UNIVERSITY OF EDUCATION, WINNEBA

USING VISUO-SPATIAL MODELS TO IMPROVE STUDENTS' PERFORMANCE IN MOLECULAR AND HYBRIDIZATION GEOMETRIES.

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A thesis in the Department of SCIENCE EDUCATION, Faculty of SCIENCE EDUCATION, submitted to the School of Research and Graduate Studies in the University of Education, Winneba, in partial fulfilment of the requirements for the award of A Master of Philosophy Degree in Science Education.

SEPTEMBER, 2015

DECLARATION

Student's Declaration

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

…………………………… ……………………

LAWRENCE SARPONG **DATE**

Supervisors' Declaration

I hereby declare that the preparation and presentation of this work was supervised in accordance with the guidelines for supervision of thesis as laid down by the University of Education, Winneba.

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OPERATIONAL DEFINITIONS

Alternative Conception: Alternative Conception is a conceptual framework consisting cognitive functioning to reason, describe, explain, or predict phenomena. Most of the mental models that will be discussed in this study are conceptual mental models such as water molecule and compounds in alkane, alkene and alkyne. Concepts may be used. context, for example, octet framework.

Declarative knowledge: It consists of the specific facts and concepts associated formula) in a person's mind. Identify, locate, and think about objects or representations, and form, inspect,

Low-scoring students : Students who score less than 50% of the administered

Mental models : Mental models are physically or conceptually intrinsic

Mental representations **:** Mental representation describes image-like information

Molecular Geometry (ies): Molecular geometry is the three-dimensional arrangement

Molecular Shapes : The three dimensional shape or configuration of a molecule. It is of bonding atom. It determines several properties of a substance including its reactivity, polarity, phase of matter, colour, magnetism, and biological activity of many sub-concepts that students apply to the framework in an inappropriate of the atoms that constitute a molecule and it is associated with the specific orientation.

Procedural knowledge: It consists of knowing how, when, and why the facts and questions. This group represent students who will encounter difficulties that will lead recall, and retention of mental models and allows an individual to manipulate (e.g., Representations of objects, ideas, or processes which individuals generate during rotate, reflect, or inverse) his/her mental model(s) to solve a problem. Stimulus is absent. Visual-spatial thinking is closely associated with construction, such as ball-and-stick or space-filling models, Lewis dot structure, or chemical to their failure in responding to the diagnostic items correctly. Transform, and maintain an image in the "mind's eye" when the original visual used interchangeably with Molecular Geometry.

Visualization: It is the spatial (physical and meta-cognitive) skills that one needs to

Visual-spatial thinking: Visual-spatial thinking involves one using his/her eyes to with a discipline work with, and to link the external and internal representations.

LIST OF ACRONYMS AND SYMBOLS

<ABC	:	Angle B of Triangle ABC
<BCD	:	Angle C of Triangle BCD
rAB	:	Atomic distance AB
rBC	:	Atomic distance BC
rCD	:	Atomic distance CD
CH_4	:	Methane Molecule
C-H	:	A single bond between Carbon and Hydrogen
CH_3Cl	:	Methylchloride
CH_2Cl_2	:	Methylene Cloride
$CHCl_3$	:	Trichloromethane
CCl_4	:	Tetrachloromethane
C_2H_2	:	Ethyne (Acetylene)
Df	:	Degree of Freedom
JOSCO	:	St. Joseph College of Education
OSSA	:	Odorgonno Senior High School
SPSS	:	Statistical Package for Social Science Students
VSM	:	Visuo-Spatial Models

ABSTRACT

The study determined the impact of using Visuo-Spatial Models (VSM) in teaching Molecular Geometry and Hybridization Geometry with associate Bond angles on College student's performance at St. Joseph College of Education, Bechem. In the study, two cohorts labelled as experimental and control groups were used. The experimental group received instructions using the visuo-spatial approach of teaching. The control group on the other hand, was taught using the conventional approach of teaching. A pre-interventional test was used to determine whether the two cohorts had similar conceptual understanding before applying the interventions. The same mean score of 22.63 was obtained for the two groups with a slight difference in their standard deviations; 10.34 for the control group and 10.32 for the experimental group. After applying the interventions on the two groups, post-interventional test was conducted for each of the groups. The calculated mean score values for post-interventional test for the two groups; the experimental group and the control group were 77.55 and 36.92 respectively. Major findings are as follows: (a) Some of the teaching approaches widely used by tutors who were teaching molecular and hybridization geometries include: lecture method only, reading from pamphlets and giving explanations and others (b) conventional teaching approach makes concepts difficult for students to comprehend (c) Students face difficulties to comprehend molecular and hybridisation geometries when presented to them in theoretical manner. (d) visuo-spatial model enhances student's academic performance and argumentative skills far better than the conventional teaching approach. The research revealed that when students are taught through manipulations of VSM, it builds their visuo-spatial thinking (thinking through imaginations), develops their creative thinking skills, creates competition in learning among students, develops speaking and presentation skills of students, enhances their argumentative skills of students, and also prepares them to become tolerant towards others' views.

CHAPTER ONE

INTRODUCTION

Overview

This chapter deals with the introduction to the study which comprises the background to the study, statement of the problem, purpose of the study, the objectives of the study as well as the research questions that guided the study and the hypotheses that were formulated and tested in the study. The chapter also deals with the significance of the study, delimitations of the study, limitations of the study, operational definition of terms and the organisation of chapters.

Background to the Study

Several and detailed researches have been conducted to find out why chemistry concepts are difficult for students to understand. Some of the findings of such research works noted several factors that account for students' difficulty in understanding chemistry concepts as: learning impediments due to incorrect explanations to three dimensional learning, missing or fragmented content knowledge (Taber, 2001); learners' limited mental working space (Johnstone, 1991), a low visuo-spatial thinking ability (Wu, 2004), insufficient understanding for the role of models (Taber, 2002), and students' common sense reasoning (Talanquer, 2011).

