UNIVERSITY OF EDUCATION, WINNEBA

THE NATURE OF FORMAL REASONING AMONG JUNIOR HIGH SCHOOL PUPILS IN SELECTED INTEGRATED SCIENCE LOGIC TASKS

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DECLARATION

STUDENT'S DECLARATION

I, DORIS NKRUMAH, hereby declare that this thesis, with the exception of quotations and references contained in published works which have all been identified and duly acknowledged, is entirely my own original work, and it has not been submitted, either in part or whole, for another degree elsewhere

Doris Nkrumah

Signature.................................... Date..

SUPERVISORS' DECLARATION

We hereby declare that the preparation and presentation of this thesis were supervised in accordance with the guidelines on supervision of thesis laid down by the University of Education, Winneba.

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DEDICATION

To daddy Kalyn, as you are affectionately called, Kezia, Chris and Judah, this work is dedicated to you with love.

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ABSTRACT

This study was carried out to determine the nature of formal reasoning among junior high school pupils in some selected schools in the Effutu Municipality. This study thus used logical reasoning tests in integrated science and in general knowledge as well as an interview protocol in collecting data. The integrated science logic tasks were based on topics chosen from the integrated science syllabus for form one, two and three pupils. However, the general logic tasks were based on general knowledge with the level of pupils taken into consideration. In choosing the sample for the study, 150 pupils were randomly selected from five public junior high schools in the Effutu Municipality. They were then served with different items based on their syllabus. Cronbach-Alpha reliability values of 0.750, 0.780, 0.860 and 0.916, 0.826, 0.783 were obtained in the ISLT and GLT for form 1,2 and 3 respectively. The validity of the instruments was established by supervisors and other senior lecturers in the Department of Science Education, University of Education, Winneba. Out of the total sample, 30 pupils were randomly selected for the interview. The results of the two tests and the interview were used to determine the nature of their formal reasoning pattern. It was found that most pupils were operating at the concrete operational level of reasoning with just a handful being at the formal operational level of reasoning. Again the few pupils who could do formal reasoning mostly exhibited conservational, probabilistic and combinatorial reasoning with few pupils doing correlational, controlling variables and proportional reasoning. On the whole, the form one pupils did more formal reasoning than form two and form three in the general logic tasks. The trend however changed in the integrated science logic tasks as the form three pupils did more formal reasoning than the form one and two pupils. It was also found that

on the average all pupils performed better in the integrated science logic tasks than in the general logic tasks, implying that pupils" formal reasoning was subject oriented.

CHAPTER ONE

INTRODUCTION

1.0 Overview

In this chapter a discussion on the background to the nature of formal reasoning among selected junior high school pupils in integrated science logic tasks was done. Here, the Researcher from her teaching experience in the Effutu Municipality has observed that pupils find it difficult to solve tasks which involve formal reasoning as compared to tasks that involve recalling answers. Also, discussions were made on the statement of the problem, purpose of the study, where the Researcher sought to find out how pupils at the junior high school level reason formally as well as the objective and research questions for the study. Furthermore, discussions were made on the rationale, significance, limitations, delimitations, as well as the assumptions and the summary.

1.1 Background to the Study

It is widely recognised that formal reasoning ability, which is the ability to reason in the abstract, is essential for understanding many concepts and principles of science and for decision-making in issues based on social or everyday context. A primary factor that causes learning difficulties that is often neglected is concerned with the child"s reasoning ability. If the cognitive ability of a child is not up to the demand of the curriculum, it is not easy for the child to develop understanding of certain science concepts. Consequently, rote memorisation is used as the main learning strategy.

In Ghanaian basic schools, science is often learnt in the abstract as adequate materials for learning the subject are not available. Teachers also often neglect the use of improvised teaching/learning materials which could replace the real materials and so science concepts are not properly built by pupils. Again science teaching in the junior high schools in Ghana generally appears to be notes giving, chalkboard illustrations and other teacher-centred methods. This enable pupils to only form mental models of concepts presented to them as this may lead to loss of interest in learning science. This may again lead to science content being often learned by rote with little understanding in Ghanaian basic schools and so pupils do not become well equipped to reason formally.

It is instructive that the designers of the JHS Integrated Science syllabus observed that schools still taught the low ability thinking skills of knowledge and understanding but ignored the higher ability thinking skills. Instruction in most cases tended to stress knowledge acquisition to the neglect of the higher cognitive skills such as application, analysis, synthesis, etc. The persistence of this situation in the school system according to MOE (2007) meant that pupils will only do well on tasks that required them to recall answers. Shayer and Adey (1993) have noted that pupils should be able to develop early science formal thinking in Piagetian terms as early as age 9 years. This they attributed to the fact that secondary school science and mathematics courses require formal operational thinking abilities.

Furthermore, dominance of expository teaching style, emphasis on examinations, the recalling of facts and the regurgitation of information have all contributed to Ghanaian

Junior High School pupils" inability to reason formally. Hence their inability to solve logic tasks in integrated science and in general knowledge since logic tasks involve deductive and inductive reasoning. Cohen (1980) has noted that the greater the ability of a person to think in an abstract way, the greater the ability of the person to function effectively in the society. It is against this background that this work was undertaken to empirically investigate the nature of formal reasoning among selected junior high school pupils in integrated science logic tasks.

1.2 Statement of the Problem

Formal reasoning abilities have been identified as essential abilities for success in science and mathematics courses in accordance with Piagetian theory (Inhelder & Piaget, 1969). The Researcher from her experience as a teacher in the Effutu Municipality has observed that pupils normally find it difficult to solve tasks which involve formal reasoning as in integrated science and general knowledge. They normally want tasks that involve the recalling of answers. Additionally, they also want problems solved for them and so when they encounter tasks that require logic and formal reasoning, it becomes difficult for them to solve.

As pupils graduate from junior high schools to senior high schools, there is the need for the pupils to develop formal reasoning skills as the senior high school science courses require such reasoning skills. For this reason, pupils should be taken through step by step procedures to enable them acquire formal reasoning skills. Again, pupils should also be given more tasks that involve formal reasoning as repetition of tasks can help to strengthen their formal reasoning skills. Thus, this study intends to find out the nature of formal reasoning among selected junior high school pupils in integrated science logic tasks in the Effutu Municipality.

1.3 Purpose of the study

This study investigated the nature of formal reasoning among selected junior high school pupils in solving logic tasks. By this, the study sought to find out how pupils at the junior high school used their several thought processes and applied their formal reasoning skills in solving logic tasks in integrated science and in general knowledge.

1.4 Objectives of the study

The objectives of this study were to:

1. Determine the thought processes junior high school pupils in the Effutu Municipality exhibit in solving integrated science logic tasks.
2. Find out the thought processes junior high school pupils in the Effutu Municipality exhibit in solving general logic tasks.
3. Ascertain the extent to which the junior high school pupils in the Effutu Municipality applied their formal reasoning skills in solving logic tasks.
4. Find out the extent to which gender influence the formal reasoning skills of the junior high school pupils in the Effutu Municipality.

1.5 Research Questions

The research questions that guided the study were:

1. What thought processes do the junior high school pupils in the Effutu Municipality exhibit in solving logic tasks in integrated science?
2. What thought processes do the junior high school pupils in the Effutu Municipality exhibit in solving general logic tasks?
3. To what extent do the junior high school pupils in the Effutu Municipality apply their formal reasoning skills in solving logic tasks?
4. To what extent does gender influence the formal reasoning skills of the junior high school pupils in the Effutu Municipality?

1.6 Rationale behind the study

Formal reasoning, which is the ability of a person to think in abstract, is an important skill that pupils at the junior high school need to exhibit before progressing to the senior high school. This is because at the senior high school, science learning requires that pupils build their ability to reason formally so as to meet the demanding science curriculum. A child operating at the formal operational stage no longer needs to have hands-on experience with objects or physical knowledge of objects in order to think about them. Everything takes place in the mind in order to solve problems that will result in adaptation to their environment. As pupils build their formal reasoning skills through step by step procedures and learner-centered teaching methods, pupils will become well equipped to reason formally.

This is in line with the findings of Ritchie, Tobin and Hook (1997) that teacher dominated lessons (authoritarian approach) cowed students into acquiring knowledge without exploring their own mental models. This will enable pupils to also solve tasks that involve logical reasoning in integrated science and in general knowledge. Furthermore, pupils will be able to graduate smoothly from the junior high school to the senior high school. It is only such early development that would enable students to grasp the full import of the current over-demanding senior high school science syllabus. Hence, the need to improve formal reasoning and thinking abilities among pupils at the junior high school before graduating to the senior high school.

1.7 Significance of the Study

The findings and recommendations of this study would be of much benefit to Ghanaian Junior High School pupils learning integrated science especially those in the Effutu Municipality as well as teachers teaching integrated science in the various junior high schools in Ghana. To the pupils, this study could help them use several thought processes in solving logic tasks in integrated science. As in the constructivists‟ approach, which advocates the acquisition of knowledge by exploring ones‟ own mental models, this study will therefore develop in pupils a solid and meaningful quest for analytical thinking.

To the teachers, this study could help them adopt teaching strategies that will enable them build formal reasoning abilities in their pupils.

Finally, this study could serve as a source of information for further research work. For example, someone could use the findings of this work to find out if the formal reasoning skills of junior high school pupils in Ghana and especially in the Effutu Municipality could be a conduit that pupils need to improve their performance in integrated science.

1.8 Delimitations of the Study

According to Simon (2011) delimitations are those characteristics that limit the scope and define the boundaries of a study. The author further states that delimitations are in the control of the researcher. The following factors were identified by Simon (2011) as delimitations in a social research: the choice of the problem for investigation, objectives, the research questions, variables of interest, theoretical perspectives that the research adopted and the selected population. Thus, stating delimitations is a way of trying to bring the problem into proper and sharp focus. In the light of this the following delimitations were treated to help the Researcher prepare adequately to mitigate their effects on the study.

The nature of formal reasoning is an abstract concept so its measurement is difficult. The Researcher thus premised the research on developmental stages and assumed that as the pupils move to higher educational levels they developed better reasoning powers. The disparate nature of the distribution of schools in the municipality made access to all of them difficult so the Researcher used five junior high schools for adequate and thorough data collection. The five public junior high school pupils in the Effutu Municipality which form the accessible population of this study may not be very literate as to comprehend sentences with many scientific terms. Efforts were therefore made to simplify the multiple choice items by using simple, short sentences and familiar language so as to enable participants easily understand the demands of the items on the questions. Too many options on the multiple choice items may confuse the pupils so the Researcher reduced the options to three.

The Researcher also paid familiarisation visits to the school prior to the administration of the instrument so as to allay any fears that the pupils may harbour.

1.9 Limitations of the Study

Best and Khan (1989) explained that limitations are conditions that are beyond the control of the researcher and may place restrictions on the validity of the study. According to Simon (2011), limitations are potential weaknesses in a study and are often out of control of the researcher. These weaknesses which may hinder the progress of the study are factors that are external to the chosen topic of the research. Ideally a large number of Junior High School (JHS) across the nation should have been targeted in this study. However, this study targeted Winneba in the Effutu Municipality in the Central Region of Ghana. The findings of this study cannot be therefore generalised to other municipalities and districts in the Central Region of Ghana.

Again, data collection in all the schools were done a week to and during the first week of their examinations. This might have affected their ability to reason formally and solve tasks that involved logical reasoning as their minds could have been focused on their impending examinations. Furthermore, some of the teachers in the schools where the Researcher worked were not cooperating despite the introductory letter from her Head of department to the school. This made the Researcher to organise the pupils herself in order to carry out her mission in some of the schools. Also in some of the schools, the

Researcher realised that some pupils had very poor command over the English Language that she had to come in to explain some portions of the instruments used especially with the interview. This might have affected the findings of this study. Moreover, it was practically impossible control all other variables that might influence the formal reasoning ability along the period of the study of the participants.

1.10 Assumptions of the Study

A number of assumptions were made in this study. It was assumed that as pupils advance to higher educational levels they move away gradually from concrete operational stage to the formal reasoning stage. Pupils in JHS 3 would perform better on the logic tasks than pupils in JHS 2 and JHS 1. Again JHS 2 pupils would also perform better than JHS 1 pupils on the logic tasks. Furthermore the tasks designed would help to find general cognitive development as well as cognitive development in integrated science of JHS pupils. Moreover learner-centred methods in teaching science would allow pupils to explore and build science concepts with ease as compared to the teacher-centred methods of teaching science.

1.11 Organisation of the Thesis

This study was organised into five chapters. Chapter one is the introduction which deals with the rationale of the study. It also identifies the importance of the nature of formal reasoning among selected junior high school pupils in solving integrated science logic tasks in the Effutu Municipality. Four research questions were addressed to guide the study. In chapter two a review of the theoretical perspectives of the nature of formal reasoning among junior high school pupils in solving integrated science logic tasks was done. This involved a review on some theories of cognitive development, formal and informal reasoning, formal operational reasoning as well as logical reasoning in adolescence and science achievement. In chapter three, there was a detailed discussion on the methodology used for the study. Areas looked at included research design, research population, sample and sampling procedure, research instruments, data collection procedures as well as data analysis. Chapter four presented the demographic description of the study and the analysis of the collected data. Each analysis was followed by some discussions leading to the results obtained. The chapter five, which is the final chapter answered the research questions, and also presented the summary, conclusions and recommendations of the study.

1.12 Summary

There was the need to critically look at how selected junior high school pupils in the Effutu Municipality used several thought processes and applied their formal reasoning skills in solving logic tasks in integrated science and in general knowledge. In doing this, logic tasks which involved formal reasoning was prepared by the Researcher and administered to ten pupils each in JHS 1-3. Five public junior high schools which were selected at random in the Effutu Municipality were considered the sample for the study. The chapter ended with a discussion on the assumptions of the study. In the next chapter, a review of the relevant literature on the nature of formal reasoning among selected junior high school pupils in integrated science logic tasks is discussed.

CHAPTER TWO

REVIEW OF LITERATURE

2.0 Overview

This chapter introduces the review of literature. This will comprise the theoretical perspective of formal reasoning with respect to some theories of cognitive development. Again, there will be a discussion on recent studies on the relationship between formal and informal reasoning as well as the importance of logical reasoning in science and student achievement. Lastly, the conceptual framework of the study would be looked at.

2.1 Science and Cognitive Development

Science for young children is about gaining new knowledge of the world around them; what they can see, hear, smell and touch. It is about being curious and following a process to make new discoveries. For children to be able to gain new knowledge and be able to use this knowledge, it is helpful to take a close look at cognitive development. Cognitive Development is the study of how thought is developed in children and young people, and how they become more efficient and effective in their understanding of the world and their mental process (Oakley, 2004). The thinking of children is different from that of adults.

As a child develops, its‟ thinking changes and develops. There are two different perspectives on cognitive development that provides us with useful information about how children‟s mental abilities develop. Jean Piaget‟s theory of cognitive development and Lev Vygotsky‟s sociocultural theory of cognitive development help us to have appropriate expectations about how children think, what they can think about logically and how you can provide direct support to each child‟s growing ability to think.

2.2 Piaget’s Theory of Cognitive Development

Some researchers (Beilin& Pufall, 1992; Gruber & Voneche, 1977) noted that, no theory has had greater impact on developmental Psychology than that of Jean Piaget. Jean Piaget observed children and asked them questions to find out how knowledge developed (Thomas, 1992). Piaget believed that people‟s thinking changed as a way to adapt to their environment and that the highest level of thinking people could develop is abstract thought. Piaget believed that we construct knowledge. Cognitive development happens as children‟s concrete, hands-on experiences and knowledge of the physical world becomes mental actions. This happens so that children can adapt to their environment (Thomas, 1992).

For example, when we read or hear a word like chair, a picture most likely comes into our heads. Our brain takes something concrete and turns it into a picture or a symbol that we can use over and over again. In this way we are organising and giving structure to our thoughts. The actions that we use to organise and give structure to our thoughts are known as schemas. They can be simple or complex. Babies‟ schemas are very simple. One example is their grasping movement. They use this action to grasp a bottle, a rattle, a finger or the edge of a crib. Schemas can also be more complex. Each of these multiple step processes are schemas. The number of schemas or actions increases as children grow older. They also become more complex. For example, learning letter sounds becomes learning words, and words connect to become sentences that children can read. Changes like these happen involuntarily.

Learners produce simple schemes by organizing what they learn, and continuously change them into more complex bodies of knowledge by two processes emphasized in this theory; assimilation and accommodation. When the individual encounters a new situation, he/she either explains it by an existing scheme, this is called assimilation; or adapts his/her schema into this new situation by modifying it or creating a new one, and this is called accommodation. Although assimilation and accommodation happen automatically, it takes four ingredients to set them in motion. These are heredity, physical experience, social transmission and equilibrium.

Heredity provides the time table and the equipment for cognitive development. Physical experience happens when a child directly manipulates, observes or listens to objects to see what occurs when they are acted upon. Social transmission also deals with the knowledge that is passed on to the child from parents, schools, their community and the world at large. Last but not the least; equilibrium is the balance that is created between the forces of heredity, physical experience and social transmission (Thomas, 1992).

More complex bodies of knowledge develop as new information becomes associated with the previously existing ones. Therefore, Piaget views intelligence as an actively changing trait rather than a stable one, so humans develop more complex understanding as they grow up. This is in part due to the fact that nervous system also undergoes developmental stages throughout the life of an individual. During this progress toward more complex reasoning, experience and social relationships play a very important role, so individuals at the same age do not necessarily have the same reasoning ability. But it is still possible to attribute certain reasoning abilities to certain age groups. Piaget summarizes the changes in reasoning patterns into four successive categories; sensory motor period, preoperational period, concrete operational period and formal operational period. Singer and Revenson (1997) explain that these stages unfold over time and all children will pass through them all in order to achieve an adult level of intellectual functioning. In the next sub-sections, the various stages of Piaget‟s cognitive development theory are briefly discussed.

2.2.1 The Sensory motor Period (Birth to age 2)

Sensory motor period is a time that in both Piaget‟s account and the child development literature more broadly report a flourishing confidence in the child (Tomasello, 1992, 1999). It is also about the time when most children have become mobile on their two legs, greatly enhancing their range of exploration as well as their sense of control of their bodies (Cole & Cole, 1996; Harris, 1983). There are two very important characteristics of the sensory motor period; object and person permanence and egocentric thinking. Object permanence is the idea that even if something is out of sight, it still exists. We see it when babies search for objects that they have seen move out of sight. According to Piaget, children at this stage are unable to stand in someone‟s shoes and see things from a different perspective. However, egocentric thinking for example is when a young three year old playing hide and seek covers up only his head and face with a blanket and considers himself hidden.

Another example of egocentric thinking is when a child thinks his or her favourite cartoon character should be everyone‟s own and not any other cartoon character.

