.
Dallas Texas.

Schneider, L.S. & Renner, J.W. (1980). *Concrete and formal teaching. Journal of Research in Science Teaching,* 29, 1101-1115

Shayer, M. & Adey, P (1981). *Towards a Science of Science Teaching*. London: Heinemann Educational Books.

Siegel, H. (1989). The rationality of science critical thinking and science education. Synthese: *An International Journal of Epistemology, Methodology and Philosophy of Science.* Khuwer Academic Publishers Aordrecht, Boston, London. Vol. 80 (1) 9 – 41.