Johnstone (1993) has pointed out that a new approach for learning and teaching chemistry needs to include macro-chemistry, where chemistry is experienced with senses as touchable and visible; sub-microchemistry, which explains macro-phenomena at the atomic and molecular level base on kinetic perspective, and finally representational chemistry which includes symbols, equations, stoichiometry, and mathematics. Even though chemistry experts are able to slide from one domain to another easily, students often encounter difficulties when shifting from one domain to another. Literature about how students shift and make transitions within Johnstone's triangle is limited and extensively focused on the transition from macroscopic to sub-microscopic levels. Research on transitions between sub-microscopic-symbolic and symbolic-macroscopic is nearly overlooked by Chemistry educators who are always trying to appeal to students to imagine abstract concepts (Justi & Gilbert, 2002).

To address instructional concerns for teachers and the problems associated with students' learning, researchers in science education have offered numerous research-based findings that offer new and varied perspectives to assist in changing chemistry instruction. For instance, developing curriculum that reflects the historical development, arguments, and thinking in chemistry concerning Molecular Geometry is one aspect and is considered to be an approach that can facilitate students' understanding of chemistry as a way of thinking over time (Niaz, Agulera, Maza & Liendo, 2002). According to Justi and Gilbert (2002), a complementary view comes from other researchers who suggest that models and understanding modelling can provide essential perspectives on the conceptual development of chemistry as well as the scope and limitations for all models. Justi and Gilbert (2002) advocate that students have opportunities to develop and test their own models. Similar research study revealed students' conceptions of the bond angles and their difficulties in understanding isotopes and allotropes (Schmidt, Baumgartner, & Eybe, 2003).

According to Kozma and Russell (2005), the studies by Justi and Gilbert have brought new dimension (visualization and visuospatial) as another way for learning chemistry which is symbolic transformations applied to graphic objects.

The current challenges for research and development in chemistry that Justi and

Gilbert (2002) advocate are the issues regarding how teachers and teacher education needs would be addressed including how teachers can effectively introduce modelling in instruction such that students really understand the nature of chemistry from a critical perspective. Clearly, these researchers and others are concerned with the current status of chemistry instruction and their perspective is that the practice of teaching be guided by symbolic presentations.

Similarly, as an experience chemistry teacher I can have come to realised that understanding molecular hybridization, molecular geometries and the associated bond angles are critical for learners of chemistry because these topics serve as the foundation for effectively understanding of organic chemistry.

It is therefore not surprising that these topics are characteristically found in the early sessions of the chemistry syllabus for colleges of education in Ghana. It can therefore be surmised that the problem for students then is, if they do not develop a firm foundation early during instruction on bond angles and geometries, studying organic chemistry can become an illusion, hence muddle of discouragement.

Meanwhile, studies conducted by Ameyaw and Sarpong (2011) affirmed that, in the 21st Century Learning, it is necessary to allow learners to get wider scope of opportunity to explore their learning environment and make decisions on their own instead of being information receivers.

It is upon this revelation that this study was conducted to investigate problems associated with teaching and learning of molecular hybridization, molecular geometries and the associated bond angles. It is also to find out if using visuo-spatial models (videos and VAST-models) can enhance instruction and learning of molecular geometries and molecular hybridization with associated the bond angles in colleges of educations in Ghana.

Statement of the Problem

Many students are not able to recognise chemistry in their everyday lives (Essumang & Bentum, 2012). These students therefore perceive chemistry to be a challenging and difficult subject which should be for a certain group of students especially those with high intelligent quotient (HIQ). As a result of this perception, students fail to recognise the value of chemistry in their future careers; even for those students who are majoring in a science and technology. For instance, many research studies have revealed that students have alternative conceptions concerning Molecular Hybridization, Molecular Geometries and associated Bond Angles (Harrison & Treagust, 2000), have misconceptions about atomic orbitals (Nakigoglu, 2003), have alternative conceptions about metals (Taber, 2002), and have even failed to distinguish between substances and atoms (Ahtee & Varjola, 1998).

Similarly, my interaction with science students of St. Joseph's College of Education (JOSCO) and Odorgonno Senior High School (OSSA), where I taught as a chemistry teacher, suggested that students have misinformation about Bond Angles and molecular geometries as well as molecular hybridization. As a result of the misinformation, students find it difficult to distinguish between molecular geometries and hybridization geometries. Many of them (students) perceive the two to be synonymous.

These misunderstandings are believed to adversely affect students' performance in external examinations regulated by the West African Examination Council (WAEC) as in the case of Odorgonno Senior High School. This is of no exception to level 200 college students' performance during their End of Semester two (2) examination regulated by Institute of Education, University of Cape Coast, where Molecular Geometries and Bond Angles are featured.

Most of the Science Colleges of Education offer technical drawing and skills as well as Mathematics that exposed students to construction of angles and identification of solid shapes and three dimensional drawings. However there is no study on the use of three dimensional drawings and construction of angles in enhancing students' understanding (performance) in Molecular Geometries and Bond Angles. As a result, the effect of visuo-spatial models on student's performance in molecular geometries and molecular hybridization with associate bond angles at St. Joseph's College of Education (JOSCO) became necessary for this study.

Purpose of the Study

The study investigated whether the use of visuo-spatial models (VSM) could improve college students' performance in molecular and hybridization geometry.

Objectives of the Study

The objectives of the study were to:

i. determine the challenges student-teachers face during their studies on molecular and hybridization geometries with associate bond angles.

ii. investigate the teaching approaches used in teaching these topics by the chemistry teachers who have taught chemistry for past four years in JOSCO.

iii. Determine the weaknesses associated with those approaches used by JOSCO chemistry teachers.

iv. assess how VSM affects science students' performance in molecular and hybridization geometries with associated bond angles at St. Joseph's College of Education.