2.2.2 The Preoperational Period (Ages 2 to 7)

Language development plays a big role in this period. Children use their spoken language to change their physical actions and experiences into mental thoughts (Thomas, 1992). According to Piaget, children at the preoperational stage of cognitive development with ages between 2 to 5 can only think about what they perceive and not more than one characteristic of an object. For example a child at this stage of cognitive development when given different shapes with different colours will put all red coloured shapes together or the same shapes together without minding the colours. Piaget calls this centration. However, as they grow, they begin to focus on more than one characteristic of an object that they can see and so are able to arrange all shapes by colour and size with great success. This is called intuitive thought. Children at this stage of cognitive development also talk to themselves and this according to Piaget is egocentric speech. In this case the child is actually thinking out loud (Thomas, 1992). Concrete experiences such as physically seeing and moving shapes of different sizes and colours and talking out loud become mental activities. Children from about four to six are often described as exceptionally creative, and much more creative and even more after age six (Winner, 1996).

2.2.3 The Concrete Operational Period (Ages 7 to 11)

The Concrete Operational stage is the initial period of logical thought.

Operations are organised, formal, logical mental processes (Feldman 2001). Concrete operation is also described as logical in the adult sense, conforming to most of the requirements of rational thought (Ginsburg & Opper, 1988). According to Piaget, at this stage, the mental activities of the learners begin to change from notions to intellectual perceptions. They demonstrate logical thinking in relation to physical objects as they develop such mental abilities as the conservation of properties of objects. There is also the ability to reason about two or more aspects of a problem simultaneously (Case, 1984). There is also quality of reversibility that allows the child to recapitulate a line of reasoning from beginning to end and from end to beginning, as well as to compensate for changes by reciprocity (Richardson, 1998). At this level, the major restrictions are that mental operations can be applied only to first-hand situations. The understanding of abstract concepts at this level is very limited.

2.2.4 The Formal Operational Period (Ages 11 to 16)

Keating (1990) has observed that the primary qualities of formal reasoning include the ability to generate and reflect upon possibilities, to think and plan in long range terms, and also to find ways to systematically reach conclusions that can be verified and revised. Piaget also believes that the learners are able to deal with ideas and think beyond the concrete reality. These ideas are expressed in terms of statements and propositions, which they use in communicating their logical thought. They also develop the ability to solve problems mentally through the use of representations and mental models. They are able to coordinate thought processes and deal with more logical operations.

According to Piaget, as students attain formal thought, they are able to apply mental operations not only to concrete objects, but to objects, situations, ideas, and concepts that are not directly perceived. The next cognitive psychologist to discuss about is Lev Vygotsky and his sociocultural cognitive development theory. There is also meta-cognition, where the child develops the ability for "thinking about thinking" that allows adolescents and adults to reason about their thought processes and monitor them (Arnett, 2013). Furthermore, children at the formal operational stage manifest higher order thinking skills by responding to inquiries logically and making effective decisions.

2.3 Lev Vygotsky's Theory of Sociocultural Cognitive Development

Lev Vygotsky, a Russian psychologist, also made very important and exciting contributions to our knowledge of how thinking develops. His ideas about how mental abilities develop show us how important and necessary the social and cultural contexts are to developing each child‟s mental abilities. Vygotsky believed that children depend on others to develop their cognitive skills and abilities. According to him, a child‟s understanding of the world and his/her ability to adapt to come from his/her interactions with their parents, their siblings and others in their environment (Thomas, 1992). This means that from Vygotsky‟s point of view, knowledge is developed as a result of social interactions in which children, working alongside others who are more experienced than they are solve problems and build knowledge. As a result of these interactions children gradually learn to think on their own (Vygotsky, 1979, 1997; Wertsch &Tulviste, 1992). Two essential elements of Vygotsky‟s theory are Zone of Proximal Development (ZPD) and scaffolding which will be discussed briefly in the next sub-sections.

2.3.1 Zone of Proximal Development

The Zone of Proximal Development (Z P D) is the difference between what a learner can do without help and what he or she can do with help. Aljaafreh and Lantolf (1994) also described the zone of proximal development as "the framework, par excellence, which brings all of the pieces of the learning setting together; the teacher, the learner, their social and cultural history, their goals and motives, as well as the resources available to them, including those that are dialogically constructed together" (p. 468). For example, a child might not be able to walk across a balance beam on her own, but she can do so while holding her mother's hand. As time goes by the child becomes more confident in her balance and her mother can go from holding both hands, to holding one hand, and eventually she can stop holding her hand. The child will soon be able to walk unassisted. For any domain of skill, a ZPD can be created (Tharp & Gallimore, 1998) or in an „expanded‟ conception formulated (Wells, 1999).It is within this zone that a person‟s potential for new learning is strongest (Fabes & Martin, 2001). Since children are always learning new things, the ZPD changes as new skills are acquired.

There can also be a situation where a child cannot fit a puzzle piece into a puzzle, even with support, putting this puzzle together goes way beyond the mental and perhaps physical abilities of the child. The task of putting this puzzle together is outside the child‟s Z P D. It is therefore up to the adult in this situation to put the puzzle away and find another one that will be challenging for the child, but not impossible. Moreover, there is also the likelihood of a child solving another puzzle within some few seconds. This activity is also not within the child‟s Z P D as it is too easy for the child. In order to support the cognitive development of each of these children, you would need to assist them in selecting a puzzle that falls within their Z P D. Providing help does not mean giving the answers right away but it means providing some scaffolding. To do this, observation is the key tool to use. The next sub- section gives the explanation of scaffolding and how it can help pupils in their learning process.

2.3.2 Scaffolding

In terms of building construction, scaffolding is the structure built alongside a building when a brand new building is being built or when a building is being repaired. After the building is completed or the repairs are made, the scaffolding is removed. Scaffolding is the structure or guidance of a more experienced person. Scaffolding therefore needs to be personal and context-specific, sensitive to learner intentions, cultural and literacy resources (Dyson, 1999). In Vygoysky"s view of cognitive development, the adults or other partners in a child"s world provide support/scaffolding to help children learn new information as they build more schemas and develop more complex thinking abilities. Schaffer (1996) gives the example of a young girl who is given her first jigsaw. Alone, she performs poorly in attempting to solve the puzzle but with supports from her father she becomes more competent to work more independently. In the example above, the father provided assistance to the child and acted as scaffold.

There are many different ways of scaffolding, including breaking the task down into smaller steps, providing motivation, and providing feedback about progress as the person progresses. Moreover, effective scaffolding may reduce cognitive load (Hmelo-Silver, Duncan& Chinn, 2007) as well as link future actions with the present, or place the end in the beginning (Cole, 1996). Also direct instruction can be used strategically and effectively as scaffolding when, for example, it follows students" engagement in inquiry activities (Schwartz & Bransford, 1998). The next sub-section deals with the nature of reasoning in humans and linking it with the topic, before pupils can solve logic tasks, the nature of their reasoning ability plays a vital role.

2.4 The Nature of Reasoning in Humans

Educators, particularly those in science education, have regarded learners" reasoning ability as one of the important perspectives for examining students" learning (Eylon& Linn, 1988). Reasoning can be defined as the process of constructing and evaluating arguments (Shaw, 1996). Although we do not normally think about how fundamental reasoning is to our well-being, reasoning is like breathing to the mind. We are constantly doing it but we rarely take notice. If it fails however, we are paralysed. Imagine being unable to infer conclusions from a conversation? Or being unable to reach a solution to an important life problem? People's knowledge of the world places pragmatic constraints on how they reason (Brewer & Samarapungavan, 1991; Johnson-Laird, 2006; Cheng, 1997).

From a psychological perspective, reasoning may be defined as the set of mental processes used to derive inferences or conclusions from premises. Reasoning helps to generate new knowledge and to organize existing knowledge, rendering it more usable for future mental work. Reasoning is therefore central to many forms of thought such as scientific, critical and creative thinking, argumentation, problem solving, and decision making. Each of these more complex forms of thought can employ inductive, deductive, and abductive reasoning which are discussed in the next section.

2.4.1 Inductive Reasoning

Inductive reasoning is ampliative, that is, it generates new knowledge. Inductive reasoning supports inferences but does not guarantee that the inferences are true. Vickers (2006) characterizes inductive reasoning as “contingent” (that is, dependent on past experiences and observations). There are many forms of inductive reasoning such as enumerative induction and analogical reasoning. The best known form is enumerative induction in which the general properties of a class are inferred from a specific set of empirical observations. For example, upon observing that all the birds in the neighbourhood have wings and fly, a person infers that all birds have wings and fly. Generalizations of this kind, though common in human reasoning, are clearly fallible (ostriches and penguins are birds and have wings, but do not fly).

Analogical reasoning involves the transfer of knowledge elements and relationships among knowledge elements (e.g., object properties and property relations such as correlated features) from a well-known domain, a base, to an unknown or partially known domain, a target (Gentner, Holyoak, &Koikinov, 2001). For example, the analogy of a biological cell as a factory allows people to transfer knowledge about how a factory works (it has parts that are specialized to perform certain tasks and that operate together to maintain the functioning of the whole) to understand how a cell works. Analogical reasoning is often employed in instruction to help student understand new concepts by analogical transfer from more familiar concepts (Thagard, 2006). Induction plays a role in concept formation and concept learning in every domain of knowledge from natural language to science.

2.4.2 Deductive Reasoning

Deductive reasoning is the process of reasoning from one or more general statements (premises) to reach a logically certain conclusion (Sternberg, 2009). It also refers to processes of inference which guarantee logically valid conclusions from a set of premises. In other words, assuming that the premises are correct, the conclusions deduced from these premises must also be correct. Transitive inference such as (Ekua is taller than Adwoa; Adwoa is taller than Kwame; therefore Ekua is taller than Kwame) is one form of deductive inference. Deduction is a constituent of many varieties of cognitive performance such as text comprehension, scientific and mathematical reasoning, and argumentation.

Research shows that complex forms of deductive reasoning such as syllogistic and conditional reasoning start to emerge in the late elementary school years and continue to develop through adolescence (Bara, Bucciarelli, & Johnson-Laird, 1995; Ward & Overton, 1990). Deduction also plays an important role in categorical reasoning. One of the main cognitive functions of deductive reasoning is to organize knowledge in ways that allow one to derive parsimonious conclusions from sets of premises.

2.4.3 Abductive Reasoning

Abductive reasoning is a form of logical inference that goes from observation to a hypothesis that accounts for a reliable data (observation) and seeks to explain relevant evidence (Magnani, 2001). It is also a form of reasoning in which individuals start by attending to a particular phenomenon and try to construct a hypothesis that best explains their observation. The process is often called inference to the best explanation (Thagard& Shelley, 1997). Many causal inferences are abductive in nature. An example of abductive reasoning would be an inquiry into a car crash in which investigators try to reconstruct what happened from forensic evidence (e.g., patterns of damage to a car and its surroundings, data from physiological and toxicological exams conducted on the driver and passengers). From the forensic data, they reconstruct the most plausible or likely explanation for the crash. Again reasoning can be formal or informal and so the next sub-sections will look at these two forms of reasoning, the relationship between them and how it can help pupils in junior high schools solve logic tasks.

2.5 The Nature of Formal Reasoning

Formal reasoning is the ability of a person to think in abstract. The development of thinking abilities is well-discussed in the world of education. Cohen (1980) stated that the higher the ability of a person to think in an abstract way, the higher the ability of the person will function effectively in the society. Hence, the improvement of formal reasoning and thinking abilities among students is one of the aims of science education at all level of schooling. Roadrangka, Yeany and Padilla (1983) have identified six modes of formal reasoning. These six modes are proportional reasoning, controlling variables, probabilistic reasoning, correlational reasoning, combinatorial reasoning and conservational reasoning which are determinants of students‟ success in science and mathematics advanced courses at secondary level. According to Roadrangka, Yeany and Padilla (1983) the six modes of reasoning are explained as follows:

- Conservational reasoning is the ability to understand that original quantity does not change even if the shape changes.
- Proportional reasoning on the other hand is realising equal proportions of two quantities and logic to understand and solve quantitative relations.
- Controlling variables also is to realise all the variables in a given condition, suppose hypothesis for the role of variables and systematically control variables to verify the hypothesis to derive conclusion.
- Probabilistic reasoning is defined as ratio of expected probability for all the possible probability.
- Correlational reasoning is the ability to realise relationship between variables even if the changes of object and phenomena are irregular
- Combinatorial reasoning is logic to count all the possible cases for solving problem without duplication.

Renner and Philips (1980) strongly believed that students should be given opportunities to develop their thinking abilities as a base for intellectual development. In relation to this, Lawson (1985) stressed that schooling system is not meant for teaching of facts and concepts which are specific to a particular knowledge domain but more importantly to assist students in acquiring thinking skills.

2.6 The Nature of Informal Reasoning

Research indicates that some aspects of reasoning develop early, even before the onset of formal schooling or instruction, and may be part of the basic cognitive machinery of humans (Baillargeon, 2004). Informal reasoning is that type of reasoning which occurs in everyday activities such as evaluating arguments in newspaper editorials. There are three characteristic features that distinguish informal arguments. First, informal arguments are not structured like formal proofs. Although they contain premises and conclusions, these components may not be clearly demarcated, and some premises may not be explicitly stated. Second, although informal arguments involve both deductive and inductive inferences, the latter are more prevalent (Green, 1994). Third, informal arguments are often used in situations where reasons exist both for and against the conclusion (e.g. making decisions about what to believe or what actions to take). Thus, informal arguments are open to criticism that may go as far as presenting a case against the conclusions.

Accordingly, there are at least three criteria for evaluating informal arguments (Halpren, 1989; Voss & Means, 1991): the truth of the premises and conclusions; the quality of the link between the premises and the conclusion, i.e. strength or validity (Osherson, Smith, & Shafir, 1986), as well as the extent to which the argument addresses relevant information on both sides of the issue. There is considerable evidence that people employ forms of inductive and abductive reasoning to construct concepts about the natural world spontaneously, even in the absence of formal instruction in science (Baillargeon, 2004; diSessa, 1993; Vosniadou &Brewer, 1992).Much of the reasoning that occurs in our daily lives is not only aimed at stating truths, but also at making decisions (Johnson- Laird & Shafir, 1993). Traditionally, research in cognitive psychology has focused on formal reasoning, particularly on deductive inference. However, it is not entirely clear how this research applies to understanding reasoning in informal, everyday contexts (Galotti, 1989).

2.7 Relationship between formal reasoning and informal reasoning.

For many years, derived from a philosophical and psychological tradition of logicism, research on reasoning has been centred on the deductive reasoning paradigm in which learners are asked to evaluate logical arguments or generate valid conclusions from given premises (Evans, 2002). In the tradition of science education, scientific reasoning often refers to deductive reasoning characterized by rules of logic and mathematics. In these reasoning tasks, learners are presented with well-defined problems, and they are told to assume the premises of problems are true and to draw or approve only conclusions that necessarily follow (Evans & Thompson, 2004). Besides, reasoners are required to avoid taking their background knowledge and personal beliefs into account, and they should try to solve the problems only by utilizing the information provided in the premises (Evans, 2002; Evans & Thompson, 2004).

Based on the assumption that logic provides the basis for rational human thought, two theories have been proposed to illustrate the mechanism of human reasoning: mental model theory (Johnson-Laird, 1983), claiming that people reason by constructing mental models and mental logic theory (Braine & O‟Brien, 1995), advocating that there is a mental logic available for people to apply when they reasoning and some large part of this logic is universal. However, it has been argued that although the results of science may be presented in the format of formal reasoning and logic, the results themselves originate through informal reasoning (Tweney, 1991). Educators also proposed that many of the reasoning tasks in the classroom are informal in nature (Perkins, 1985; Means & Voss, 1996). Thus, informal reasoning skill may be of considerable importance, and the significance of informal reasoning has been increasingly highlighted by educational researchers (Kuhn, 1993; Sadler, 2004).

The majority of students" science learning experiences actually take place outside of formal classroom settings and in informal learning environments. Such learning may take place at home, in museums, through club membership activities or in simple everyday experiences. Nonetheless, little is currently known about the impact of students" experiences in informal learning environments on science learning. A group of students were given a paper-pencil test on the Piagetian conservation of volume task (Lawson 1995a). In this task, students were to observe drawings of two graduated cylinders with the same water levels. The students were to determine the resulting water levels after hypothetically dropping equal-sized steel and glass balls into one of each cylinder. One seventh-grade student explained (correctly):

I have learned that if I put my hand in a glass of water, then my bigger-handed cousin puts his hand in a glass of water and we take them out, his glass will have less water than mine because his hand is bigger. So, if the balls were the same size then the water level would have to be the same. In this response, the student used an example from real-world experiences to demonstrate an understanding of conservation of displaced volume. This student‟s response raises important questions regarding relationships among the activities which may occupy a student‟s time in informal learning environments, the nature of their in-school science experiences and scientific reasoning abilities.

As the literal meaning, formal reasoning and informal reasoning seem to be two opposite forms of reasoning. In fact, informal reasoning shares some commonalities with formal reasoning, but there are some essential distinctions between these two forms of reasoning. As aforementioned, the problems of formal reasoning are well-defined and the premises in these problems are always explicit and clear. However, unlike formal reasoning or scientific reasoning, the problems of informal reasoning are not well-defined, but ill-structured ones. In general, informal reasoning involves the generation and evaluation of position in response to complex issues that lack clear-cut solutions (Sadler, 2004). The premises may not be explicitly stated in informal reasoning tasks. As a result, the conclusions of the arguments in informal reasoning may not be demarcated. Therefore, informal reasoning is often used in situations where reasons exist both supporting and against the conclusion, such as making decisions about what to believe or what actions to take (Shaw, 1996).

Nevertheless, as formal reasoning, informal reasoning is also recognized as a rational process of constructing and evaluating arguments (Kuhn, 1993). In recent years, to provide accounts of informal reasoning, both the advocates of mental model theory and mental logic theory have tried to modify their theories to account for numerous pragmatic influences that appear in reasoning tasks, including informal reasoning tasks (Evans & Thompson, 2004).

The next sub-section is a brief discussion on formal operational reasoning. The sample used in this study all fell within the formal operational period which is the final stage of Piaget‟s cognitive development theory.

2.8 Formal Operational Reasoning

Formal operation is the fourth and final stage in one‟s cognitive development as proposed by Piaget. Formal operational reasoning as advanced by Inhelder and Piaget (1958) entails the structured whole which allows one to synthesize inversions and reciprocities in a unitary system of transformations. According to Piaget's theory, the formal operations stage is the apex in the ontogenesis of cognitive functioning (Inhelder & Piaget 1958; Piaget, 1972). The approximate ages for development of formal operational reasoning are 11-15 years of age (Inhelder & Piaget, 1958). Piaget described formal thought as a system of second-order operations; that is, operations that are based on the coordination of relations among relations. He also maintained that these operations usually emerge during early adolescence and that they are characterized by a high degree of inter-dependence. Formal operational skills should not be thought of as skills that naturally unfold over the course of development, instead these are skills that are acquired with considerable effort and often require instruction.