Research Questions

The study focused on the following research questions:

1. What are the challenges faced by the Science Students of St. Joseph's College during their studies of molecular geometries and molecular hybridization with associated bond angles?
2. What approaches do chemistry teachers of the college use during lessons in molecular geometries and molecular hybridization with associated bond angles?
3. What are the weaknesses of the approaches used by the chemistry teachers in facilitating science students' performance in molecular geometries and molecular hybridization with associate bond angles?
4. What effect do visuo-spatial models have on students' performance in molecular geometries, Molecular Hybridization and associated bond angles?

Hypotheses

The following null hypotheses were tested in the study:

H_{01}: There are no challenges faced by the Science Students of St. Joseph's College of Education during their studies in Molecular Geometries, Molecular Hybridization and associate Bond Angles.

H_{02}: Visuo-spatial models have no significant effect on students' performance in molecular and hybridization geometries with associate bond angles.

Significance of the Study

The results of the study can improve student-teachers' content knowledge and performance in Molecular Geometries, Bond Angles and other related topics in organic chemistry. It can also motivate science students to appreciate chemistry, how it is related to nature, since everything has to do with bonding. The study would provide chemistry teachers with better and alternative approaches to handle Molecular Geometries and Molecular Hybridizations as well as their associated Bond Angles. Finally, the study would serve as additional document to the new dimension of teaching chemistry (Visualization and Visuo-Spatial approaches) as pointed out by Justi and Golbert (2002).

Delimitation of the Study

The study subjects were only Science Students of St. Joseph's College of Education and the selection was based on closeness and accessibility of these students to the researcher. It was also focused on only molecular and hybridization geometries with associate bond angles (which are aspects of organic chemistry in Science curriculum). The selection of the target participants and the choice of selecting only one aspect of topics under organic chemistry was to enable the researcher to break barriers of economic and geographical constraints that were likely to adversely influence the accessibility of large number of subjects within the shorter time frame.

Limitations of the Study

Since questionnaires and interviews played major role in the study, false information given by respondents was likely to affect the reliability of the results. The population was limited to only students in St. Joseph's College of Education (JOSCO) for easy handling of the data and cross-examination of given information.

It was also assumed that students of JOSCO had similar characteristics with students in other Colleges of Education since run both Science and General courses. This made it possible to generalize the findings of the study within the context of the targeted population.

Again, not all molecular shapes were used in the study during the teaching and learning process. It was assumed that those molecules used in the study could provide good basis for reliable generalization of findings.

CHAPTER TWO

LITERATURE REVIEW

Overview

The topical issues reviewed in the literature include the theoretical and conceptual framework of the study, which discusses among others the Johnstones Triangle upon which the study was hinged. It also reviewed literature on challenges associated with teaching and learning of hybridization and molecular geometries with associate bond angles.

Theoretical Framework

The theoretical framework that underpinned this study is conceptual change which hinged on Johnstone's triangle that was modified by the researcher to facilitate the study as illustrated in Figure1.

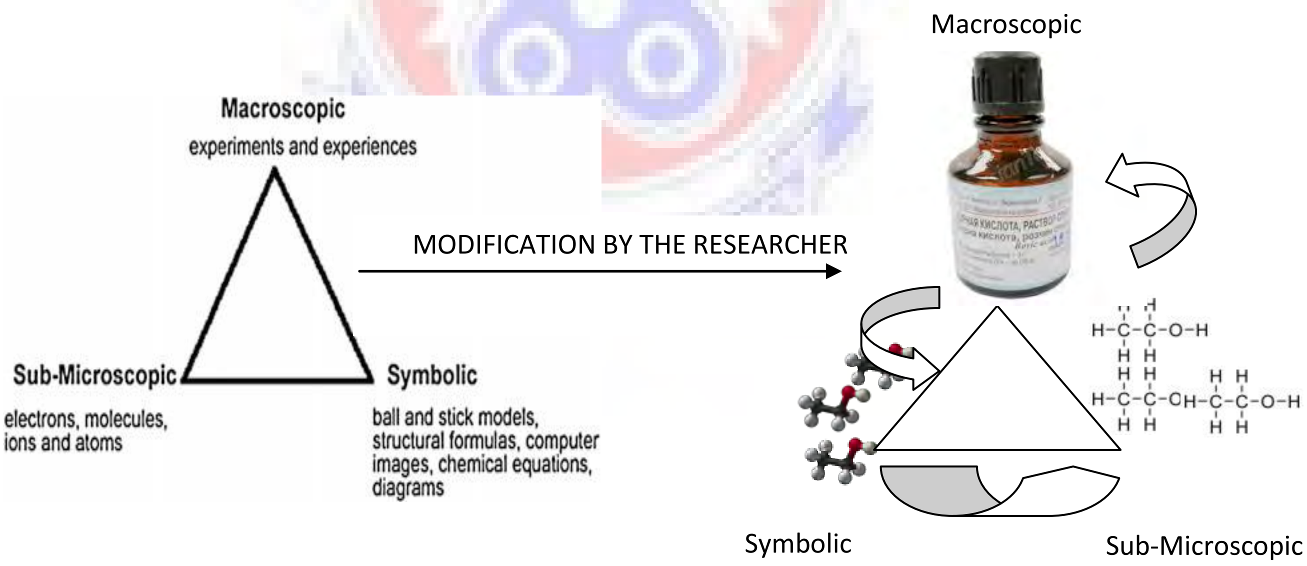


Figure 1: Modification of Johnstones triangle

Conceptual change theories (Chi, 1992; She, 2004; Strike & Posner, 1992; Vosniadou, 2003) share a common view that human knowledge is schema-like, consisting of various interrelated conceptual components. The base of knowledge that one possesses about a specific concept varies among individuals due to their different prior knowledge and experience. Learners systematically and consistently conceptualize a new idea by applying this base of knowledge to assimilate it into the existing knowledge base (Schema). When this new conception is in conflict with their existing knowledge; the learners must reconstruct their prior knowledge to reconcile this new information (accommodation). This prior knowledge also allows the learner to recognize a problem and to select appropriate existing conceptions for reasoning (Chi, 1992).

Research by Vosniadou and Ioannides (1998) has shown that an individual generates models and/or mental models based upon their existing knowledge so they can assimilate or reconcile new information. These generated mental models are applied and tested in new situations and retained by the individual who created them for a considerable length of time (Eilam, 2004).

When conceptual models are introduced in chemistry classrooms, students are tempted to make sense and construct meaning by comparing their mental models with the newly introduced models. The generated mental models then evolve and become more elaborate and often are modified by adding, deleting, and modifying concepts, features, and relationships. Glynn and Duit (1995) recommended that mental models should be considered as an important part of learners' conceptual framework.

Briggs (2004) has argued that visualization and construction of mental models serve an important role that provides students with a tool of thinking for model-based reasoning. They found that second-year organic chemistry students employed a set of visualization operations to make sense of an input from their eyes and to manipulate a constructed mental model to solve a problem. Five components of the visualization operations have been identified including referent, relation, rules/syntax, operation, and result (Briggs, 2004).

Unfortunately, students sometimes do not construct mental models due to their lack of practice with the visual-spatial ability and/or a lack of awareness about the importance of constructing mental models (Briggs, 2004). In such situations, students may draw several representations to make personal sense of a problem; however, they may not be successful because static representations provide limited information (Bodner & Domin, 2000). Stieff, Bateman, and Uttal (2005) indicated that secondary and post-secondary students were able to have discussions about stereochemistry by directly inspecting molecular representations without generating a mental image. Instead, the students developed some rules or strategies, such as simply looking for planes of symmetry within a molecular representation to make their decisions in a specific context. When the rule failed to provide an immediate solution, they then applied visual-spatial thinking to solve the problem. Stieff, Bateman, and Uttal (2005) claimed that this ability to alternate between the use of visualization strategies and non-imagistic heuristics increases as students' experience grows.

The two components (macroscopic and symbolic levels) of the theoretical framework which underpins this study suggest that fundamental knowledge and construction of mental models play a crucial role in learning chemistry.

Thinking with models requires an individual to construct and use mental models based on his or her personal knowledge and sometimes to think in three dimensional (3D) sphere of reasoning.

It is therefore believed that examining students' mental models of Molecular and Hybridization Geometry as well as Bond Angles provides a window to investigate the processes of Visuo-spatial based thinking and the relationships among the fundamental knowledge. It is also provide opportunity for learners to develop their visual-spatial thinking, and think through the use of mental models (Glynn & Duit, 1995).

Challenges faced by Science Students in Chemical representations (Models) used by Chemistry Teachers

Three types of students' difficulties in learning chemical representations have been identified by Krajcik, (1991). Krajcik (1991) pointed out that majority of students at the secondary school level cannot appropriately interpret chemical meanings of representations. Krajcik (1991) also explored the levels of description students generated (e.g., the macroscopic level, the atomic molecular level, the multiatomic level) when chemical symbols and formulas were used, such as $Cu_{(s)}$, $H_2O_{(l)}$, and $Cl_{2\,(g)}$. Although most of them generated some macroscopic descriptions, such as the physical properties of a compound, they could not use appropriate atomic-molecular models to explain the phenomena. It seems that students rely on their intuitive mental models of atoms and molecules in their explanations or descriptions about these representations and view chemical formulas as representing one particle without the concept of atoms. Some students, even after receiving substantial chemistry instruction, still view formulas as abbreviations for names rather than a way to represent the composition or structure, while others hold an alternative conception that a formula is an abbreviation for a mixture (Ben-Zvi, Eylon, & Silberstein, 1987).

In addition to the difficulty of interpreting representations, compared with chemists, students are less capable of providing equivalent representations for a given representation (Kozma & Russell, 1997). According to Keig and Rubba (1993), a large number of students was unable to make translation among formula, electron configuration, and ball-and-stick model when students' performances on translations were correlated to their understanding of underlying concepts. Keig and Rubba (1993) argued that making translation between representations is an information-processing task that requires understanding of the underlying concept. The conceptual knowledge allows students to interpret the information provided by the initial representation and to infer the details in order to construct the target representation (Lesh, Post, & Behr, 2003).

A third learning difficulty involves the mental transformation between two-dimensional (2-D) and three-dimensional (3-D) representations. Many students are not able to form 3-D mental images by viewing 2-D chemical structures and to mentally rotate 3-D images (Copolo & Hounshell, 1995; Tuckey, Selvaratnam, & Bradley, 1991). In order to successfully create a 3-D image by viewing a 2-D diagram, students are required to decode the visual information provided by depth cues used in the diagram (Shubbar, 1990). These depth cues include the foreshortening of lines, relative sizes of different parts of the structure, representations of angles, and the extent to which different parts of the diagram overlap. Tuckey, Selvaratnam, and Bradley (1991) have found that some students cannot correctly identify depth cues, and even if they can, they may not be able to mentally track how depth cues change as a result of rotation (Shubbar, 1990). This makes mentally rotating chemical structures difficult for students. The study therefore tries to synchronise the three levels of mental models indicated in Figure 1 so as to bring meaning of concepts in chemistry to students.

Traditional approaches (Type of teaching models) used by the Chemistry teachers

The traditional model is considered as one dimensional because according to this model the one important consideration in chemistry education is teaching the content. This model is more of a summary of views on how chemistry is traditionally taught and served as a background for science education researches on how to improve post-secondary science and chemistry education (Gabel, 2000; Sirhan, 2007). Teaching and learning are based on the behaviourist view, in which students' minds are viewed as empty vessels that need to be filled with knowledge by the teacher given the right stimuli. The approach is also based on the assumption that chemistry will be understood by students if basic principles of chemistry are taught.