Piaget‟s fourth stage, formal operational stage, reflects on how students starting at 11 to 15 years of age begin to reason in a more abstract, idealistic, and logical ways (Inhelder & Piaget, 1958). Students now can use abstract logic to make up possible scenarios to decide on how to accomplish something or how different choices might play out. Adolescents in this stage are able to use verbal problem solving to find solutions to problems efficiently through logic. Adolescents in this stage also think about thinking- a process described by Mbano (2002) as meta-cognition. It is important to note that not everyone will reach formal operational thought at the same time or in the same way. Piaget also stresses the ability for an adolescent to use hypothetical-deductive reasoning to solve a problem and this was seen as central to formal operations. This is done by, the adolescent thinking about the problem, making an educated guess as to what would work best, and then trying that option to achieve the result.

The early formal operational thought sub-period focuses on the adolescent‟s ability to think hypothetically with infinite possibilities, and the world they live in is perceived in a very idealistic and subjective manner. In late formal operational thought, most adolescents are able to test their idealistic reasoning through experience and a balance between reality and idealism is reached. It is important to note that not every youth reaches complete formal operational thought. Piaget originally indicated that formal operational thought was typically achieved completely between the years of 11 and 15, but then later revised his theory to say that formal operational thought is not completely achieved until the ages of 15 to 20 (Piaget, 1972). In the next sub-section formal operational reasoning and science achievement is discussed.

2.9 Formal Operational Reasoning and science achievement

Formal operational reasoning has been found to be a predictor of achievement in science and mathematics (Bitner, 1986, 1988; Hofstein & Mandler, 1985; Howe & Durr, 1982; Lawson, 1983). This is in agreement with the work of researchers such as Danjuma

(2005), Demide (2000) and Oloyede (1998) who all agreed that formal reasoning is the strongest predictor of process science achievement. Shayer and Adey (1994) also pointed out that operational reasoning abilities are significantly related to achievement. Again Bello (1993) reported that formal reasoning is positively related to science achievements. In the same vein, the work of Tobin and Capie (1981) also suggested that students that have learnt process skills think analytically and are more successful with new problems. It is again reported that formal reasoning ability was the strongest predictor of process skill achievement and retention (Tobin & Capie, 1981).

Piaget states that children go through various developmental stages throughout their life. They do not only undergo physical changes, but also development with respect to cognitive abilities. Knowledge into the developmental stages enables instructional designers to implement activities or learning tasks suitable for the particular capabilities of that age group. Part of this mental development is attributed to alterations in brain structure and formation of new connections between nerve cells. Therefore, there are some developmental patterns that are common to all children. However, they may show differences in physical and cognitive properties depending on their unique life experiences, the environment they come from and inherited characteristics (Parsons, Hinson & Brown, 2001). This may result in variation between children‟s decision making and reasoning abilities, which may account for differences in science achievement.

This connection seems reasonable taking into consideration the fact that high levels of formal reasoning abilities are required for science process skills like hypothesizing, controlling variables and collecting and analysing data used in science courses

(Valanides, 1997). Although there are various explanations of mental development regarding neural changes, insight into psychological theories of cognitive development is crucial for being able to understand the change in intellectual abilities of children over time and differences between them regarding reasoning ability. The most influential theory in this area is the cognitive development theory of Piaget. Learning of science requires intellectual skills and high levels of reasoning ability of students (Bitner, 1991). Quite a number of researchers have given special importance to reasoning ability and have reported that there is a positive relationship between students‟ logical thinking ability and their science achievement (Cavallo, 1996; Johnson & Lawson, 1998; Lawson &Thompson ,1988; Oliva, 2003).One example for early research in reasoning ability is a study carried out by Lawson and Renner (1975) concerning concrete and formal operational concepts in secondary school biology, chemistry and physics classes. The aim of the study was to access the understanding of concrete and formal operational subjects by concrete and formal operational students.

Researchers used four Piagetian styled tasks to determine intellectual development of 134 students from a suburban university town high school in selected biology, chemistry and physics classes. Students were classified into one of seven categories ranging from concrete to formal- operational thinkers. Among the whole sample, 85% of the students were above concrete operational and below formal operational, only 4.8% were formal operational thinkers. Lawson and Renner (1975) attributed this retarded development to inappropriate subject matter and teaching procedures. Students were also tested in their respective discipline with subject matter tests evaluating their understanding of concrete operational and formal operational concepts.

Analysis of the relationship between these scores and the students" scores on the Piagetian tasks showed that the concrete-operational subjects were able to understand concrete concepts but not formal concepts, and formal operational subjects understood both concrete and formal concepts. The correlation between the tasks and understanding of formal concepts is more positive compared to the correlation with concrete concepts. This may be explained by the fact that the teaching procedures used are largely expository so donot provide direct concrete experiences to students. These materials are relatively abstract or formal for the student and understanding does not occur until the student enters formal stage.

Cavallo (1996) explored relationships among school students' meaningful learning orientation, reasoning ability and acquisition of meaningful understandings of genetics topics, and ability to solve genetics problems. After measuring students' meaningful learning orientation (meaningful and rote) and reasoning ability, students were tested before and after laboratory-based learning cycle genetics instruction. Using a multiple choice assessment format and an open-ended assessment format (mental model), regression analyses was 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. Results revealed that meaningful learning orientation best predicted students' understanding of genetics interrelationships, whereas reasoning ability best predicted their achievement in solving genetics problems. Lawson, Abraham and Renner (1989) also reported that many inquiry-based curricula were developed to help promote students critical thinking, concept understanding, and scientific reasoning abilities.

An earlier research concerned with the relationship between Piaget"s theory of cognitive development and how children perform at school was carried out by Mwamwenda (1993). This study investigated university students" cognitive development levels in relation to their academic performance. The study revealed that students that have fully developed formal operations performed better than others.

2.10 Logical Reasoning in Adolescence

Adolescence is a time during which new and powerful forms of reasoning emerge, resulting in fundamental transformations in how people think about themselves, others, and the world. Central to adolescent progress are the ongoing development of logical and hypothetical reasoning (Amsel, 2011; Barrouillet & Gauffroy, 2013; Markovits, 2013).

Logical reasoning, in its core meaning, is the deduction of conclusions that follow necessarily from given premises. The significance of logical reasoning is that it allows the mind to go beyond perceptions of immediately available information to formally and systematically entertain deductively valid and ontologically possible propositions. Logical thinking also improves as adolescents become better able to make deductive inferences on abstract conditional reasoning tasks. These tasks provide no knowledge-based counter examples to support a sufficiency relation between antecedent and consequent. For example, Markovits and Lortie-Forgues (2011) had participants aged 12 and 15 years make inferences about abstract conditionals. The older group outperformed the younger, on average, particularly when resisting making invalid inferences on denying the antecedent and asserting the consequent items. Such errors would be expected if participants assume a necessary and sufficient relation between the abstract antecedent and consequent. These and other results suggest that abstract understanding of conditional premises as sufficient relations between antecedents and consequents may continue to improve at least through age 15 years (Markovits, 2013). These changes in reasoning documented above occur as part of a broader set of cognitive changes affecting adolescents (Kuhn, 2009). For example, problem solving can be performed more quickly and efficiently by adolescents than by children because a larger range of relevant experiences, knowledge, and heuristics (simplified inference strategies which lead to quick but sometimes incorrect conclusions) can be automatically activated in memory (Reyna & Farley, 2006). However, the unique challenge of logically abstract inferences is to inhibit automatically activated knowledge, experiences and heuristics in favour of making carefully controlled inferences that are intentionally guided by meta-logical knowledge. That is, although meta-logical knowledge aids in adolescents‟ understanding what inference to make, adolescents need to exercise executive control over their information processing system in order to make such inferences free from bias resulting from automatically activated experiences, knowledge and heuristics.

It is notable then that middle adolescence is for many a period of improvements in executive function, which is a "deliberate top-down neurocognitive process involved in the conscious, goal-directed control of thought, action, and emotion" (Zelazo & Carlson, 2012, p. 354). The improvement of executive function is linked to neurological changes in the speed and efficacy of neurons in a specific area of the brain‟s prefrontal cortex and their connections to other brain areas (Blakemore, 2012).In addition to executive function and other information processing abilities necessary for improved inferential skills, many adolescents continue to construct meta-logical knowledge and increasingly use it to guide their inferences. Many adolescents become increasingly focused on whether knowledge claims are best treated as objective statements that are either factually true or validly deduced, subjective tastes that are merely more or less preferred, or reasonable interpretations that can be rationally evaluated as convincingly justified (Chandler, Boyes, & Ball, 1990; Kuhn, 1991, 2009; Moshman, 2011, 2013b).

Besides changes at the personal level, there are also changes at the interpersonal level that contribute to adolescent logical reasoning, including disputes and disagreements with peers and parents. Effective argumentation requires coordinating hypothetical and logical reasoning by highlighting the quality (strengths and weaknesses) of logically possible justifications of knowledge claims (Clark & Sampson, 2008; Kuhn, 1991). Furthermore, argumentation implicates both (a) the availability of meta-logical knowledge about the quality of arguments and (b) inferential skills to strategically apply that knowledge in ongoing arguments to defend one‟s own and undermine one‟s opponent‟s positions. Adolescents improve in understanding the need to strategically undermine their opponents‟ positions and not just to defend their own positions (Kuhn &Udell, 2007), although they may not always implement such a strategy (Stanovich, West, &Toplak, 2012).

Finally, argumentation has been shown to improve with practice, particularly with interventions that help arguers reflectively assess the quality of their performance (Chinn & Anderson, 1998; Iordanou, 2010; Udell, 2007).However, cultural variation exits in the perceived value of argumentation as a mean of promoting cognitive development or educational outcomes (Kuhn, Wang, & Li, 2011).

2.11 Conceptual Framework of the study

A conceptual framework is a structure that can be used to explain the natural progression of a phenomenon that is being studied (Camp, 2001). Miles and Huberman (1994) also defined a conceptual framework as a visual or written product that "explains, either graphically or in narrative form, the main things to be studied-the key factors, concepts, or variables and the presumed relationships among them" (p. 18). It is the researcher"s own position on the problem and gives direction to the study. The function of the framework is to inform the rest of the design of the study in order to help assess and refine the goals of the study. The conceptual framework also is the development of realistic and relevant research questions, selection of appropriate methods, and identification of potential validity threats to the conclusions to be drawn from the study.

Based on the topic with which this study was carried out, that is, the nature of formal reasoning among selected junior high school pupils in integrated science logic tasks, the concepts here are; formal reasoning and logic tasks. The theorists used for the study are; Jean Piaget and Lev Vygotsky. Piaget in his theory states that cognitive development stems largely from independent explorations in which children construct knowledge on their own. Vygotsky on the other hand states that cognitive development stems from social interactions from guided learning within the zone of proximal development as children and their partners co-construct knowledge. Hence the environment in which children grow up will influence how they think and what they think about.

Case (1992) in alluding to Piagetian theory agrees that there exist domain-independent internal operations in any child. These coherent internal operations are supposed to evolve and transform the cognitive developmental changes of the child. Piagetian theory therefore falls under what may be termed as contextual-neutral theories of cognitive development. These theories have, however, been criticised by many developmental theorists. For example, Bidell and Fischer (1992) debased the extensive reliance on the cognitive approach to education and wondered if it ever made any widespread success. The reason for this doubt is that there still existed a wide gap between developmental theory and education practice. In this study, the conceptual framework adopted is presented in Fig 2.1 below. In the figure, one directional arrow head describes the study direction and elements under consideration. Double arrow heads show that the connected elements have effect on each other.

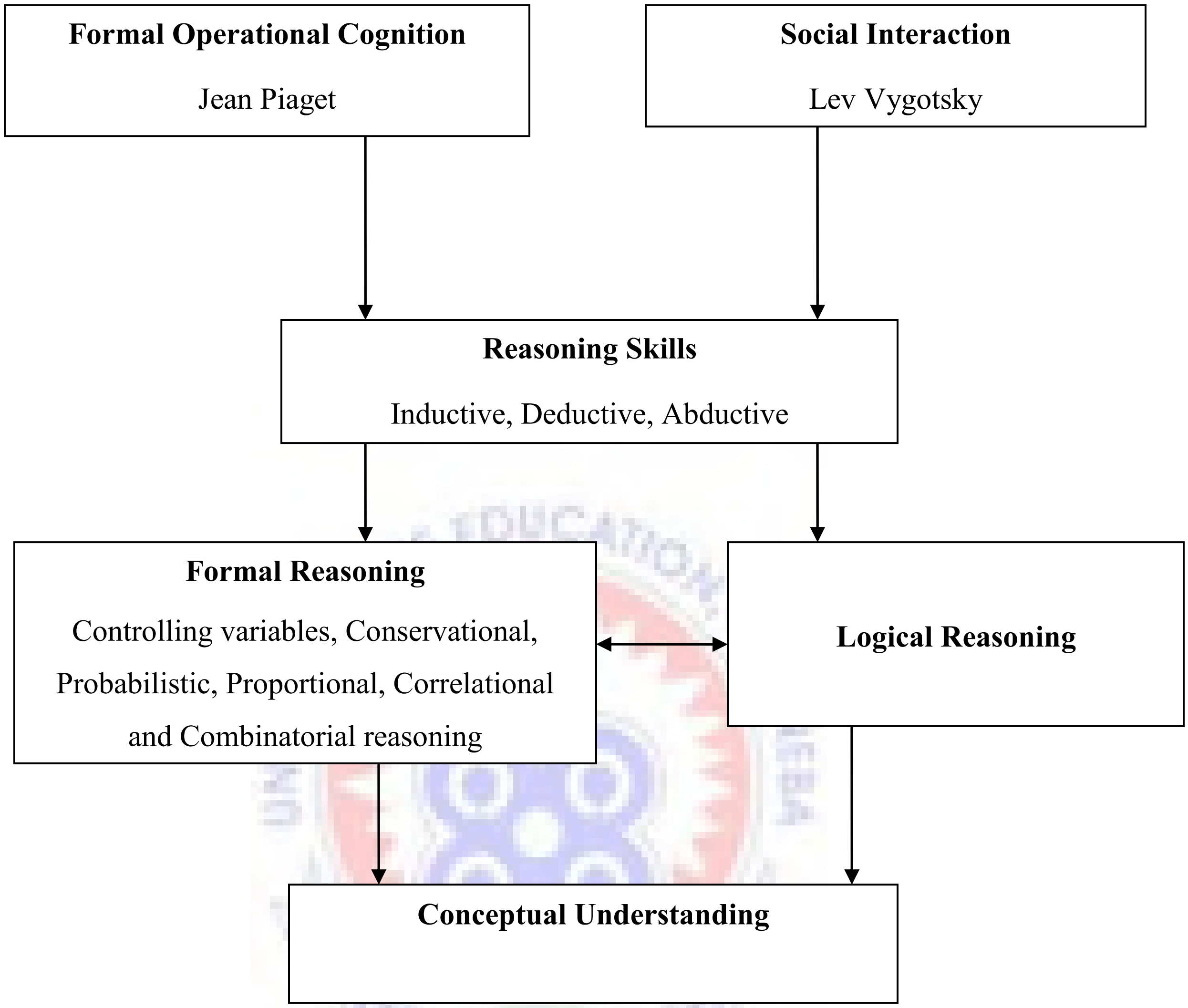

Fig2.1: Diagrammatic form of the Conceptual framework of the study

Jean Piaget in his cognitive development theory proposed that children as they attain formal operational cognition develop reasoning skills. Vygotsky also claims that as a child interacts with his/her environment he/she develops reasoning skills. As the child develops the reasoning skills which include inductive, deductive and abductive reasoning the child builds more schema or thought processes which can help him/her engage in formal and logical reasoning. Furthermore, a child"s ability to engage in formal reasoning also serves as a predictor for him/her to be able to engage in logical reasoning. Thus, a child"s ability to engage in logical reasoning in solving ISLT and GLT therefore depends on whether that child has built more schemas or thought processes to help him/her reason formally. Hence, learners who have developed conceptual understanding of tasks demonstrate maturity in solving tasks.

2.12 Summary

Piaget and Vygotsky agreed that children's cognitive development takes place in stages (Jarvis & Chandler, 2001). Again, both Piaget and Vygotsky believe that as children learn they develop certain reasoning skills. These reasoning skills include induction, deduction and abduction. However they were distinguished by different styles of thinking. Piaget proposed that children at the formal operational stage manifest higher order thinking skills by responding to inquiries logically and making effective decisions (Woolfolk, 2004). These help children to build more schemas or thought processes. Vygotsky on the other hand proposed that children through their social interaction with parents, peers and other members of the community are able to develop cognitively and are able to build more schemas. Furthermore, children who have built more schemas or thought processes and have developed conceptual understanding have the ability to reason formally. Hence, they develop the ability to solve tasks which involve logical reasoning as in solving logic tasks in integrated science and in general knowledge.

CHAPTER THREE

RESEARCH METHODOLOGY

3.0 Overview

This chapter is a description of the research methodology for the study. Thus the chapter described the research design used by the Researcher in carrying out the study, research population, sample and sampling procedures. The sample for the study included five selected public junior high schools in the Effutu Municipal where the Researcher currently teaches. Sampling procedures also was done using the basic simple random sampling technique. The main research instruments used here were questinnaire of logic tasks in integrated science and also in general knowledge. Furthermore, the research instruments were pilot tested to improve on the authenticity and quality of the research instrument thereby the likelihood to advance on the quality of data and results. The Researcher also checked for the validity and reliability of the instrument. This chapter was concluded with data collection procedures, where permission was sought from the appropriate quarters in order that the Researcher would administer the research instruments after which data analysis was done.

3.1 Research Design

Research design refers to the plan and structure of the investigation used to obtain evidence to answer research questions (McMillan & Schumacher, 1997). Again a design of a study is the basic plan for a piece of empirical research (Johnson & Christensen, 2008). The design describes the procedures for conducting the study, including when, from whom, and under what conditions the data will be obtained.

Among the ideas that are included in a design are the strategy, who and what will be studied, and the tools and procedures to be used for collecting and analysing empirical materials (Punch, 2006). In other words, a design indicates how the research is set up: what happens to the subjects and what methods of data collection are used. A design is again used to structure the research, to show how all the major parts of the research project- the samples or groups, measures, treatments or programmes and methods of assignment worked together to try to address the central research questions (Trochim, 2006). The purpose of a research design is to provide the most valid, accurate answers possible to research questions (McMillan & Schumacher, 1997).

According to McMillan and Schumacher (1997), research designs can be classified into two major types: quantitative research design and qualitative research design. Quantitative research design emphasise objectivity and quantification of phenomena and as a result maximises objectivity by using numbers, statistics, structure, and experimenter control (McMillan & Schumacher, 1997). Quantitative research design therefore presents statistical results represented with numbers. Experimental research design and nonexperimental research design are the two major categories that fall under quantitative research designs. According to McMillan and Schumacher (1997), there are different types of experimental designs which include true experimental, quasi-experimental, single subject, etc. Nonexperimental research design also has types such as descriptive, correlational, survey, etc.