Thus, according to this model, during the duration of the course a teacher tries to build the students' basic chemistry knowledge. It is assumed that if the students are taught all the basic concepts they can apply the knowledge in real life situations. The collection of facts and principles are considered prerequisite for learning at higher academic levels. More often than not, during delivery of lessons students are first taught definitions, basic concepts and principles of chemistry. This is followed by teaching experiments and data that support the principles and laws (Sirhan, 2007).

Finally, students are exposed to how to apply the knowledge in experiments, calculation problems and in real life examples of application. Similarly, Chemistry is also presented in its disciplinary context. Lesson topics are organised according to classical chemistry sub disciplines; organic chemistry, inorganic chemistry, physical chemistry, general chemistry and biochemistry. This model can be seen in the order of content in post-secondary chemistry texts and introductory university chemistry reference texts and serve as basis that support the principles and theories application in experiments, calculation and real life situations. There are however, shortcomings to this model. This model of teaching chemistry gives students the impression that chemistry is a collection of abstract concepts, various theories, symbols and chemical equations (Johnstone, 1993).

According to information processing model in chemistry learning, separation between learning and its practical, as well as intellectual applications, result in pieces of information which are rarely remembered and much less used (Evan, Karabinos, Leinhardt, & Yaron, 2004; Holbrook, 2005).

Again, though this structure seems neat and logical to experts in the field like text book writers and chemistry professors, it is not necessarily the best way to organise content for instruction (Gabel, 1999). This argument holds because if the practical aspect of the lesson presented together with the theoretical aspect, most students will find it difficult to merge the two. It also presents both practical and theoretical aspects of chemistry as independent course areas. Such organisation of content is termed by Ware (2001) as “science for scientists”. Students who are new to science and scientific processes may not be ready to accept the theories and principles being taught to them as a way they look at the world. Shortcomings of the model can further be explained by comparing the model with the learning cycle (Spencer, 1999).

Studies in the field of cognition have shown that the model that best resembles the way man learns a new concept is the learning cycle. The best way for a student to build understanding of a concept begins with the exploration and data collection phase. Next comes the concept building phase and finally the application of the new knowledge. Studies have shown that students prefer and learn concepts better if the concept building phase and introduction of definitions come after exploration phase. However, most reference text and teaching begin by introducing terms, theories and concepts followed by data and evidence to support the theories. This order goes against the order of phases in the learning cycle (Spencer, 1999).

The Traditional Chemistry Education Model is based on the assumption that if students learn the basic principles of chemistry they can use them to solve chemistry problems. Thus, if a student can solve a chemistry problem, say a limiting reactant calculation problem, it is assumed that she or he understands the underlying concepts. This assumption is challenged pieces of by evidence which show that there are students who do not understand some basic chemistry concepts even after years of studying the subject. Gabel (2000) reports that there are chemistry major students who show misconceptions about bubbles in boiling water similar to those shown by secondary school students. The persistence of such misconceptions can be related to other studies which show that students answer examination questions using strategies unrelated to conceptual understanding of chemistry (Saul, 2003). Students memorise calculation steps and answers of certain types of questions as preparation for examinations.

Tsarpalis and Papaphotis (2008) have stated that learning of science can occur in the form of conceptual learning and algorithmic learning. According to Tsarpalis and Papaphotis (2008) algorithmic learning refers to the ability to use specific procedures to solve a problem or complete a task such as writing an electron configuration. Conceptual learning, on the other hand, refers to learning to achieve deep understanding of a concept, such that it affects the construction of the mental framework of knowledge. Both types of learning have roles to play in the development of a student. However, too much emphasis on algorithmic learning can impair conceptual learning. Tsarpalis and Papahotis (2008) conducted qualitative and quantitative studies to compare algorithmic and conceptual learning of upper secondary chemistry students. The conclusion made was that the ability of students to answer algorithmic problems was independent of conceptual understanding. A majority of the students in the study could only answer algorithmic problems, while a very small minority could answer only the conceptual problems or both conceptual and algorithmic problems. This showed that ability to answer examination questions does not necessarily mean that the students understand the underlying concepts related to the question. This model with all its shortcomings is not without merit. According to Spencer (1999), students with abstract reflective learning style, prefer general to specific approach, like abstract ideas and autonomy. Thus, these students are a better match to chemistry teaching based on the traditional model of chemistry education.

However, according to Schroeder (1993) as reported by Spencer (1999), though the students with the abstract reflective learning style composed of ten percent of the research subject, they rather had the highest scores compared to students of three other learning styles. These students are also the ones who would continue their studies in science and technology degree courses and later on become science and technology professionals. Because their learning style is a better match to the traditional model of chemistry education, they have less problem when learning chemistry. Increasing importance of science and technology have seen larger number of students required to enrol into chemistry courses, hence diversity of learning styles are more pronounced than ever before in post-secondary chemistry classes. The model that has been successful in producing many scientists and chemists may no longer be good enough to face the challenges of learning style diversity and the goal of producing a science literate society.

Challenges associated with teaching models used by the chemistry teachers during Molecular Geometries and Bond Angles

Extensive research in this field over recent decades has identified further challenges for chemistry teaching. For chemistry in general, many of the problematic issues can be identified as a mismatch between the abstract nature of teaching models and the experienced macro-level view of students (Gabel, 1999). In students' attempt to make sense of formally introduced theoretical models, they not only make use of previous experiences but also make their own assumptions (Driver, 1983). This mostly brings about mismatch between the abstract nature of teaching models and the experienced macro-level view of students and this has gained much attention within educational science (Talanquer, 2011). Importantly, although previous research in the field of student reasoning or students' explanations has been performed at different educational levels and in varying educational settings, commonalities in student reasoning can be found in researchers interpretations of data (Nakigoglu, 2003; Harrison & Treagust, 2000).