Qualitative research design on the other hand is less structured and presents facts in a narration with words (McMillan & Schumacher, 1997). Ethnographic and analytical designs are the two major categories that fall under qualitative research designs. In an ethnographic study the researcher relies on observation, interviews, and document analysis, or a combination of these, to provide an in-depth understanding of what is studied. Analytical research designs investigate historical, legal and policy concepts and events through an analysis of documents, oral history, and relics (McMillan & Schumacher, 1997).

In this study the survey research design was used. A survey is a method through which the researcher can obtain the opinions, attitudes and suggestions for improvement (Khan, 1990). Typically, surveys gather data at a particular point in time with the intention of describing the nature of existing conditions or identifying standards against which existing conditions can be compared, or determining the relationships that exist between specific events (Cohen & Manion, 1994). Thus surveys may vary in their levels of complexity from those which provide simple frequency counts to those which present relational analysis. Survey studies are usually used to find facts by collecting data directly from the population or sample. They are the most commonly used descriptive method in educational research. Neuman (2000) argues that such an approach can be justified in terms of the nature of information gathered.

A survey has several characteristics and several claimed attractions; typically it is used to scan a wide range of issues, populations and programmes in order to measure or describe any generalised feature as stated by Cohen, Manion and Morrison (2000). As Kasumic (2005) noted "A survey, when conducted properly, allows you to generalise about the beliefs and opinions of many people by studying a subset of them" (p. 15). Based on the survey approach the Researcher used logic tasks and interview protocol to explore and gather data on the nature of pupils‟ formal reasoning. The usefulness of the survey approach is that it allows the collection of data from the sample and determination of the status of the sample with respect to the variables (Fraenkel &Wallen, 2003). Moreover, the survey approach has the advantage of making it possible for the researcher to measure the reactions of many respondents to a limited set of questions, thus facilitating comparison and statistical aggregation of the data (Patton, 2002; Kumekpor, 2002). It is also an efficient and accurate means of determining relatively inexpensive, quicker and reliable information about the population (Kumekpor, 2002).

The above enumerated characteristics of a survey informed the Researcher to choose survey as the research design for the study. Moreover, the purpose of this study which was to obtain large data on the nature of formal reasoning of pupils in the junior high school, the Researcher found survey appropriate.

3.2 Area of the Study

This study was conducted in the Effutu Municipality which is one of the six municipalities in the Central Region of Ghana. The Municipal covers an area of 417.3 square kilometres. According to Population and Housing Census of 2000, the Municipal had a population of 169,972, which represents 10.7% of the population of the Central Region. The Municipal has 168 settlements with Winneba as its capital.

3.3 Research Population

The population of a study is the group that conform to specific criteria and to which the researcher would like to generalise the result of the study (Fraenkel & Wallen, 2003). Again Castillo (2009) also defined a research population as a well-defined collection of individuals or objects having similar characteristics. Castillo distinguishes between two types of population: the target population and the accessible population. Borg and Ball (1996) stated that target population is all the members of a real or hypothetical set of people, events or objects to which we wish to generalise the results. The target population which is also known as the theoretical population refers to the group of individuals to which researchers are interested in generalising the conclusions. Whilst the accessible population which is also known as the study population is the population in research to which researchers can apply their conclusions. The accessible population is also the population of participants that is accessible to the researcher for a study (Patton, 2002). This population is a subset of the target population and is from the accessible population that researchers draw their samples.

The target population for this research was made up of all junior high school pupils in the Effutu Municipality. However, in order to collect reliable data from the pupils, five schools out of the 17 public junior high schools in the Effutu Municipality were chosen.

These schools were chosen as a result of proximity, familiarity and convenience. Ten pupils each from J.H.S. 1, J.H.S. 2 & J.H.S. 3 making thirty pupils were chosen from each school. In all, the sample (accessible population) was made up of one hundred and fifty pupils.

3.4 Sample and Sampling procedure

A sample is a finite part of a statistical population whose attributes are studied to gain information about the larger population (Webster, 1985). The sample of a study is also known as the smaller group that researchers study (Borg, Gall, & Gall, 1996). According to Castillo (2009), sampling techniques are the strategies applied by researchers during the sampling process. McMillan (1996) described sampling as a process of selecting a number of individuals from a population, in such a way that the selected individuals are representative of the population. The purpose of sampling is to a group of subjects that will be representative of the larger population or will provide specific information needed. Also the advantages of sampling are that the cost is lower, data collection is faster, and since the data set is smaller it is possible to ensure homogeneity and to improve the accuracy and quality of the data.

According to McMillan (1996), there are two types of sampling procedures, probability and non-probability sampling. Probability sampling is a method of sampling in which the subjects are selected randomly in such a way that the researcher knows the probability of selecting each member of the population (McMillan, 1996). Probability sampling procedures include simple random sampling, systematic sampling, stratified sampling and cluster sampling. A non probability sample on the other hand is one in which the probability of including population elements is unknown. Usually not every element in the population has a chance of being selected (McMillan, 1996). Non probability sampling procedures include convenience sampling, purposive sampling, quota sampling and snowball sampling.

In this study, the simple random sampling which is an example of a probability sampling was used as the sampling technique. Simple random sampling is one in which each and every member of the population has an equal and independent chance of being selected (Fraenkel & Wallen, 2003). The simple random sampling technique was used because it tends to yield representative of the population, it is easy to analyse, interpret results and it is easy to understand. With the simple random sampling, the Researcher used the lottery approach where pieces of papers representing the exact number of the particular class with yes or no written on them were put in a bowl. Since the Researcher wanted ten pupils from each class, the pieces of papers with yes on were exactly ten in number out of the total population of the class. In every class, the Researcher herself sent the bowl containing the pieces of papers round for pupils to pick. Picking of the papers were done with each pupil picking just one of the papers. Ten pupils in each class who picked the yes were included as the sample for the study. The same procedure was employed in all the schools. In all one hundred and fifty pupils were selected from the five schools within the accessible schools with thirty pupils from each school.

3.5 Research Instruments

There are different types of instruments that a researcher can employ to collect data in a study. Examples include questionnaires, interviews, observational checklist, tests, etc. Questionnaires are documents that ask the same questions of all individuals in the sample and respondents record a written response to each questionnaire item (Borg, Gall, & Gall, 1996). Questionnaires are the most widely used instruments for data collection and they are based on the objectives of the study. Advantages of using questionnaire include lower cost of sampling respondents over a wide area, less time is required to collect data and confidentiality is also assured. Forms of questionnaire include closed, open and pictorial forms and any combination of these.

Interviews on the other hand are essentially vocal questionnaire involving direct interaction between individuals which can be flexible and adaptable (McMillan & Schumacher, 1997). Interviews involve individual respondents and group respondents as well. Respondents speak in their own words and their responses are recorded by the interviewer (Borg, Gall & Gall, 1996). Forms of interview include structured, semi-structured, informal and retrospective (Fraenkel & Wallen, 2003). Structured and semi-structured interviews are rigidly standardised and formal. In the structured interview, questions are followed by set of choices and the respondent selects one of the choices as the answer. With semi structured interviews, questions have no choices from which respondent selects an answer. Rather the questions are phrased to allow for individual responses (McMillan & Schumacher, 1997). Informal interviews are much less formal than structured or semi-structured interviews. They tend to resemble casual conversations, pursuing the interest of the researcher as well as respondents. Furthermore, the interviewer may have a number of key issues which he/she raises in a conversational style instead of having a set of questionnaires (Cohen & Manion, 1994). Retrospective interviews can be structured, semi-structured or informal. In retrospective interview a researcher tries to get a respondent to recall and then reconstruct from memory something that has happened in the past.

An observational checklist is a strategy to monitor specific skills, behaviours or dispositions or individual students in a class as described by Burke (1999). She suggests that teachers use observation checklists for formative assessments by focusing on specific behaviours, such as thinking, social skills, writing skills and speaking skills. Again an observational checklist is listing of specific concepts, skills, processes or attitudes and it is designed to allow the observer to quickly record the presence or absence of specific qualities or understanding (Saskatchewan Education, 1994). According to Saskatchewan Education, an observational checklist is most appropriately used in situations where teachers wish to record information on explicit students‟ behaviours, abilities, processes, attitudes or performances. For example, it can help to access communication skills, cooperative learning skills, extent of participation and motor skills. According to Johnson, Johnson and Holubec (1998), there are two types of observation procedures: formal observation form which is used to record how often target actions take place and informal observation which is a teacher‟s impressions of what is happening in the classroom.

However, the most common instruments used in surveys are questionnaire and the interview schedules (Patton, 2002). Hence with the purpose of this study, there was the need to gather data on the nature of pupils‟ formal reasoning and how pupils applied their formal reasoning skills in solving logic tasks. Thus, the main instruments used for data collection were questionnaire of logic tasks in integrated science and in general knowledge and interview. The questionnaire was used to gather quantitative data from the respondents whiles the interview was used to collect qualitative data. Due to this, the Researcher developed test items which involved logical reasoning in both integrated science and general knowledge to collect data. Also as a way of validating the main instrument, the Researcher conducted an interview on how pupils applied their formal reasoning skills in solving logic tasks.

3.6 Description of the Research Instruments

Cohen, Swerdlik and Philips (1996) define testing as "the process of measuring variables by means of devices or procedures designed to obtain a sample of behaviour" (p.6). Test also means that a standard set of questions is presented to each participant in a study that requires completion of cognitive tasks. The responses or answers are summarised to obtain a numerical value that represents a characteristic of the participant (McMillan & Schumacher, 1997). The cognitive task can focus on what the person knows (achievement), is able to learn (ability or aptitude), chooses or selects (interests, attitudes, or values), or is able to do (skills). Different types of tests include standardised tests, aptitude tests, achievement tests, norm-reference tests, criterion-reference tests as well as performance or performance-based assessment tests. In order to determine what thought processes junior high school pupils use in solving logic tasks, a questionnaire of logic tasks was used. The Researcher set 60 questions in Integrated Science Logic Tasks (ISLT) and 60 in General Logic Tasks (GLT) with 20 in ISLT and 20 in GLT for J.H.S.1, J.H.S. 2 and J.H.S. 3 respectively.

The items on the ISLT were based on topics chosen from the Integrated Science syllabus. Items for JHS 1 were based on topics in the first year, for JHS 2 topics from first and second years, as well as topics from first to third year for the JHS 3 pupils. This was done with the anticipation that the senior classes (JHS 2 and JHS 3) had learnt the topics in the previous class and probably would have covered most of the topics in their syllabus as well. The Researcher herself being an integrated science teacher at the junior high school had an idea of the probable topics pupils might have been taught at the time of data collection. Furthermore, there were few consultations from some integrated science teacher friends from some of the schools chosen for the study on the topics treated. Each task had three options from which pupils were expected to choose the one they considered the most appropriate. The options represented conclusions that were drawn from two premises stated earlier. Only one option was correct for an answer. The respondents were then required to draw conclusion from the two premises and this was chosen from the three options given below the premises (lettered A-C). For example;

The density of a substance is the mass per unit volume of a substance.

The mass of a piece of metal is 5g and volume $2cm^3$, therefore

A. the density will be $2.5g/cm^3$

B. the density will be $0.4g/cm^3$

C. no conclusion can be drawn

The items on the GLT were also set based on the level of the pupils in the three classes respectfully, with items for JHS 1 pupils comprising simple logical statements, those for the JHS 2 pupils a little complex and those for the JHS 3 pupils more complex logical statements. Again, each question was assigned three options from which pupils were expected to choose the one they consider the most appropriate. Here again, options represented conclusions that were drawn from two premises stated earlier and only one option was correct for an answer. As with the ISLT, the respondents were required to draw conclusion from the two premises and this was chosen from the three options given below the premises (lettered A-C). For example;

Most public school pupils find it difficult to communicate using the English language.

Esi communicates fluently using the English language, therefore

A. Esi attends a private school

B. Esi attends a public school

C. no conclusion can be drawn

With regards to the interview, the Researcher ascertained from pupils the extent to which they applied their formal reasoning skills in solving logic tasks by asking them what informed them in choosing a particular answer. The responses provided by pupils from the different forms were examined, interpreted and used to find out the extent to which they were able to make logical analysis. Six interview questions were posed to a total of 30 respondents, consisting of ten (10) from each level (JHS 1-JHS 3). The questions were formulated to cover the six (6) modes of logical thinking as identified by Roadrangka, Yeany and Padilla (1983). These six modes are proportional reasoning, controlling variables, probabilistic reasoning, correlational reasoning, combinatorial reasoning and conservational reasoning. One question from each of the 6 modes outlined above was posed to each of the 30 respondents. They were then given alternative answers and asked to provide reasons to support their choice of answer.

3.7 Validity of the Instrument

According to Golafshani (2003), validity describes whether the means of measurement are accurate and whether they are actually measuring what they are intended to measure. On the whole, validity is the degree to which the instrument measures what it purports to measure. A test is valid if its results are appropriate and useful for making decisions and judgment about an aspect of students‟ achievement (Gronlund & Linn, 1990). The Researcher sought to establish the face and content validity of the research instruments. Face validity pertains to whether the test "looks valid" to the examinees who take it, the administrative personnel who decide on its use and other technical untrained observers (Anastasi, 1988). The face validity of the logical tasks was established with the help of my supervisors and other science education experts. These experts helped to correct all typographical errors and elements of ambiguity in the instruments before it was used in the pilot test. They deemed it suitable for gathering information on the nature of the formal reasoning of pupils in the junior high schools.

Content validity on the other hand is based on the extent to which a measurement reflects the specific intended domain of content (Carmines & Zeller, 1991). Similarly, Waltz, Strickland and Lenz (1991) defined content validity as the extent to which an instrument adequately samples the research domain of interest when attempting to measure phenomena. To enhance content validity of the instrument, the tasks were developed in consultation with supervisors and other senior lecturers in the Department of Science Education at the University of Education, Winneba. These senior lecturers examined the instrument to identify any ambiguities and also make the necessary clarifications to the items based on the topics in the syllabus. This resulted in the deletion of incorrect items and replacement of such deleted items with more suitable ones. Some items were also modified based on the recommendations of experts in order to ensure that the instrument would be suitable for gathering the required data.

According to Merriam (1998), to ensure internal validity, peer reviews or peer debriefing strategy must be employed. Therefore colleague graduate students at the department of Science Education, University of Education, Winneba were also given the tasks to read through. Necessary and constructive corrections and suggestions made were taken into consideration.

3.8 Reliability of the Instrument

The quality of a research instrument or a scientific measurement is determined by both its validity and reliability (Aikenhead, 2005). Reliability is the degree to which the instrument consistently measures what it purports to measure. In terms of reliability, Koul (2000) reiterated that repeated measures of an attribute characteristics or trait by a test may produce different results. Therefore in determining the quality or consistency of the instruments for the study, a pilot test was conducted with thirty (30) pupils from Asebu D/A J H S in the Gomoa district in the same region where the main study was conducted. This school was chosen because it was outside the accessible population. Besides, there was homogeneity in characteristics between the accessible and the pilot school populations. The reliabilities of the logical reasoning tasks were determined and the reliability co-efficients (Cronbach‟s Alpha) were calculated using SPSS.

George and Mallery (2003) gave the following categorization for Cronbach‟s Alpha (α): when α is greater or equal to 0.9, its means is excellent; when α is greater or equal to 0.8, its means is Good; when 0.8 is less than α but is greater or equal to 0.7, then it is acceptable; when 0.7 is less than α but greater or equal to 0.6, then it is questionable; when 0.6 is less than α but greater or equal to 0.5, then it is poor and when α is less than 0.5, then it is unacceptable. Again, Borg, Gall and Gall (1996) reiterated that coefficient of reliability values above 0.75 are considered reliable. This gives an indication that the instrument was adequate to be used in gathering data for the subsequent study. Below is a table showing the reliabilities of the various classes on both the ISLT and GLT.

Table 3.1: The reliabilities for the pilot test on the ISLT and GLT for the different levels

LEVEL	TASK	RELIABILITY
J. H. S. 1	ISLT	0.750
	GLT	0.780
J. H. S. 2	ISLT	0.860
	GLT	0.916
J. H. S. 3	ISLT	0.826
	GLT	0.783

(NB: The analytical tables of the various levels as presented by SPSS are attached as Appendices E-J).

3.9 Pilot Testing

Baker (1994) noted that a pilot study is often used to pre-test or try out a research instrument. This is to ensure that instructions, questions and scale items are understandable and meaningful. The purpose of pilot test is to reveal defects in the research instrument (Jack & Norman, 2003). Again, pilot testing improves on the authenticity and quality of the research instrument thereby the likelihood to advance on the quality of data and results. It will again help recognize questions that respondents have difficulty understanding or interpreting, wording and their reading ability as well as determining the length of time they may use to respond to the test items. Therefore the instruments were developed and pilot-tested with a small sample of thirty (30) pupils in a neighbouring district. Each subject was given a questionnaire of (20) logic tasks each in both Integrated Science Logic Tasks (ISLT) and General Logic Tasks (GLT) respectively to answer. Response from the pilot testing was used to restructure the instruments and the data from the pilot test was analysed to determine the reliability using the Cronbach"s alpha coefficient.

3.10 Scoring the Instrument

The responses to the logical reasoning tasks in integrated science and in general knowledge were put together, edited and scored. Both the integrated science logic tasks and the general logic tasks were marked over twenty for all the three levels, form one, two and three respectively. The answers for the multiple choices were scored one mark for a correct answer and zero for an incorrect answer. In order to determine the nature of pupils" formal reasoning in solving integrated science logic tasks, the mean score as well as the standard deviation for each of the level in both integrated science and general logic tasks were computed. The score range of 1-7 was interpreted by the Researcher as low performance, 8-14 as satisfactory and 15-20 as excellent performance. According to Lawson (1995), students" performance can be categorized into three levels of cognitive development i.e. concrete operational stage (score 0 to 8), transitional operational stage (score 9 to 15), and formal operational stage (score 16 to 21).Hence, the performance of pupils were categorised as such.

3.11 Data collection procedure

Data collection is the process in which data of a study is gathered (UNICEF, 2000). Data collection is also the process of gathering and measuring information on variables of interest, in an established systematic fashion that enables one to answer stated research questions, test hypotheses, and evaluate outcomes. First, the Researcher obtained an introductory letter from the Head of Science Education Department of the University of Education, Winneba which was used to obtain permission from the Municipal Director of Education (Appendix K). An initial visit was made to each of the selected schools to seek permission from the head teachers to undertake the study. This visit sought to establish rapport with teachers and most especially with pupils that formed the sample and to solicit their participation in the study and to select a date for the administering of the instruments. The purpose of the study was explained to the respondents, and their consent sought verbally.

The second visit was used to administer the questionnaire of logic tasks in integrated science and in general knowledge. As mentioned earlier, tasks were administered to the participants comprising of one hundred and fifty (150) pupils and their responses collected and studied. Each subject sampled was given a set of logical tasks in integrated science and general knowledge, twenty each for integrated science and general knowledge to do independently under my personal supervision. The researcher directed and run the data collection procedure herself with the help of few teachers who were available.

The third and last visit to the schools was used to interview thirty of the respondents. Since data was compiled from different schools in the Effutu Municipality, duration of three weeks was used. The summary of the data collection procedure is presented in Figure 3.1. In the diagram, one directional arrow head describes the data collection process and elements under consideration.

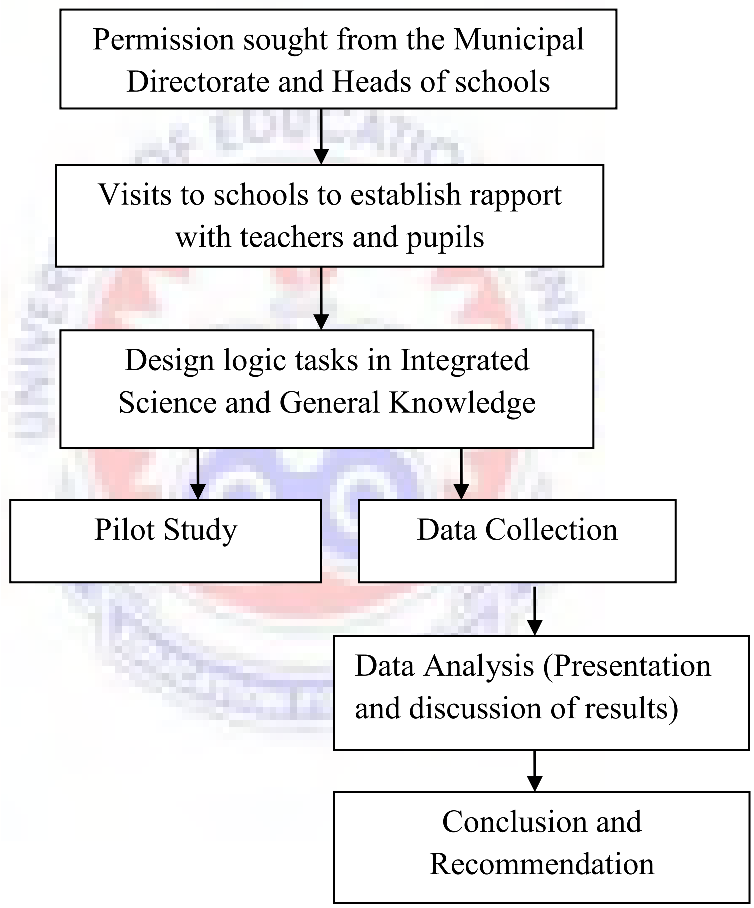

Figure 3.1: Diagrammatic form of Data Collection Process

Figure 3.1 shows the steps taken in the data collection process. Firstly, logic tasks in integrated science and in general knowledge were designed to determine the nature of formal reasoning of pupils after permission was sought from the appropriate quarters and familiarisation visits to the schools. Secondly, the logic tasks were pilot tested and subsequently used to collect data from the pupils within a period of two weeks. Thirdly, the data collected was analysed, then results were presented and discussed. Finally, conclusion was reached and recommendations made from the findings.

3.12 Data Analysis

Data analysis is the process of converting raw data collected into usable information (Statistics Canada, 1998). Again data analysis according to Jack and Norman (2003) is the process of simplifying data in order to make it comprehensive. They further indicated that in data analysis, any statistical techniques, both descriptive and inferential to be used should be described. The data collected from this study were edited, corrected and analysed as mentioned by Blaxter, Dodd and Tight (1996), that editing data detects errors and possibly corrected.

The logical test items were arranged serially and data gathered was analysed using Statistical Package for Social Sciences (SPSS) version 16. This is because it provided among other things, variety of ways to summarise data and accurately describes variables of interest (Easterby-Smith, Thorpe & Lowe, 1991). The analysis was done by making use of the research questions developed from the objectives of the study. The means, frequencies, standard deviation and percentages of the responses provided by the pupils were calculated using the descriptive function of the SPSS. Again, the inferential statistics function of the software was also used by the Researcher to draw conclusions, inferences or generalisations from the sample to the population of the study using t-test. Samples of pupils‟ test items on logical reasoning in integrated science and in general knowledge as well as the interview protocol is presented in the Appendices A-D.

3.13 Summary

A research design was used as the overall plan for obtaining answers to the research questions being investigated. In this study, the survey research design was used. Neuman (2000) argues that such an approach can be justified in terms of the nature of information gathered. The target population was all junior high school pupils in the Effutu Municipality with the accessible population being 150 pupils chosen from five accessible schools. This was because of their common binding characteristics or traits. Simple random sampling was used to obtain a group of participants that represented the larger population, which according Fraenkel and Wallen (2003), is one in which each and every member of the population has an equal and independent chance of being selected. Quantitative data collection procedure was used mainly in the study as it produces results that can be summarised, compared, and generalised easily. Questionnaire of logic tasks in integrated science and in general knowledge were used as the main instruments. However, the Researcher conducted an interview to find out the extent to which pupils applied their formal reasoning skills in solving the logic tasks as a way of validating the main instrument. Cronbach alpha reliability coefficient was used to verify the internal consistency reliabilityof the items on logical reasoning. Subsequently, the Statistical Package for Social Sciences (SPSS) version 16 was used in analysing data collected as it provided among other things, variety of ways to summarise data and accurately describes variables of interest (Easterby-Smith, Thorpe & Lowe, 1991).

CHAPTER FOUR

PRESENTATION, DATA ANALYSIS AND DISCUSSIONS

4.0 Overview

This chapter discusses the details of the study. It presents the demographic description of the participants of the study as well as the results of the study obtained through the analysis of data. The data collected was analysed and results presented. The main instruments used to gather data are questionnaire of logic tasks in integrated science and general knowledge and an interview. These instruments were used to gather data from a total of one-hundred and fifty (150) respondent pupils. Fifty pupils each were selected from forms one to three from the five selected schools in the Effutu municipality.

4.1 Demographic Description of Participants

Demographic description may be referred to as how people are classified into groups using common characteristics such as race, gender, income level or age. Demographic information provides data regarding research participants and is necessary for the determination of whether the individuals in a particular study are a representative sample target population for generalisation purposes (Lee & Schuele, 2010). The profile of the respondents in this study was looked upon in terms of gender, level and age.

4.1.1 Gender of Respondents

Out of the 150 pupils involved in the study, (84) of them were males which represent 56% with the remaining (66) being females which represent 44% as shown in Figure 4.1

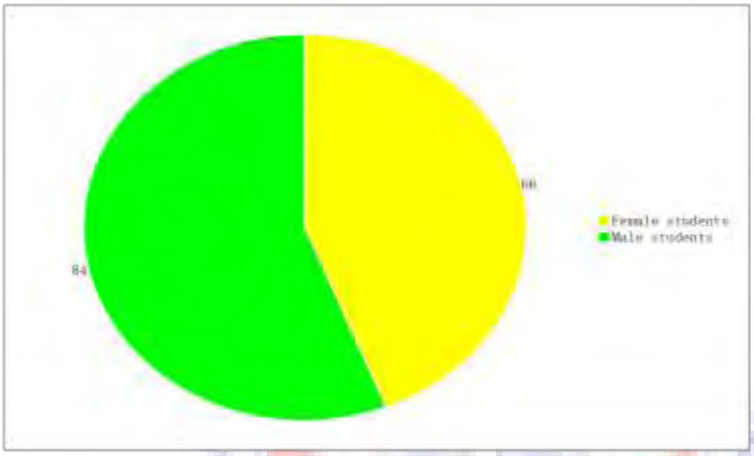

Fig 4.1: Gender distribution of respondents

4.1.2 Level of Respondents

Fifty respondents each were selected from (5) public junior high schools in the Effutu Municipality. As such, there was an equal distribution of respondents with respect to the status of respondents‟ level as in JHS 1, 2 or 3 respectively.

4.1.3 Age of Respondents

As displayed in Table 4.1, 40 pupils were 15years old representing 26.67%, 31 pupils were 14years old representing 20.67%, 26 pupils were 16years old representing 17.33%, 19 pupils were 17years old representing 12.67%, 14 pupils were 13years old representing 9.33%, 11 pupils were 17years old and above representing 7.33%, 7 pupils were 12years old representing 4.67% as well as 2 pupils were 11years old representing 1.33%.

Table 4.1: Age distribution of respondents

Age (Years)	Frequency	Percentage (%)
11	2	1.33
12	7	4.6
13	14	9.33
14	31	20.67
15	40	26.67
16	26	17.33
17	19	12.67
Above 17	11	7.33
Total	**150**	**100**

4.2 Presentation of Tables and Analysis

4.2.1: Distribution of Scores in Integrated Science Logic Tasks (ISLT)

The scores of ISLT which was organised for the pupils participating in the study are represented in terms of frequency, mean scores and standard deviation in Table 4.2.

Table 4.2 shows the distribution of the scored attained by form 1, 2 and 3 pupils in the ISLT

Table 4.2 Distribution of scores of form 1, 2 and 3 pupils in ISLT

Scores	**Form One Frequency**	**Form Two Frequency**	**Form Three Frequency**
1-7	13	9	1
8-14	37	41	44
15-20	0	0	5
Mean Score	9.02	8.28	11.92
SD	2.06	1.64	2.09

The score range of 1-7 is interpreted by the Researcher as low performance, 8-14 as good and 15-20 as excellent performance. It can be seen from the Table 4.2 that none of the form one pupils attained scores higher than 14. It can also be seen that 13 form one pupils, representing 26% scored between the range of 1-7. All of the remaining 37(74%) pupils scored between 8 and 14. Again, 9 pupils in form two scored marks within the range of 1 -7 as evident on Table 4.2. Majority of the 50 form two pupils who wrote the ISLT test had marks ranging from 8 to 14. They represented 82% of the population. However, none of the 50 students managed to attain a score above 14 as evident on Table 4.2. Furthermore, the data available on Table 4.2 also gives a breakdown of the marks attained by the 50 form three pupils involved in the present study. Only one pupil attained a score less than 8 in the test. Forty-four pupils scored within the range of 8 and 14. The number of pupils who scored within the range of 15 to 20 was 5 constituting 10% of the total number of fifty form three pupils. Moreover, as presented in Table 4.2, it is evident that the pupils in form two performed poorly on the average based on the fact that they had the lowest mean score among the three forms. The form three pupils had the highest average mark of 11.92 which was higher than the mid mark of 10 out of 20. The mean marks of forms one and two pupils were 9.02 and 8.28 respectively. Both marks are made up of less than 50% of the total mark. Summarily, all forms basically operated at the concrete and transitional operational stages as proposed by Lawson (1995). Comparing the three forms, it is evident that most of the form threes operated at the transitional stage with a few operating at the formal operational stage whiles most pupils in form one and form two operated at the transitional stage. Moreover, 13 pupils in form one operated at the concrete operational stage with 9 pupils in form two also operating at the concrete operational stage as evident on Table 4.2

Major Finding 1

Most pupils (96.7%) operated at the transitional and concrete operational stages in the ISLT. However, 5 pupils (3.3%) from form three operated at the formal operational stage.

4.2.2: Distribution of Scores in General Logic Tasks (GLT)

The scores of GLT which was organised for the pupils participating in the study are represented in terms of frequency, mean scores and standard deviation in Table 4.3.

Table 4.3 shows the distribution of the scores attained by form 1,2 and 3 pupils in the GLT.

Table 4.3: Distribution of scores of form 1, 2 and 3 pupils in GLT

Score	Form One Frequency	Form Two Frequency	Form Three Frequency
1-7	38	48	39
8-14	10	1	9
15-20	2	1	2
Mean Score	6.72	3.29	6.34
SD	2.49	2.43	3.17

The score range of 1-7 is interpreted by the Researcher as poor performance, 8-14 as good and 15-20 as excellent performance. As displayed in Table 4.3, thirty eight pupils scored between 1 to 7 marks out of the fifty form one pupils in the GLT. A further ten pupils (20%) had marks ranging from 8 up to 14. The two remaining pupils scored above 14 as seen on the Table 4.3. Again, the marks distribution of form two pupils revealed that 48 of the pupils had less than 8 marks out of the total of 20 marks. Only 2 pupils managed to score above 8 as evident on Table 4.3. Out of these 2 pupils, 1 attained a score above 14. In the case of the form three pupils, 2 respondents managed to attain a score within the range of 15 to 20. As can be seen on Table 4.3, thirty nine pupils scored between 0 and 7 marks. Nine of the form three pupils recorded marks within the range of 8 to 14.

Furthermore, Table 4.3 gives a summary of the average scores of pupils from the three different levels in the GLT. The form with the highest mean mark was form one. The average mark of the form one pupils was 6.72. The form three pupils followed closely with a mean mark of 6.34 with the form two recording the lowest mean score of 3.29. In summary, it is evident from Table 4.3 that most pupils operated at the concrete operational stage. Furthermore, 10 pupils from form one operated at the transitional operational stage with just 2 pupils operating at the formal operational stage. Again, 9 pupils in form three operated at the transitional stage with 2 pupils at the formal stage whiles just a pupil each in form two operated at both the transitional and formal operational stages.

Major Finding 2

Most pupils (96.7%) operated at the concrete and transitional operational stages in the GLT. However, 5pupils (3.3%) with 2 pupils each from form one and form three operated at the formal operational stage with just a pupil from form two.

4.2.3: Interview Protocol

The responses provided by pupils from the different forms to some interview questions were examined and used to find out the extent to which they were able to make logical analysis. Six interview questions were posed to a total of 30 respondents, consisting of ten (10) from each form (form one to form three). The questions were formulated to cover the six (6) modes of logical thinking as identified by Roadrangka, Yeany and Padilla (1983). These six modes are proportional reasoning, controlling variables, probabilistic reasoning, correlational reasoning, combinatorial reasoning and conservational reasoning. One question from each of the 6 modes outlined above was posed to each of the 30 respondents. They were then given alternative answers and asked to provide reasons to support their choice of answer.

Interview Item 1(Conservational reasoning)

Kofi has two balls of clay. They are of the same size and shape.

When he weighed them, their weights were the same. The balls of clay are removed from the weighing scale. Clay 2 is flattened like a pancake. Would the two balls still weigh the same or not.

A) The pancake-shaped clay weighs more.

B) The two pieces weigh the same.

C) The ball weighs more.

Table 4.4 shows the distribution of pupils‟ responses to the first item on the interview protocol.

Table 4.4: Distribution of pupils' responses to item on conservational reasoning

Level	pupils who showed conservational reasoning	pupils who did not show conservational reasoning
Form one	6	4
Form two	6	4
Form three	8	2

It is evident from Table 4.4 that most respondents out of the 30 pupils were able to do conservational reasoning. Out of the 30 pupils, 20 pupils representing 66.67% were able to do conservational reasoning with 10 pupils representing 33.33% not being able to do conservational reasoning. Again out of the 20 pupils who could do conservational reasoning, 6 pupils each were from form one and two whiles 8 were from form three. Furthermore, 4 pupils each again from form one and two could not do conservational reasoning with 2 pupils from form three.

The following reasons were provided by pupils as to why they chose particular answers as well as the Researcher"s remarks on each reason:

1. The flattened clay has more length so it will weigh more. Since the child has placed more emphasis on the length, conservational reasoning is not achieved.
2. Since Kofi did not add or remove any clay from the original, the clay was expected to still weigh the same. This reason shows the child was able to do conservational reasoning as he/she was able to come out with the fact that the different shapes did not affect the original weight.
3. Clay 2 was flattened like a pancake, it had a greater area. From the reason given, it is clear that the child could not do conservational reasoning as he/she thinks the flattened clay had a greater surface area and so will weigh more.
4. When something is flattened, it loses weight. The reason given here clearly indicates that the child could not do conservational reasoning as the child thinks shape can affect the weight.
5. Because of its density, the round ball had more clay in it. This child could not do conservational reasoning since he/she thinks the shape of a substance can change its weight/density.

Interview Item 2(Proportional Reasoning)

There are two plastic cups, one is bigger than the other.

Each has equally spaced marks along the side. Abena pours the same amount of water into each cup. The water level comes up to the 4thmark in the bigger cup and to the 6th mark in the smaller cup. She pours a larger glass of water into the bigger cup. The water level comes up to the 6thmark.

How high would the same amount of water come if it were poured into the smaller cup?

A) 6

B) 8

C) 9

Table 4.5 shows the distribution of pupils‟ responses to the second item of the interview protocol.

Table 4.5: Distribution of pupils' responses to item on proportional reasoning

Level	**pupils who showed conservational reasoning**	**pupils who did not show conservational reasoning**
Form one	3	7
Form two	2	8
Form three	4	6

It is evident from Table 4.5 that most respondents out of the 30 pupils were not able to do proportional reasoning. Out of the 30 pupils, only 9 pupils representing 30% were able to do proportional reasoning with 21 pupils representing 70% not being able to do proportional reasoning. Again out of the 21 pupils who could not do proportional reasoning, 6 pupils were from form three, 8 pupils from form two and 7 pupils from form one. Furthermore, 4 pupils from form three could do proportional reasoning with 2 pupils from form two and 3 pupils from form one.

The following reasons were provided by pupils as to why they chose particular answers as well as the Researcher"s remarks on each reason:

1. The water level in the smaller cup will be very high. This reason indicates the child has not yet acquired proportional reason since he/she could only say the water level will go high but not exactly the level of the water.
2. If you pour the same amount of water in the bigger and smaller cups, the ratio will always be 2 to 3. This reason shows the child was able to do proportional reasoning as he/she was able to realise the equal proportions of two quantities.
3. If the water level is 6 in the bigger cup, it will be two more in the smaller cup. This reason clearly indicates this child could not do proportional reasoning because he/she could not realise the equal proportions of two quantities.
4. If the water level is 6 in the bigger cup, it will be more than 6 in the smaller cup. This child could not do proportional reasoning as he/she was not also able to say the exact level of the water in the smaller cup.
5. There is no way of predicting. This reason clearly shows the child could not do proportional reasoning at all.

Interview Item 3 (Controlling variables)

Three strings are hanged from a bar. String 1 and 3 are of equal length. String 2 is longer. Ama attaches a 5g weight at the end of string 1, 2 and 3. Each string with a weight can be swung. Ama wants to find out if the length of the string has an effect on the amount of time it takes the string to swing back and forth. Which string would she use for her experiment?

A) strings 1 and 2

B) string 2 only

C) strings 1, 2 and 3

Table 4.6 shows the distribution of pupils‟ responses to the third item of the interview.