The gap between student experience and the abstract level of teaching

Gabel (1999) defined the major barrier to understanding chemistry as being the *abstract level* of educational models and this is well supported in the scientific literature. For example, research findings from many different educational settings, including students of different ages, show how students commonly place their own experiences of the world, on to the sub-microscopic level of teaching models (Gabel, 1999; Andersson, 1990). Students often perceive matter as continuous and static (Andersson, 1990). Students (age 14-15) think of soft substances as made up of soft particles (Andersson, 1990, p 67). Students suggest that copper atoms are malleable and have colour (Ben-Zvi, Elyon, & Silberstein, 1986). These results display the difficulty of making the transition between experienced macro-level phenomena and abstract sub-microscopic teaching models. There are numerous examples provided in the literature where students' expressed models do not match the intended teaching target model (Ozem, 2004). These phenomena have been given many general labels, such as: alternative explanations, alternative conceptions, misconceptions, naïve theories and common sense reasoning (Ozem, 2004).

Moreover, other observations have been reported on students' understanding and use of specific models, such as for the atom (Griffiths & Preston, 1992). Furthermore, Taber (2002) elicited the interrelated nature of students' alternative conceptual framework through the "the octet framework.

Subsequently, Talanquer (2006), who derived "the common-sense framework" from an analysis of research reports concerning students' alternative conceptions, found this framework to be useful tool for describing student reasoning patterns. Bridging the gap between the student experienced world and the abstract level of chemical models is indeed a challenge, where the various means to resolve this issue, for example, the use of analogies can in themselves become a hindrance.

Through a survey of literature one can identify four possible general strategies for bridging the gap between the macroscopic and sub-microscopic models of chemistry as: analogy, development of teaching models, anthropomorphic and teleological formulations and *technology-based approaches* (Taber, 2001; Levy-Nahum, Hofstein, Mamlok-Naaman, & Bar-Dov, 2008).

Conceptual Frame Work

Based on Johnstones triangle, a conceptual model (Figure 2) was developed for the study. According to Pintrich, Marx and Boyle (1993), when students are exposed to confusing or complex concepts, they are thrown into a state of disequilibrium. Visuo-spatial instructional model (administered in cooperative or individualised learning settings), however, seems to enable students to develop cognitive structures or mental models or reorganise their already existing ones to better understand confusing and complex concepts, such as molecular and hybridization geometry with their associate Bond angles. Some researchers (Gardner, 1993; Pintrich, Marx & Boyle, 1993; Von Glasersfeld, 1999) have noted that the constructivists' position that students should have access to multiple viewpoints and representations for information is satisfied by Visuo-spatial model. From this assertion and Johnstone's triangle, the conceptual framework in Figure 2 was designed for the study.

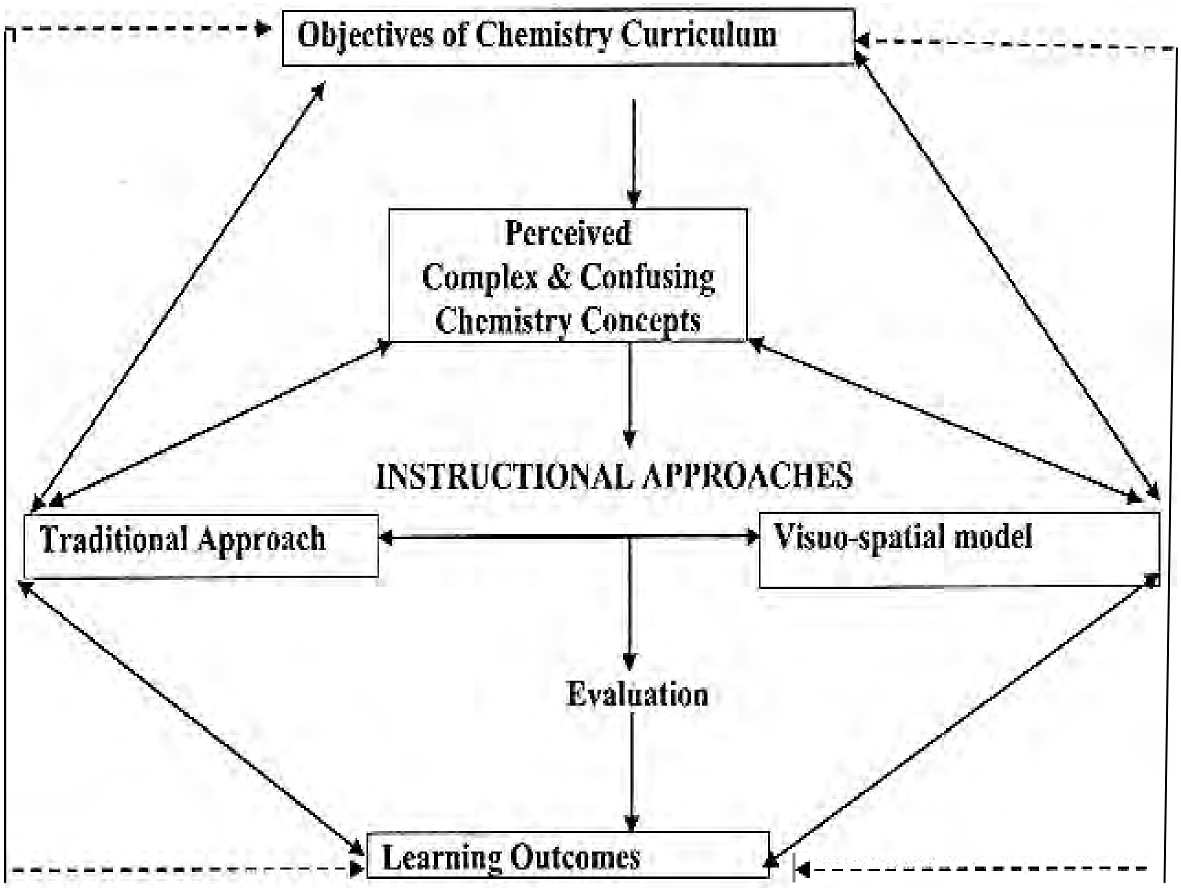


Figure 2: Conceptual Framework for the Study

Visuo-spatial Model

Visuo-spatial as a term is coined from visualization and spatial (Mathew, 1999). Visualization is a powerful tool that can facilitate processes of constructing and reconstructing successful relationships between relevant declarative and procedural knowledge. The role of visualization in science education has become an important, active, and productive area of research that does not only provide lens to investigate phenomena within science, but it also offers new ways of viewing learning and understanding scientific inquiry including the use of models in scientific representation. It also offers an entirely new dimension for students to explore and engage in scientific inquiry (Gobert, 2005)