Table 4.6: Distribution of pupils' responses to item on controlling variables

Level	pupils who showed reasoning in controlling variables	pupils who did not show reasoning in controlling variables
Form one	3	7
Form two	3	7
Form three	4	6

It is evident from Table 4.6 that most respondents out of the 30 pupils were not able to do reasoning in controlling variables. Out of the 30 pupils, only 10 pupils representing 33.33% were able to do reasoning in controlling variables with 20 pupils representing 66.67% not being able to do reasoning in controlling variables. Again out of the 20 pupils who could not do reasoning in controlling variables, 6 pupils were from form three with 7 pupils each from form two and form one. However, 4 pupils from form three could do reasoning in controlling variables with 3 pupils each from form two and form one.

The following reasons were provided by pupils as to why they chose particular answers as well as the Researcher‟s remarks on each reason:

1. Different lengths with different weights should be tested. This child could not reason controlling variables as he/she wanted a proof, which is testing different lengths with different weights.
2. All strings and their weights should be tested. Again the reason given by this child also clearly indicates that he/she could not reason controlling variables.
3. Only the longest string should be tested. The experiment is concerned with length not weight. This child could do reasoning by controlling variables as he/she was able to state that only the longest string should be tested.
4. The length of the strings should be the same with the same weights. The reason given by this child also indicates that he/she could do reasoning controlling variables.
5. Everything needs to be the same except the length so you can tell if length makes a difference. This child could not also clearly predict or hypothesised controlling variables in his/her reasoning.

Interview Item 4 (Probabilistic Reasoning)

In a cloth sack, there are 3 red balls, 2 black balls, 5 white balls, 4 yellow balls and 6 green balls. All the balls are of the same size and shape. One ball is pulled out of the sack.

What are the chances that it is a white ball?

A) 1 out of 3

B) 1 out of 4

C) 1 out of 20

Table 4.7 shows the distribution of pupils‟ responses to the fourth item of the interview protocol.

Table 4.7: Distribution of pupils' responses to item on probabilistic reasoning

Level	pupils who showed probabilistic reasoning	pupils who did not show probabilistic reasoning
Form one	5	5
Form two	4	6
Form three	6	4

As it is evident from Table 4.7, half of the respondents representing 50% showed probabilistic reasoning by answering correctly to the questions. Out of the 10 pupils for each level, 5, 4 and 6 pupils from form one, two and three respectively answered correctly and therefore showed probabilistic reasoning whiles 5, 6 and 4 pupils from form one, two and three respectively could not do probabilistic reasoning.

The following reasons were provided by pupils as to why they chose particular answers as well as the Researcher‟s remarks on each reason:

1. There are twenty balls in the cloth sack. The reason given by this child clearly indicates that the child could not do any probabilistic reasoning as he/she could not even say anything about white balls but balls in general.
2. One white ball must be chosen from the twenty. This child could not do probabilistic reasoning as he/she thinks if a ball is taken then it is a white ball.
3. One white ball needs to be selected from a total of 5 white balls. This child could not do probabilistic reasoning as he/she could not clearly state the chance of selecting a white ball.

4. Five of the 20 balls are white in colour. This child only could state how many white balls were in the sack and not the chance of selecting a white ball.
5. One white ball can be selected from the twenty balls. The reason given by this child also shows that he/she could not do probabilistic reasoning.

Interview Item 5 (Correlational Reasoning)

A teacher decided to conduct a test to find out the level of performance of 10 male and10 female students in science. He observed that three male students scored the lowest marks and a girl had the highest mark. This made him wonder if there might be a relation between the gender of students and their scores. So he analysed the entire result of all 20 students. Their marks are as summarised in the Table 4.8.

Table 4.8: Distribution of marks of the level of performance of students in science

Marks	Frequency of boys	Frequency of girls
0	1	0
1	0	0
2	2	4
3	5	5
4	2	0
5	0	1
Mean	3.1	3.3

Do you think there is a relation between the gender of students and the marks they had?

A) Yes

B) No

Table 4.9 shows the distribution of pupils‟ responses on the fifth item of the interview.

Table 4.9: Distribution of pupils' responses to item on correlational reasoning

Level	Students who showed correlational reasoning	Students who did not show correlational reasoning
Form one	3	7
Form two	3	7
Form three	6	4

It is evident from Table 4.9 that 18 pupils representing 60% out of the 30 pupils were not able to do correlational reasoning. Again, 12 pupils representing 40% out of the 30 pupils were able to do correlational reasoning. Furthermore, out of the 18 pupils who could not do correlational reasoning, 7 pupils each were from form one and two with 4 pupils from form three. However, 3 pupils each from form one and two as well as 6 pupils from form three could do correlational reasoning.

The following reasons were provided by pupils as to why they chose particular answers as well as the Researcher‟s remarks on each reason:

1. Since a girl had the highest mark, girls perform better than boys. The reason given by this child clearly indicates that he/she could not find the relationship between the gender and scores of the students.
2. A boy had the least mark so boys are worse than girls. This reason also indicates clearly that this child could not do correlational reasoning.
3. Both boys and girls did well. This child also could not do correlational reasoning as he/she could only state that both boys and girls did well.
4. Their average marks were close, meaning there isn‟t much difference in the performance of boys and girls in the test. This child was able to do find the

relationship between the gender of students and their scores and so could do correlational reasoning.

5. Girls did better than the boys since their mean mark was higher. The reason given by this child also indicates he/she could do correlational reasoning as he/she was able to come out with the relationship between the boys and girls and their scores.

Interview Item 6 (Combinatorial Reasoning)

In a new shopping centre, 4 stores are going to be placed on the ground floor. A barber shop (B), a drug store (D), a grocery store (G), and a cloth 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 drug store next, followed by the grocery store and then the cloth shop. List the other possible ways that the stores can be lined up in the four locations.

A. DGCB, GCBD, CBDG

B. DGCB, GCBD, CGDB

C. DGCB, GCBD, GDBC

Table 4.10 shows the distribution of pupils‟ responses to the sixth item of the interview protocol.

Table 4.10: Distribution of pupils' responses to item on combinatorial reasoning

Level	pupils who showed combinatorial reasoning	pupils who did not show combinatorial reasoning
Form one	3	7
Form two	4	6
Form three	6	4

It is evident from Table 4.10 that 17 pupils representing 56.67% out of the 30 pupils were not able to do combinatorial reasoning. Again, 13 pupils representing 43.33% out of the 30 pupils were able to do combinatorial reasoning. Furthermore, out of the 17 pupils who could not do combinatorial reasoning, 7 pupils were from form one and 6 from form two with 4 pupils from form three. However, 3 pupils from form one and 4 pupils from form two as well as 6 pupils from form three could do combinatorial reasoning.

The following reasons were provided by pupils as to why they chose particular answers as well as the Researcher"s remarks on each reason:

1. The stores could be arranged in any manner. This child could not do combinatorial reasoning as he/she could not count all the possible ways the stores could be arranged.
2. The stores should be arranged in a sequential manner. This reason given by the child indicates that he/she could do combinatorial reasoning.
3. Any of the stores could be started with in the arrangement. This child also could do some form of combinatorial reasoning but could not be specific if the arrangement should be in a sequential order.
4. The stores could be arranged in any manner so far as they are four. The reason given by this child shows that he/she could not do combinatorial reasoning.
5. The last store could be started with in the arrangement. The reason given by this child is good but it still does not mean he/she could do combinatorial reasoning.

Major Finding 3

It was evident from the interview session that majority of pupils showed great potential in the domains of conservational, probabilistic and combinatorial reasoning as compared to correlational reasoning, proportional reasoning and controlling variables.

4.2.4: Gender Distribution of Scores Attained by Pupils in ISLT and GLT

This section presents the gender distribution of scores attained by pupils in integrated science logic tasks and general logic tasks. The section also gives brief comments on what the tables contain. Table 4.11 shows the gender distribution of scores attained by pupils in the ISLT and GLT.

Table 4.11: Gender distribution of marks attained by pupils in the ISLT

	Boys		Girls	
Marks	**Frequency**	**Percentage**	**Frequency**	**Percentage**
1 –7	17	20.2	17	25.8
8- 14	52	61.9	46	69.7
17- 20	15	17.8	13	4.5
Total	**84**	**100**	**66**	**100**

It can be seen on the Table 4.11 that the boys performed slightly better than the girls. The males who scored not more than 7 out of 20.2%, compared to 25.8% of the females. In addition, it can be seen that 52 of the male pupils scored marks ranging from 8-14 which was high compared to the total of 46 girls who managed to achieve the same feat.

Again, 15 male pupils attained scores greater than 16 compared to the female pupils‟ 13 as seen on Table 4.11. T-test analysis was performed on the mean scores of the male and female pupils in the ISLT to determine whether there was a significant difference in their scores as shown in Table 4.12.

Table 4.12: T-test results on the performance of male and female pupils in the ISLT

Compared Group	N	Mean Score	S.D	t	d.f	p-Value
Male	84	10.45	2.61	4.161	149	0.000
Female	66	8.83	2.04	4.161		

The mean score of the responses of male pupils in the ISLT was marginally higher than that of their female counterparts. The t-test results showed that statistically, there was a significant difference in the performance of male and female pupils in the ISLT (t (149) = 4.161, $p<0.05$). Therefore, the male pupils performed significantly better than their female counterparts in the ISLT as shown in Table 4.12.

Table 4.13: Gender distribution of marks attained by pupils in the GLT

	Boys		Girls	
Marks	**Frequency**	**Percentage**	**Frequency**	**Percentage**
1 – 4	55	65.54	8	72.72
8– 14	26	30.95	16	24.24
15- 20	3	3.55	2	3.04
Total	**84**	**100**	**66**	**100**

The gender distribution of scores attained by pupils is as displayed in Table 4.13. Only 2 girls and 3 boys managed to have marks ranging from 15-20. A total of 81 boys attained marks ranging between 1-14 whiles only 24 girls managed to attain scores within the same range in the GLT as displayed in the Table 4.13. T-test analysis was performed on the mean scores of the male and female pupils in the GLT to determine whether there was a significant difference in their scores as shown in Table 4.14.

Table 4.14: T-test results on the performance of male and female pupils in the GLT

Compared Group	N	Mean Score	S.D	t	d. f	p-Value
Male	84	5.83	3.34	-1.297	149	0.197
Female	66	5.17	2.79	-1.297		

The information provided on Table reveals that the performance of females in the GLT was slightly lower than that of the male pupils. The mean scores of the boys and girls in the GLT were 5.83 and 5.17 respectively. A t-test analysis of the performance of the male and female pupils showed that there was no statistically significant difference in their performance (t (149) = -1.297, p> 0.05). Thus it can be inferred that the male and female pupils did not differ much as far as their performance in the GLT is concerned.

Major Finding 4

There wasn‟t any influence on gender on the formal reasoning of pupils as far as the GLT was concerned but with the ISLT, the males did more formal reasoning as compared to their female counterparts.

4.3 Discussion of Findings

The study set out to find the nature of formal reasoning among junior high schools pupils in selected integrated science logic tasks in the Effutu Municipality. In the earlier part of this chapter, results were mainly presented and analysed based on the specific research questions with brief comments on them. In this part, however, the findings have been discussed in detail under the research questions set to guide the study.

4.3.1 Research Question 1: What thought processes do junior high school pupils in the Effutu Municipality exhibit in solving integrated science logic tasks?

It was revealed in the present study that most JHS pupils in the study operate at the concrete operational and transitional stages of thinking as evident in the major finding 1. The mean marks of 9.02, 8.28 and 11.92 attained by JHS one, two and three pupils respectively also supports the notion that pupils generally are operating below the formal level of reasoning. Going into details, it was evident that 94%, 96% and 84% of pupils in form one, two and three respectively were operating at the concrete operational level. This finding is in consonance with the study done by Lawson (1995) which surprisingly revealed that 98% of the respondents are categorized at the concrete operational stage whereas only 2% are categorized at the transitional operational stage.

The finding that few of the form three pupils could do formal reasoning in the ISLT could be attributed to the fact that, they had received more instruction in science compared to those in the junior classes. Having spent more than 2 academic years at the JHS level, the form three pupils had obviously received more instruction and thus had a stronger foundation compared to the form one and two pupils.

Previous researches conducted by Bitner (1991) and Siti (1998) amongst several other studies showed that the ability of students to reason formally has a close relation to their attainment in science. Lawson (1982) showed that students" score in „Lawson Classroom Test of Formal Reasoning" (Lawson, 1978) was correlated with their achievement in school subjects i.e. social studies, science and mathematics. This finding provides concrete evidence that formal reasoning abilities can be related to students" general performance, not only to science and mathematics.

Similarly, Roadrangka (1995) found that there is a relationship between formal operational reasoning abilities and students" achievement in biology, physics and chemistry. Students at formal operational stage scored significantly higher in biology, physics, and chemistry tests compared to those at concrete operational stage. Students at formal operational stage also found to obtain significantly higher score in physics and chemistry tests than students at the transitional operational stage.

This also shows the importance of engaging students in problem solving exercise so as to build their innate abilities. It also tells us that students who shy away from problem solving will likely be less productive when it comes to problems in science because they may have the ability but since it has not been developed (to think and reason) they lack to know how to operate in that field. This finding, however corroborate with the work of Piaget (1972) and his associates on development as a continuous process of organisation of structure, each new organisation integrating the previous solving. He also emphasises the critical role that thinking and reasoning play in development of human as a whole. This also goes further to show that before one can effectively function in his environment or field; he must have gone through a process of developing the necessary skills. This is also demonstrating in humans as growth and development occurs i.e., before a child can speak, he must babble, before he can walk, he must crawl, etc.

4.3.2 Research Question 2: What thought processes do junior high school pupils in the Effutu Municipality exhibit in solving general logic tasks?

Based on the students‟ test-scores in the GLT, it can be deduced that only 6% of the form one pupils were above the concrete operational level of reasoning, compared to 4% and 16% of form two and form three pupils respectively who were operating at either the transitional or formal operational stage of reasoning. Apparently, the extent of classroom instruction received by pupils did not have an influence on their ability to solve general logic tasks. As evident in major finding 2, the fact that 2 pupils each from form one and three could do formal reasoning as compared to only one pupil in form two meant that inevitably, other factors such as age, home background and probably the method of teaching adopted by teachers might have influenced the development of the reasoning skills of pupils rather than the academic class of pupils. However, it was observed that generally pupils‟ performance in the ISLT though not very encouraging, was comparatively better than their performance in the GLT. This observation might be due to the fact that the educational system of the nation is largely examination-orientated. Hence, less emphasis is given to the teaching and use of thinking skills. Science teaching and learning strategies are aligned to objectivism with the aim to cover the syllabus within the allotted time without "investing" too much time to nurture thinking skills among pupils.

Furthermore, school evaluation systems which only emphasise the acquisition of content knowledge contribute to low logical thinking abilities among pupils. Syed (2000) reported that the evaluation of students" science achievement does not give equal emphasis on the process and product component of scientific skills. Almost 100% of the evaluation focused on the science product component i.e. concepts, theories, and formulae. Hence, high achievers in science are students who can explain the related concepts and theories and solve routine problems by using related formulae.
Analysis of the GLT and ISLT scores showed that the form two pupils attained the least marks in both tests. This revelation is unsurprising considering the fact that previous studies have outlined the core relationship between the logical thinking abilities of students and their understanding and learning of abstract science concepts at secondary level. The ability of a pupil to operate at higher cognitive level results in him attaining better results in science tests compared to other students operating at lower levels of reasoning.

4.3.3 Research Question 3: To what extent do junior high school pupils in the Effutu Municipality apply their formal reasoning skills in solving logic tasks?
The development of students" abilities should be of great importance as it shows a high and positive significance in problem solving which also relates to the effective learning

which will return result in higher level of achievement to the individual, society and the nation at large. As evident through the analysis of interview transcripts, the level of mastery of the different modes of logical thinking in descending order are conservational reasoning, probabilistic reasoning, combinatorial reasoning, correlational reasoning, controlling variables and proportional reasoning. This finding is in contrast with a model of hierarchical relationships between Piagetian modes of cognitive reasoning and integrated science process skills as proposed by Yap (1985).

In the proposed model mentioned above, probabilistic reasoning is situated at a higher hierarchy as compared to proportional reasoning, controlling variables, combinatorial reasoning and conservational reasoning which are placed at a lower hierarchy of the model. Although, JHS pupils learn about ratios and proportions, the formation of the proportional reasoning ability among middle school and high school students appears low (Choi &Hur, 1987; Jeon, Kwon, & Lawson, 1999). When teaching science in relation to proportional reasoning, it is necessary to understand the students' level of ability to understand ratios and proportions and their proportional reasoning ability.

In relation to this, Syed (2000) reported that the logical thinking abilities of students in local higher learning institutions were low. Syed (2000) found that only 19% of matriculation college students possess high scientific reasoning abilities, 66% at medium stage whereas 15% possesses low scientific reasoning abilities. In the same study, Syed (2000) reported that only 19% of students with average age of 19 years old possess high scientific reasoning abilities compared to 22% students with average age of 16 years old (Lawson, 1995).

Going through the interview transcripts it was also evident that generally, the form three pupils gave better responses to items under most of the different domains of logical thinking compared to their counterparts in the lower forms. It was also evident through the interview sessions that majority of the pupils showed great potential in the domains of conservational reasoning, probabilistic reasoning and combinatorial reasoning. The domains of logical thinking which posed the most problems to the interviewees were correlational reasoning, controlling variables and proportional reasoning. This is evident in the responses and explanations that students provided to the questions under these two domains of reasoning.

4.3.4 Research Question 4: To what extent does gender influence the formal reasoning skills of junior high school pupils in the Effutu Municipality?

This research question was answered using the marks attained by male and female pupils in both the ISLT and GLT. T-test analysis was conducted to determine whether the scores of the male and female pupils in the GLT and ISLT differed significantly.

A major finding of the present study was the fact that the male pupils perform significantly better than the females in the ISLT. This finding was in consonance with some previous works (DeLuca, 1981; Meehan, 1984; Shemesh, 1990) which found a significant difference in logical thinking abilities between male and female students. Male students performed better in Piagetian formal reasoning tasks compared to female students.

Another key finding of this study is that there is no significant difference in the performance of male and female pupils in the GLT, although the males performed slightly better than the females. This finding was found consistent with the findings of Keig and Rubba (1993); Michael-Liau (1982), and Roadrangka (1995). As an example, Michael-Liau (1982) in his research to investigate primary school students" ability in conservation of length via three Piagetian experiments, he found that there is no significant difference in the ability of conservation of length between male and female students.

The findings of this study also revealed that up to 95.5% of female respondents and 82% of male respondents are categorized at concrete operational stage based on their performance in the ISLT. This finding was found consistent with the findings of Keig and Rubba (1993) and Roadrangka (1995) both of whom established that most generally operate at the concrete operational level regardless of gender. The research results obtained from the data analysis indicate that there is no significant relationship between the stages of cognitive development and problem task in physics. This is supported by the view of Arnett and Taber (1994). They documented that most adolescents and adults (in Western and non-Western cultures) do not exhibit reasoning skill that Piaget called formal operational thinking. The non-Universality in attainment of formal thought as measured by Piagetian task has been demonstrated by Blasi and Hoeffe (1974).

Cross-cultural studies carried out by Rogoff and Chavagary (1995) also indicates that formal operational thinking is not universal which also led to the acceptance that the formal operational stage which is required in cognitive problem solving in cultural variable. However, it can be said that since every human function at different levels of cognitive development, some above the expected level and others below, cognitive development cannot be used to determine the level of an individual problem solving-skills

CHAPTER FIVE

SUMMARY, CONCLUSION AND RECOMMENDATIONS

5.0 Overview

This chapter discusses the summary of the findings of the study and conclusions drawn from the outcome of the study. In addition, the recommendations and implications based on the findings of the study have also been discussed.

5.1 Summary of the Study

In Ghanaian basic schools, science is often learnt in the abstract and so science concepts are not properly built by pupils. This may lead to science content being often learned by rote with little understanding in Ghanaian basic schools and so pupils do not become well equipped to reason formally. The Researcher from her experience as a teacher in the Effutu Municipality has observed that pupils normally find it difficult to solve tasks which involve formal reasoning as they normally want tasks that involve the recalling of answers and not tasks that involve higher cognitive skills such as analysis, synthesis, etc.

The main purpose of this study was to investigate the nature of formal reasoning among junior high school pupils in selected integrated science logic tasks in the Effutu Municipality. The design employed in this study was the survey research design. The target population for this study was made up of all junior high school pupils in the Effutu Municipality with an accessible population of 150 pupils randomly picked from five public schools in the Municipality using the simple random sampling technique. Two main instruments were used in this study. The Researcher developed questionnaire of logic tasks in integrated science and in general knowledge as well as an interview.

The instruments were pilot tested and subsequently used to collect data from the pupils within a period of two weeks. The analysis of the data was done by making use of the research questions developed from the objectives of the study. The means, frequencies, standard deviation and percentages of the responses provided by the pupils were calculated using the descriptive function of the SPSS. Again, the inferential statistics function of the software was also used by the Researcher to draw conclusions, inferences or generalisations from the sample to the population of the study using t-test.

5.2 Summary of Major Findings of the Study

This section of the study focuses on the summary of the major findings. In this study, the Researcher sought to find out the nature of formal reasoning among some selected junior high school pupils in the Effutu Municipality in integrated science logic tasks. The findings of the study are summarised and presented as follows:

- Out of the 150 pupils used in this study, only 5 pupils each in the ISLT as well as the GLT operated at the formal operational stage with most pupils operating at the concrete and transitional operational stages.

- It was evident from the interview that the different modes of logical thinking abilities of pupils in descending order include; conservational reasoning, probabilistic reasoning, combinatorial reasoning, correlational reasoning, controlling variables and proportional reasoning. This indicates that majority of pupils showed great potential in the domains of conservational, probabilistic and combinatorial reasoning.
- It was again evident that the form three pupils gave better responses to items on the various thinking modes as compared to their lower counterparts.
- Comparing the formal reasoning of the males and the females used for the study, it was evident that there wasn"t any influence on gender as far as the GLT was concern. However, the males did more formal reasoning as compared to their female counterparts in the ISLT.

5.3 Conclusions

It was evident in the present study that most JHS pupils in the Effutu Municipality operate at the concrete operational and transitional stages of thinking with just a handful operating at the formal level of reasoning in both the GLT and the ISLT. However, it was observed that generally pupils" performance in the ISLT though not very encouraging, was comparatively better than their performance in the GLT. This observation might be due to the fact that there is less emphasis given to the teaching and use of thinking skills in the Effutu Municipality. Science teaching and learning strategies are aligned to objectivism with the aim to cover the syllabus within the allotted time without "investing" too much time to nurture thinking skills among pupils. Furthermore, school evaluation systems which only emphasis the acquisition of content knowledge contribute to low logical thinking abilities among pupils.

It was also evident through the interview sessions held with the pupils that generally, the form three pupils gave better responses to items under most of the different domains of logical thinking compared to their counterparts in the lower forms. It was again revealed through the interview sessions that majority of the pupils showed great potential in the domains of conservational reasoning, combinatorial reasoning and probabilistic reasoning. The domains of logical thinking which posed the most problems to the interviewees were correlational reasoning, proportional reasoning and controlling variables.

Results from the present study was again evident that the male pupils perform significantly better than the females in the ISLT. Again it was revealed in this study that there is no significant difference in the performance of male and female pupils in the GLT, although the males performed slightly better than the females. The findings of this study also surprisingly revealed that up to 95.5% of female respondents and 87% of male respondents are categorized at concrete operational stage based on their performance in the GLT.

5.4 Recommendations

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

- Findings from the study have shown that pupils operate at the concrete reasoning level and greater percentage of the 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 pupils. There is also the need for science teachers to use relevant and appropriate teaching aids to concretise the teaching and learning of those formal science concepts that could assist pupils in understanding them.

- Again, findings from this study have shown that majority of pupils exhibit very low level of formal reasoning ability, this means that there is the need for science teachers to determine the reasoning ability of pupils before commencing science teaching especially at the junior high school level.
- Other strategies or perhaps the use of innovative and more effective student-centred methods should be encouraged to enhance pupils‟ acquisition of correlational reasoning, controlling variables and proportional reasoning skills.
- STME clinics should be organised often in the Municipality to encourage pupils in the learning of science especially female pupils.
- This study recommends similar studies with larger samples to determine whether the trend observed in this work is typical of junior high school pupils in any of the municipalities in the central region or other regions in Ghana. Furthermore, research using similar methods should cover other levels of education. The data collected were based exclusively on junior high schools and did not include students from the senior high schools or even the tertiary institutions. Thus, further studies could include for example; the nature of formal reasoning among senior high school students in the Effutu Municipality in integrated science logic tasks or in any other area of study.

5.5 Implications of the Study

The following implications could be drawn:

- From this study, it is important for teaching and learning of integrated science in the junior high schools to be full of activities that will encourage pupils to become well equipped to solve tasks which involve logical reasoning. The pupils should be made to come to conclusions and understand concepts through their own efforts with the teacher as a "guide on the side" not as a "sage on stage".
- The pupils should also be made to seek for clarifications and help from their peers, and be made to interact with them more and more than to always rely on notes and facts from teachers. This will help to avoid the problem of "chew, pour, pass and forget" syndrome where pupils complete courses in integrated science and are still unable to solve simple tasks which involve the application of their formal reasoning skills.
- There is also the need to modify teaching and learning of integrated science at the junior high schools for improvement in the reasoning skills and performance of pupils in integrated science.

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APPENDIX A

Integrated Science Logic Tasks (ISLT) and General Logic Tasks (GLT)

Name:………………………………………………………………………Age:………

Integrated Science Logic Tasks- J.H.S.1

Read carefully the questions below and answer by ticking the correct alphabet that best describes the answer.

Task 1:

In melting a substance is converted from the solid state into liquid.

Heating a piece of candle turned into a liquid, therefore

A. The piece of candle has melted

B. The piece of candle is converted into solid

C. no conclusion can be drawn

Task 2:

One of the characteristics of a liquid is that it takes the shape of its containing vessel.

A glass of water is poured into a coke bottle, therefore

A. its shape will be flat

B. its shape will be that of the bottle

C. no conclusion can be drawn

Task 3:

All living things can perform a life process such as movement on their own.

Plants are living things, therefore

A. their branches can move on their own

B. their roots can move on their own

C. no conclusion can be drawn

Task 4:

The density of a substance is the mass per unit volume of that substance.

The mass of a piece of metal is 5g and volume $2cm^3$, therefore

A. the density will be $2.5g/cm^3$

B. the density will be $0.4g/cm^3$

C. no conclusion can be drawn

Task 5:

Unicellular organisms are made up of only one cell.

Amoeba is a one cell organism, therefore

A. amoeba is a unicellular organism

B. amoeba is a multi-cellular organism

C. no conclusion can be drawn

Task 6:

A food chain is made up of producers and consumers.

Producers are plants and consumers are animals that feed on plants and other animals, therefore

A. some animals are consumers

B. all animals are consumers

C. no conclusion can be drawn

Task 7

Lungs are important organs for respiration.

A fish swimming in a pond has no lungs, therefore

A. It does not respire

B. It does respire

C. no conclusion can be drawn

Task 8:

All animal cells have mitochondrion.

A red blood cell is an animal cell, therefore

A. a red blood cell has no mitochondrion

B. a red blood cell has mitochondrion

C. no conclusion can be drawn

Task 9:

Base quantities do not depend on other quantities for their definition.

Temperature is a base quantity, therefore

A. the unit of temperature does not depend on other quantities

B. the unit of temperature is dependent on other quantities

C. no conclusion can be drawn

Task 10:

An object which is less dense than the fluid in which it is placed will float.

Kofi puts a stone in a bowl of water and it sunk, therefore

A. the stone is denser than the water

B. the stone is less dense than the water

C. no conclusion can be drawn

Task 11:

Soil organisms are plants and animals that live in the soil.

Bacteria are organisms that can live in the soil, therefore

A. all bacteria are plants

B. all bacteria are animals

C. no conclusion can be drawn

Task 12:

After fertilisation in plants, fruits and seeds are produced.

Ovules form the seed and ovaries form the fruit, therefore

A. ovaries are found in ovules

B. ovules are found in ovaries

C. no conclusion can be drawn

Task 13:

A true fruit develops only from the ovary.

Tomato is a fruit, therefore

A. tomato develops from the ovary

B. tomato does not develops from the ovary

C. no conclusion can be drawn

Task 14:

One of the conditions necessary for germination of seeds is the presence of oxygen.

A seed put in the soil did not germinate after two weeks, therefore

A. oxygen was lacking in the soil

B. oxygen was available in the soil

C. no conclusion can be drawn

Task 15:

Amphibians are animals that live in water and on land.

Fishes live in water only, therefore

A. fishes are amphibians

B. fishes are not amphibians

C. no conclusion can be drawn

Task 16:

Plants prepare their food using the energy from the sun.

There was no sunlight for two weeks, therefore

A. all plants were lacking food

B. all plants died

C. no conclusion can be drawn

Task17:

Renewable sources of energy are sources that are replaced as they are used.

The energy from the sun is regenerated regularly, therefore

A. the sun is a renewable energy source

B. the sun is not a renewable energy source

C. no conclusion can be drawn

Task 18:

Transparent bodies allow light to pass through them and so one can see through them.

Doris saw her face in a bucket of water in her mother‟s kitchen, therefore

A. the water in the bucket is a transparent body

B.the water in the bucket is not a transparent body

C. no conclusion can be drawn

Task 19:

All aquatic organisms live in water.

Frogs can live in water, therefore

A. frogs are not aquatic organisms

B. frogs are aquatic organisms

C. no conclusion can be drawn

Task 20:

Matter is made up of particles and occupies space.

A piece of chalk is made up of particles and occupies space, therefore

A. a piece of chalk is matter

B. a piece of chalk is not matter

C. no conclusion can be drawn

General Logic Tasks

Task 1:

All nurses are sympathetic.

No sympathetic person is lazy, therefore

A. all nurses are not lazy

B. all nurses are lazy

C. no conclusion can be drawn

Task 2:

All science teachers can teach mathematics.

Miss Nkrumah is a science teacher, therefore

A. Miss Nkrumah can teach mathematics

B. Miss Nkrumah cannot teach mathematics

C. no conclusion can be drawn

Task 3:

Kofi is a bad boy.

Kwame is a boy, therefore

A. Kwame is a bad boy

B. Kwame is not a bad boy

C. no conclusion can be drawn

Task 4:

Abena has measles which is contagious disease

Esi sleeps on the same bed with Abena, therefore

A. Esi may not have measles

B. Esi has measles

C. no conclusion can be drawn

Task 5:

All my friends are intelligent.

Akosua is my friend, therefore

A. Akosua is intelligent

B. Akosua is not intelligent

C. no conclusion can be drawn

Task 6:

No hardworking person is careless.

Asiedu is hardworking, therefore

A. Asiedu isn"t careless

B. Asiedu is careless

C. no conclusion can be drawn

Task 7:

Tema is in Ghana.

Ghana is in West Africa, therefore

A. Tema is in West Africa

B. Tema is not in West Africa

C. no conclusion can be drawn

Task 8:

Rich people are never happy.

Mrs. Amissah is a rich woman, therefore

A. Mrs. Amisssah is never happy

B. Mrs. Amissah is always happy

C. no conclusion can be drawn

Task 9:

Policemen in Ghana are usually seen in black clothing.

A man is spotted wearing black clothing, therefore

A. the man is not a policeman

B. the man is a policeman

C. no conclusion can be drawn

Task 10:

Students in the sick bay do not do their homework.

Samuel did not do his homework, therefore

A. Samuel is in the sick bay

B. Samuel is not in the sick bay

C. no conclusion can be drawn

Task 11:

Fast cars are expensive.

Mary‟s car is a fast car, therefore

A. Mary‟s car is expensive

B. Mary‟s car is not expensive

C. no conclusion can be drawn

Task 12:

There is no soldier who does not use gun.

A man is found with a gun in his pocket, therefore

A. the man is a soldier

B. the man is not a soldier

C. no conclusion can be drawn

Task 13:

Fruits and vegetables are good for healthy growth.

Naomi eats fruits and vegetables every day, therefore

A. Naomi will never fall sick

B. Naomi will grow healthy

C. no conclusion can be drawn

Task 14:

Most junior high school pupils are well behaved.

Chris is a well behaved boy, therefore

A. Chris is in junior high school

B. Chris is not in junior high school

C. no conclusion can be drawn

Task 15:

All the good students of mathematics are in the school football team.

Winifred is in the school football team, therefore

A. Winifred is a good student of mathematics

B. Winifred is not a good student of mathematics

C. no conclusion can be drawn

Task 16:

Any sportsman who trains very hard is likely to win the impending race.

Kweku trains very hard, therefore

A. Kweku will win the race

B. Kweku will not win the race

C. no conclusion can be drawn

Task 17:

There is no short man who is cruel.

Mr. Asare is a short man, therefore

A. Mr. Asare is not cruel

B. Mr. Asare is a cruel

C. no conclusion can be drawn

Task 18:

One effect of teenage pregnancy is resulting in ectopic pregnancy.

The pregnant woman we saw at the hospital is a teenager, therefore

A. her pregnancy will result in ectopic pregnancy

B. her pregnancy will be normal

C. no conclusion can be drawn

Task 19:

Farmers living in the rural areas are usually poor people.

Mr. Mensah is a farmer living in the rural area, therefore

A. Mr. Mensah is a poor man

B. Mr. Mensah is not a poor man

C. no conclusion can be drawn

Task 20:

You are allowed into the cinema hall if you buy a ticket at the gate.

A man bought his ticket at the gate, therefore

A. the man is not in the cinema hall

B. the man is in the cinema hall

C. no conclusion can be drawn

APPENDIX B

Integrated Science Logic Tasks (ISLT) and General Logic Tasks (GLT) - J.H.S.2

Name:……………………………………………………………………...Age:………………

Integrated Science Logic Tasks- J.H.S.2

Read carefully the questions below and answer by ticking the correct alphabet that best describes the answer

Task 1:

A mixture is a material formed from the combination of two or more different substances.

A boy added hot water to cold water to take his bath, therefore

A. The boy formed a mixture

B. The boy did not form a mixture

C. no conclusion can be drawn

Task 2:

In diffusion, particles of a substance move from a region of higher concentration to a region of lower concentration.

The scent of a boy chewing groundnuts is smelled by other pupils in a class because

A. diffusion has taken place

B. diffusion has not taken place

C. no conclusion can be drawn

Task 3:

Work is performed when a force moves through a distance in the direction of the force.

Kezia pushed her baby brother‟s trolley to move it, therefore

A. Kezia did work

B. Kezia did not do work

C. no conclusion is drawn

Task 4:

Atoms are made up of electrons and nucleus. The nucleus is made up of protons and neutrons, therefore

A. atoms are made up of protons, neutrons and electrons

B. atoms are made up of protons and nucleus

C. no conclusion can be drawn

Task 5:

Metals are mostly solids at room temperature.

Mercury is a metal which is a liquid at room temperature, therefore

A. all metals are solids at room temperature

B. all metals are not solids at room temperature

C. no conclusion can be drawn

Task 6:

An alloy is the mixture of two or more metals or a metal and non-metal.

Brass is made up of copper and zinc, therefore

A. brass is an alloy

B. brass is not an alloy

C. no conclusion can be drawn

Task 7:

Heredity is the passage of characteristics from parents to their offspring.

Kofi looks exactly like his father, because

A. all his father"s characteristics have been passed on to him

B. not all his father"s characteristics have been passed on to him

C. no conclusion can be drawn

Task 8:

A chemical change occurs with an alteration in the chemical composition of a substance.

A piece of paper was burnt into ashes, therefore

A. the paper has undergone a chemical change

B. the paper has undergone no chemical change

C. no conclusion can be drawn

Task 9:

Plants prepare their food using the energy from the sun.

There was no sunlight for two weeks, therefore

A. all plants were lacking food

B. all plants died

C. no conclusion can be drawn

Task 10:

Soil organisms are plants and animals that live in the soil.

Bacteria are organisms that can live in the soil, therefore

A. all bacteria are plants

B. all bacteria are animals

C. no conclusion can be drawn

Task 11:

Animal cells have mitochondrion.

A red blood cell is an animal cell, therefore

A. a red blood cell has no mitochondrion

B. a red blood cell has mitochondrion

C. no conclusion can be drawn

Task 12:

Soft water lathers easily with soap.

The girl used more soap in washing the plates, therefore

A. the water she used is soft

B. the water she used is not soft

C. no conclusion can be drawn

Task 13:

Ammonia is a compound made up of only nitrogen and hydrogen.

The gas in this jar is made up of only nitrogen and hydrogen, therefore

A. the gas is ammonia

B. the gas is ammonium

C. no conclusion can be drawn

Task 14:

All organisms are living things.

The specimen labeled Z is an organism, therefore

A. it is a plant

B. it is an animal

C. no conclusion can be drawn

Task 15

Metals generally expand when heated.

The effect of heat on metals, therefore is to

A. increase the volume

B. decrease the volume

C. no conclusion can be drawn

Task 16:

Unicellular organisms are made up of only one cell.

Amoeba is a one cell organism, therefore

A. amoeba is a unicellular organism

B. amoeba is not a unicellular organism

C. no conclusion can be drawn

Task 17:

1m is equivalent to 100cm

1000cm is equivalent to 1km, therefore 5m

A. is equivalent to 500m

B. is equivalent to 500cm

C. no conclusion can be drawn

Task 18:

Annual crops complete their life cycle in one season.

Rice is a crop which grows and matures for harvesting within a year, therefore

A. rice is an annual crop

B. rice is not an annual crop

C. no conclusion can be drawn

Task 19:

All aquatic organisms live in water.