Meaning of Visualization

Visualization is currently thought of as including three domains: external and internal representations and the spatial (physical and meta-cognitive) skills that one needs to work with and link to the external and internal representations (Gobert, 2005). The external representations aspect of visualisation refers not only to the physical models, graphics, diagrams, Power Point presentations, and videos scientists construct in doing science, but also those representations teachers and students use for instruction and learning. The internal representations, on the other hand, refers to the mental constructs and representations that are developed and used by scientists / teachers / students in their construction and understanding of scientific concepts like Hybridisation Geometry and Bond Angles. The third aspect of visualization is spatial skill, which refers to the student's ability to manipulate or transform images or spatial patterns into other arrangements, such as interpreting how a two-dimensional textbook diagram can be compared to a three-dimensional physical model.

Visualization in Chemistry

According to Johnstone (1993), there are three levels of visualization in chemistry; these are the macroscopic, microscopic, and symbolic levels. Chemical representations at the macroscopic level refer to observable phenomena and range from laboratory activities and experiments, such as chemical reactions and their associated colour changes, to the pictures and diagrams teachers and students use in textbooks or construct on teaching and learning boards. Microscopic representations in chemistry can refer to those models or other visual displays that depict the arrangement and movement of particles. Chemical representations at the symbolic level include symbols, numbers, and signs used to represent atoms, molecules, compounds, and chemical processes, such as chemical symbols, formulas, and chemical structures (Johnstone (1993).

In teaching science, models become vital if the visualization of entities within exemplar phenomena take place (Gobert, 2005). The development of models and their representations are crucial in the production of meaningful knowledge. Models can function as a bridge between the scientific theory and the world as experienced. They can act as simplified depictions for abstract theories and can also present imaginary concepts in materialistic form. Models can also depict many different classes of entities, covering both macro- and micro- levels of representation. Cartier, Rudolph and Stewart (2001) have expanded the concept and use of scientific models to include set of ideas that may be used to describe a natural phenomenon as. According to Cartier, Rudolph and Stewart (2001), a scientific model is a set of ideas that describes a natural process, models are constituted by empirical or theoretical objects and the processes in which they participate. Models can be used to explain and predict natural phenomena, models are consistently assessed on the basis of empirical and conceptual criteria and models are also useful as guides to future research (Cartier, Rudolph & Stewart (2001).

Gobert (2005) opined that visualization has central role in learning science. Wu (2004), also saw chemistry as visual science in which visualization plays a major role in its daily practice. It is therefore of no doubt that natural phenomena can be investigated through ideas of molecules, atoms, subatomic particles, and the relationships amongst them.

In this respect, visualization becomes essential for the communication of these concepts to students in chemistry. For instance, representations using pictures, diagrams, flow charts, and chemical formulae and symbols are as equally important to learning and understanding of chemistry concepts just as the printed descriptions found in chemistry textbooks are. The use of visuo-spatial models for learning and understanding chemistry is becoming an essential component for instruction with increasing availability of technologies and, subsequently, an area of research into learning in chemistry. This is seen in the work of Wu (2004), which investigated the relationship of visuo-spatial thinking to constructing meaningful understanding.

Wu (2004) suggested in his study that when designing chemistry visualization tools for facilitating student understanding, the following should be considered; a) multiple representations and descriptions should be provided, b) linked referential connections must be visible, c) presentation of chemistry should be interactive and dynamic reflecting the nature of chemistry, d) students need to have explicit instruction in making transformations between two-dimensional and three-dimensional models, and e) the cognitive difficulty of chemistry can be reduced by making information explicit and integrative for students. Besides, Wu (2004) proposed that in chemistry, visuo-spatial abilities are relevant to learning and that some visualization tools have been effective in helping students overcome conceptual errors.

VSMs help students to engage with fundamental ideas, especially, for students who have developed relevant macroscopic conceptions and interrelated conceptions (Snir, Smith, & Raz, 2003).

Visual representations in chemistry, such as molecular structures and atomic models are partially schematized so it difficult to use partially iconic diagrams that depict abstract concepts to illustrate both their components and organization. This difficulty can be defeated by linking students' visuo-spatial models to particular cognitive operations that may already exist in the students' construct (Wu, 2004).

It is suggested that curricula which include sets of model representations provide students with opportunities to learn about the conceptual subject matter of particular disciplines and the nature of scientific knowledge (Cartier, Rudolph, & Stewart, 2001). Copolo and Hounshell (1995) recorded in their study that those students who used combinations of three dimensional ball and stick models with three dimensional isomeric molecular computer models scored significantly higher in understanding and retention than those who used two dimensional models.

Models in Chemistry learning

Halloun (1996) states that scientific model is a conception system. It is composed of conceptions and represent primary features of the modelled pattern. Primary features are features which are common to all systems in the model represented to classes and are responsible for producing the pattern that include certain bodies and/or field, in the make-up of models referents, and system they belong to. This is the model from the perspective of what scientists actually do. Scientific model makes up or contributes to scientific practice. It is a set of ideas that describes a natural process (Cartier, Rudolph, & Stewart, 2001). Models are experimental evidence constituted by empirical or theoretical objects and the processes in which they participate. They contain abstract elements that cannot be visualized. They can be used to explain and predict natural phenomena (Johnson-Laird, 1996; Carter, Rudolph, & Stewart, 2001).