Frogs can live in water, therefore

A. frogs are not aquatic organisms

B. frogs are aquatic organisms

C. no conclusion can be drawn

Task 20:

Regular exercising of the body can help prevent heart diseases in humans.

Mr. Mensah goes to the gym every Saturday to exercise his body, therefore

A. Mr. Mensah cannot suffer from a heart disease

B. Mr. Mensah can suffer from a heart disease

C. no conclusion can be drawn

General Logic Tasks

Task 1:

All bullies are strong people.

The boy is a strong person, therefore

A. the boy is a bully

B. the boy is not a bully

C. no conclusion can be drawn

Task 2:

People from the Northern region of Ghana are mostly tall.

Agnes comes from the Northern region of Ghana, therefore

A. Agnes is tall

B. Agnes is not tall

C. no conclusion can be drawn

Task 3:

Children at the concrete operational stage are expected to be able to reason formally.

Ama is in the concrete operational stage, therefore

A. Ama can reason formally

B. Ama cannot reason formally

C. no conclusion can be drawn

Task 4:

Yesterday the weather was cold and it rained.

Today the weather is sunny, therefore

A. It will not rain today

B. It will rain today

C. no conclusion can be drawn

Task 5:

Mary goes shopping every day.

Today is Saturday, therefore

A. Mary will not go shopping

B. Mary will go shopping

C.no conclusion can be drawn

Task 6:

The old woman living behind our school is a witch.

Janet also lives behind our school, therefore

A. Janet is not a witch

B. Janet is a witch

C. no conclusion can be drawn

Task 7:

Most public school pupils find it difficult to communicate using the English language.

Esi communicates fluently using the English language, therefore

A. Esi attends a private school.

B. Esi attends a public school

C. no conclusion can be drawn

Task 8:

People who work at the bank are normally seen in suit.

The woman is wearing suit, therefore

A. the woman works at the bank

B. the woman does not work at the bank

C. no conclusion can be drawn

Task 9:

Children are fond of eating sweets.

All the girls in Mr. Boamah"s class are fond of eating toffees, therefore

A. all the girls in Mr. Boamah"s class are children

B. all the girls in Mr. Boamah"s class are not children

C. no conclusion can be drawn

Task 10:

Sandra is the girl"s prefect of St. John"s Anglican Junior High School.

Mavis is a friend of Sandra, therefore

A. Mavis will become the next girl"s prefect

B. Mavis will not become the next girl"s perfect

C. no conclusion can be drawn

Task 11:

All Catholics are Christians.

Emy is a Catholic, therefore

A. Emy is a Christian

B. Emy is not a Christian

C. no conclusion can be drawn

Task 12:

The people of Winneba celebrate the Aboakyer festival.

Kwamena is from Winneba, therefore

A. Kwamena celebrates the Aboakyer festival

B. Kwamena does not celebrates the Aboakyer festival

C. no conclusion can be drawn

Task 13:

Pupils who do well in school also have beautiful handwriting.

Akosua has a beautiful handwriting, therefore

A. Akosua does well in school

B. Akosua does not do well in class

C. no conclusion can be drawn

Task 14:

Omo is a detergent which is used for washing.

Sunlight soap is also a detergent, therefore

A. Sunlight soap is used for washing

B. Sunlight soap is not used for washing

C. no conclusion can be drawn

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All dwarfs like banana.

Monkeys also like banana, therefore

A. monkeys and dwarfs are organisms from the same family

B. monkeys and dwarfs are organisms from different families

C. no conclusion can be drawn

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Kofi is a stubborn boy.

Ama is a sister to Kofi, therefore

A. Ama is a stubborn girl

B. Ama is not a stubborn girl

C. no conclusion can be drawn

Task 17:

Beauty they say lies in the eyes of the beholder.

Kate said her mum is beautiful, therefore

A. everybody will see Kate‟s mum to be beautiful

B. not everybody will see Kate‟s mum to be beautiful

C. no conclusion can be drawn

Task 18:

The use of mobile phones in Ghana today is a common practice.

Dorcas uses mobile phone in school, therefore

A. all school children use mobile phones

B. not all school children use mobile phones

C. no conclusion can be drawn

Task 19:

Fufu is a food enjoyed by all Ghanaians.

Ekua‟s family eat fufu twice in a week, therefore

A. all families in Ghana eat fufu twice a week

B. all families in Ghana eat fufu trice a week

C. no conclusion can be drawn

Task 20:

All the good students of mathematics are in the school football team.

Winifred is in the school football team, therefore

A. Winifred is a good student of mathematics

B. Winifred is not a good student of mathematics

C. no conclusion can be drawn

APPENDIX C

Integrated Science Logic Tasks (ISLT) and General Logic Tasks (GLT) - J.H.S.3

Name:……………………………………………………………………...Age:………………

Integrated Science Logic Tasks- J.H.S.3

Read carefully the questions below and answer by ticking the correct alphabet that best describes the answer

Task 1:

A mixture is a material formed from the combination of two or more different substances.

A boy added hot water to cold water to take his bath, therefore

A. The boy formed a mixture

B. The boy did not form a mixture

C. no conclusion can be drawn

Task 2:

In diffusion, particles of a substance move from a region of higher concentration to a region of lower concentration.

The scent of a boy chewing groundnuts is smelled by other pupils in a class because

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Kezia pushed her baby brother"s trolley to move it, therefore

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C. no conclusion is drawn

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Atoms are made up of electrons and nucleus. The nucleus is made up of protons and neutrons, therefore

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Brass is made up of copper and zinc, therefore

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Winifred is in the school football team, therefore

A. Winifred is a good student of mathematics

B. Winifred is not a good student of mathematics

C. no conclusion can be drawn

APPENDIX D

Interview Protocol on the extent to which pupils apply their formal reasoning skills in solving logic tasks

Interview Item 1(Conservational reasoning)

Kofi has two balls of clay. They are of the same size and shape.

When he weighed them, their weights were the same. The balls of clay are removed from the weighing scale. Clay 2 is flattened like a pancake. Would the two balls still weigh the same or not.

A) The pancake-shaped clay weighs more.

B) The two pieces weigh the same.

C) The ball weighs more.

The following reasons were provided by pupils as to why they chose particular answers:

1. The flattened clay has more length so it will weigh more.
2. Since Kofi did not add or remove any clay from the original, the clay was expected to still weigh the same.
3. Clay 2 was flattened like a pancake, it had a greater area.
4. When something is flattened, it loses weight.
5. Because of its density, the round ball had more clay in it.

Interview Item 2(Proportional Reasoning)

There are two plastic cups, one is bigger than the other. Each has equally spaced marks along the side. Abena pours the same amount of water into each jar. The water level comes up to the 4th mark in the wide jar and to the 6th mark in the narrow jar. She pours a larger glass of water into the wide jar. The water level comes up to the 6th mark.

How high would the same amount of water come if it were poured into the narrow jar?

A) 6

B) 8

C) 9

The following reasons were provided by pupils as to why they chose particular answers:

1. The water level in the smaller cup will be very high.
2. If you pour the same amount of water in the bigger and smaller cups, the ratio will always be 2 to 3.
3. If the water level is 6 in the bigger cup, it will be two more in the smaller cup.
4. If the water level is 6 in the bigger cup, it will be more than 6 in the smaller cup.
5. There is no way of predicting.

Interview Item 3 (Controlling variables)

Three strings are hanged from a bar. String 1 and 3 are of equal length. String 2 is longer. Ama attaches a 5g weight at the end of string 1, 2 and 3. Each string with a weight can be swung.

Ama wants to find out if the length of the string has an effect on the amount of time it takes the string to swing back and forth. Which string would she use for her experiment?

A) strings 1 and 2

B) string 2 only

C) strings 1, 2 and 3

The following reasons were provided by pupils as to why they chose particular answers:

1. Different lengths with different weights should be tested.
2. All strings and their weights should be tested.
3. Only the longest string should be tested. The experiment is concerned with length not weight.
4. The length of the strings should be the same with the same weights.
5. Everything needs to be the same except the length so you can tell if length makes a difference.

Interview Item 4 (Probabilistic Reasoning)

In a cloth sack, there are 3 red balls, 2 black balls, 5 white balls, 4 yellow balls and 6 green balls. All of the balls are of the same size and shape. One ball is pulled out of the sack.

What are the chances that it is a white ball?

A) 1 out of 3

B) 1 out of 4

C) 1 out of 20

The following reasons were provided by pupils as to why they chose particular answers:

1. There are twenty balls in the cloth sack.
2. One white ball must be chosen from the twenty.
3. One white ball needs to be selected from a total of 5 white balls.
4. Five of the 20 balls are white in colour.
5. One white ball can be selected from the twenty balls.

Interview Item 5 (Correlational Reasoning)

A teacher decided to conduct a test to find out the level of performance of 10 male and10 female students in science. He observed that three male students scored the lowest marks and a girl had the highest mark. This made him wonder if there might be a relation between the gender of students and their scores. So he analysed the entire result of all 20 students. Their marks are as summarised in the table below:

Marks	**Frequency of boys**	**Frequency of girls**
0	1	0
1	0	0
2	2	4
3	5	5
4	2	0
5	0	1
Mean	3.1	3.3

Do you think there is a relation between the gender of students and the marks they had?

A) Yes

B) No

The following reasons were provided by pupils as to why they chose particular answers:

1. Since a girl had the highest mark, girls perform better than boys.
2. A boy had the least mark so boys are worse than girls.
3. Both boys and girls did well.

4. Their average marks were close, meaning there isn't much difference in the performance of boys and girls in the test.
5. Girls did better than the boys since their mean mark was higher.

Interview Item 6 (Combinatorial Reasoning)

In a new shopping centre, 4 stores are going to be placed on the ground floor. A barber shop (B), a drug store (D), a grocery store (G), and a cloth 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 drug store next, followed by the grocery store and then the cloth shop. List the other possible ways that the stores can be lined up in the four locations.

A. DGCB, GCBD, CBDG
B. DGCB, GCBD, CGDB
C. DGCB, GCBD, GDBC

The following reasons were provided by pupils as to why they chose particular answers:

1. The stores could be arranged in any manner.
2. The stores should be arranged in a sequential manner.
3. Any of the stores could be started with in the arrangement.
4. The stores could be arranged in any manner so far as they are four.
5. The last store could be started with in the arrangement.

APPENDIX E

RELIABILITY COEFFICIENT FOR ISLT-FORM ONE

Case Processing Summary

		N	%
Cases	Valid	10	100.0
	Excluded[a]	0	.0
	Total	10	100.0

a. Listwise deletion based on all variables in the procedure.

Reliability Statistics

Cronbach's Alpha	N of Items
.750	20

Item-Total Statistics

	Scale Mean if Item Deleted	Scale Variance if Item Deleted	Corrected Item-Total Correlation	Cronbach's Alpha if Item Deleted
Item one	29.80	33.956	.443	.870

Item two	30.70	38.900	.265	.847
Item three	30.50	29.389	.778	.834
Item four	30.20	37.733	.122	.868
Item five	30.50	29.389	.778	.780
Item six	29.70	33.122	.806	.812
Item seven	30.50	36.278	.107	.880
Item eight	30.70	34.011	.380	.784
Item nine	30.40	30.044	.692	.862
Item ten	30.50	32.500	.530	.841
Item eleven	30.80	34.844	.607	.791
Item twelve	30.10	29.878	.778	.783
Item thirteen	30.10	31.878	.433	.873
Item fourteen	30.70	36.011	.202	.882
Item fifteen	30.80	35.511	.425	.795
Item sixteen	30.40	34.489	.200	.823
Item seventeen	30.10	34.322	.190	.901
Item eighteen	29.80	34.844	.607	.817
Item nineteen	29.20	35.511	.155	.867
Item twenty	30.60	36.711	.005	.857

APPENDIX F

RELIABILITY COEFFICIENT FOR GLT-FORM ONE

Case Processing Summary

		N	%
Cases	Valid	10	100.0
	Excluded[a]	0	.0
	Total	10	100.0

a. Listwise deletion based on all variables in the procedure.

Reliability Statistics

Cronbach's Alpha	N of Items
.780	20

Item-Total Statistics

	Scale Mean if Item Deleted	Scale Variance if Item Deleted	Corrected Item-Total Correlation	Cronbach's Alpha if Item Deleted
Item one	32.50	38.056	.129	.796
Item two	32.00	42.889	.805	.877
Item three	32.30	30.233	.799	.791

Item four	32.00	38.000	.399	.822
Item five	32.70	41.789	.310	.842
Item six	32.60	34.933	.535	.856
Item seven	32.20	37.289	.232	.819
Item eight	32.10	34.100	.698	.778
Item nine	32.10	42.322	.518	.789
Item ten	32.90	39.656	.000	.809
Item eleven	32.10	30.767	.789	.827
Item twelve	31.90	35.878	.630	.840
Item thirteen	32.10	33.878	.561	.801
Item fourteen	31.60	34.933	.416	.833
Item fifteen	31.80	36.178	.462	.840
Item sixteen	32.70	37.567	.370	.828
Item seventeen	31.70	36.900	.503	.851
Item eighteen	32.50	31.833	.747	.773
Item nineteen	32.30	30.233	.799	.760
Item twenty	32.00	34.889	.663	.875

APPENDIX G

RELIABILITY COEFFICIENT FOR ISLT- FORM TWO

Case Processing Summary

		N	
Cases	Valid	10	100.0
	Excluded[a]	0	.0
	Total	10	100.0

a. Listwise deletion based on all variables in the procedure.

Reliability Statistics

Cronbach's Alpha	Cronbach's Alpha Based on Standardized Items	N of Items
.860	.863	20

Item-Total Statistics

	Scale Mean if Item Deleted	Scale Variance if Item Deleted	Corrected Item-Total Correlation		Cronbach's Alpha if Item Deleted
Item one	32.90	61.656	.203	.	.875
Item two	32.50	56.944	.188	.	.865

Item three	32.40	61.156	.148	.	.877
Item four	32.80	54.622	.371	.	.857
Item five	32.40	50.044	.697	.	.842
Item six	32.90	53.878	.567	.	.849
Item seven	32.90	52.989	.663	.	.846
Item eight	32.60	53.822	.438	.	.854
Item nine	32.30	51.344	.763	.	.841
Item ten	31.70	54.678	.641	.	.849
Item eleven	32.30	55.122	.535	.	.852
Item twelve	32.40	54.933	.493	.	.852
Item thirteen	32.40	47.600	.792	.	.836
Item fourteen	32.10	51.878	.580	.	.848
Item fifteen	32.90	56.322	.314	.	.858
Item sixteen	32.90	53.433	.615	.	.848
Item seventeen	32.10	52.544	.642	.	.846
Item eighteen	32.80	54.844	.446	.	.854
Item nineteen	32.10	53.433	.747	.	.845
Item twenty	32.40	58.933	.064	.	.866

APPENDIX H

RELIABILITY COEFFICIENT FOR GLT-FORM TWO

Case Processing Summary

		N	%
Cases	Valid	10	100.0
	Excluded[a]	0	.0
	Total	10	100.0

a. Listwise deletion based on all variables in the procedure.

Reliability Statistics

Cronbach's Alpha	N of Items
.916	20

Item Statistics

	Mean	Std. Deviation	N
Item one	1.20	.632	10
Item two	1.50	.850	10
Item three	1.30	.675	10
Item four	1.30	.675	10
Item five	1.60	.699	10

Item six	1.80	.919	10
Item seven	1.40	.843	10
Item eight	1.40	.843	10
Item nine	1.30	.483	10
Item ten	1.60	.966	10
Item eleven	1.40	.699	10
Item twelve	1.00	.000	10
Item thirteen	1.50	.850	10
Item fourteen	1.00	.000	10
Item fifteen	1.50	.850	10
Item sixteen	1.80	.919	10
Item seventeen	1.30	.675	10
Item eighteen	1.80	.422	10
Item nineteen	1.90	.994	10
Item twenty	1.30	.675	10

APPENDIX I

RELIABILITY COEFFICIENT FOR ISLT-FORM THREE

Case Processing Summary

		N	%
Cases	Valid	10	100.0
	Excluded[a]	0	.0
	Total	10	100.0

a. Listwise deletion based on all variables in the procedure.

Reliability Statistics

Cronbach's Alpha	N of Items
.826	20

Item-Total Statistics

	Scale Mean if Item Deleted	Scale Variance if Item Deleted	Corrected Item-Total Correlation	Cronbach's Alpha if Item Deleted
Item one	29.80	33.956	.443	.770
Item two	30.70	38.900	.265	.808

Item three	30.50	29.389	.778	.739
Item four	30.20	37.733	.122	.814
Item five	30.50	29.389	.778	.739
Item six	29.70	33.122	.806	.758
Item seven	30.50	36.278	.107	.786
Item eight	30.70	34.011	.380	.772
Item nine	30.40	30.044	.692	.746
Item ten	30.50	32.500	.530	.762
Item eleven	30.80	34.844	.607	.770
Item twelve	30.10	29.878	.778	.741
Item thirteen	30.10	31.878	.433	.768
Item fourteen	30.70	36.011	.202	.782
Item fifteen	30.80	35.511	.425	.775
Item sixteen	30.40	34.489	.200	.786
Item seventeen	30.10	34.322	.190	.789
Item eighteen	29.80	34.844	.607	.770
Item nineteen	29.20	35.511	.155	.786
Item twenty	30.60	36.711	.005	.795

APPENDIX J

RELIABILITY COEFFICIENT FOR GLT-FORM THREE

Case Processing Summary

		N	
Cases	Valid	10	100.0
	Excluded[a]	0	.0
	Total	10	100.0

a. Listwise deletion based on all variables in the procedure.

Reliability Statistics

Cronbach's Alpha	N of Items
.783	20

Item-Total Statistics

	Scale Mean if Item Deleted	Scale Variance if Item Deleted	Corrected Item-Total Correlation	Cronbach's Alpha if Item Deleted
Item one	32.50	38.056	.129	.833
Item two	32.00	42.889	.805	.848
Item three	32.30	30.233	.799	.791

Item four	32.00	38.000	.399	.822
Item five	32.70	41.789	.310	.850
Item six	32.60	34.933	.535	.812
Item seven	32.20	37.289	.232	.827
Item eight	32.10	34.100	.698	.804
Item nine	32.10	42.322	.518	.847
Item ten	32.90	39.656	.000	.829
Item eleven	32.10	30.767	.789	.792
Item twelve	31.90	35.878	.630	.811
Item thirteen	32.10	33.878	.561	.809
Item fourteen	31.60	34.933	.416	.819
Item fifteen	31.80	36.178	.462	.816
Item sixteen	32.70	37.567	.370	.821
Item seventeen	31.70	36.900	.503	.817
Item eighteen	32.50	31.833	.747	.797
Item nineteen	32.30	30.233	.799	.791
Item twenty	32.00	34.889	.663	.807