Modes of model representation

Gobert (2005) specified the models' version of a phenomenon in the public domain in five modes of representation which include concrete, verbal, symbolic, visual and gesture modes.

According to Gobert (2005), the concrete mode is three-dimensional which is made up from plastic ball-and-stick model of an ion lattice whereas the verbal mode is a description of the entities and the relationships between them in a representation. Gobert (2005) described the symbolic mode as chemical symbols and formula, chemical equations, and the mathematical expression used in teaching chemical concepts whereas the visual mode is made up of graphs, diagram, and animations, such as two- dimensional form of chemical structure. Gobert (2005) described the fifth mode; the gesture mode, as the use of movement by the body or its part to explain concepts and phenomena.

Use of videos in learning Chemistry

Videos have become an integral component for teaching and learning in the classroom because videos can show information that is otherwise inaccessible with regard to time, space, and matter. For example, using QuickTime videos, animations may provide comparisons of 2- and 3-dimensional views of molecules or they may be reversed or stopped in the middle of a representation of a molecular / chemical reaction or process to demonstrate time-space-matter relationships that are un-observable to the naked eye. The goal of showing pictures or movies to students is to draw out important ideas, stimulate creative thought, and promote meaningful conceptual linkages within a particular context (Lavoie 1995).

According to Lavoie (1995), research investigating the use of videos in cognitive science has shown that they lead to more elaborate and explicit knowledge relationships than the use of audio, verbal or textual means alone. The information contained in visuals is inherently high density and there are more opportunities for the learner to establish linkages with pre-existing knowledge (Lavoie, 1995). Science teaching should, therefore, be concurrent with visual aids during all phases of instruction and at all levels of cognitive development. Video technology combined with appropriate teaching and learning strategies can be used to achieve high levels of visual interactivity, and it then becomes an effective vehicle for delivering anchored instruction that provides students with a focus on inquiry. It helps the student in the identification and application of visual information that is relevant to solving a posed problem (Brandsford, Sherwood, Hasselbring, Kinser, & Williams, 1990). Teachers can increase visual interactivities by asking appropriate divergent and convergent questions, giving opportunities for feedback and posing visually-oriented problems.

Video is typically multi-dimensional facility composed of a variety of simulated and animate processes, still pictures, motion pictures, and dynamic graphics. The advantage of videos over printed media is that an animate or real-life experience can be slowed-down, sped-up, frozen, manipulated, and experimented within the context of time and space (Lavoie, 1995). Videos also allow students to explore and discover concepts in real world contexts that would otherwise concern safety, time, expense, or accessibility (Escalada, Rebello, & Zollman, 1996; Escalada & Zollman, 1997). Using videos in teaching is also useful for improving students' visuo-spatial skills, providing techniques for creative visualization, and allowing the use of various visual- learning modes. Video does not only provides opportunities for students to develop their understanding and reinforcement of scientific concepts, but also allows them to develop their skills in scientific investigation and inquiry (Escalada & Zollman, 1997).

Clearly, videos and their tools offer new dimensions to both learners and researchers interested in understanding their impact on learning in chemistry (Escalada, Zollman, & Grabhorn, 1996).

Use of Hands-on models in learning Chemistry

The concept of hands-on science is based on the methods students employ to make sense of the world around them. These experiences should allow students to be actively engaged in the manipulation of everyday objects and materials from the real world. This physical manipulation and handling of objects is an effective way for students to learn science and for that matter chemistry (Vesilind, & Jones, 1996). When students do hands-on science they are typically holding, touching, moving, observing, listening, smelling, and sometimes tasting objects under investigation. This use of multiple senses in learning is often considered to be part of the developmental process of moving from concrete to abstract thinking (Loucks-Horsley, Kapitan, Carlson, Kuerbis, Clark, Melle, Sache, & Walton, 1990).

To facilitate student's understanding in abstract concepts within chemistry, manipulatives are often advocated as instructional tools. Manipulatives have been found to increase students' learning significantly and, most often in chemistry, there are concrete hands-on models such as hand-made paper models, styrofoam ball and pipe cleaner models, and various commercial ball and stick models (Steff, Bateman & Uttal, 2005). Hands-on models help students to construct tangible experiences with models that are otherwise abstract. Hands-on-models have become indispensable for teaching and learning science because they stimulate students' curiosity and imagination well as verbal descriptions for complex phenomena that can be overwhelming for young students. Hands-on activities and manipulatives encourage students' creative thinking and allow students to understand scientific phenomena that are not visible (Harrison & Treagust, 2000). Moreover, hands-on learning develops more positive attitudes about science and results in students becoming highly engaged and interested in science topics (John, Andre, Kubasko, Bokinsky, Treatter, Negishi, Taylor, & Superfine, 2004).

Visuo-spatial Thinking

Chemistry is perceived by many scholars as visual science which is learnt through chemical representations. These chemical representations, such as atomic models, are partially schematized and partially iconic diagrams that depict abstract concepts and apply conventions to illustrate both component and organizations (Wu, 2004). The relationship between visual displays and chemistry concepts is very strong. A series of studies emphasize the role of visuo-spatial thinking by investigating the correlation between spatial abilities and chemistry learning (Wu, 2004). There are explicitly many chemistry concepts and problems such as stoichiometry problems that require visuo-spatial abilities for discussions and to answer the questions thereof. Using chemical representations to perform tasks requires series of cognitive operations in spatial domain, thus, it is likely that chemistry learning involves student visuo-spatial thinking.

There is some variation in the meaning of terms used in the literature on Visuo-spatial thinking. Visuo-spatial thinking (cognitive, or intelligence) used for the mental visual image within memory and higher level cognition, includes vision-using the eyes to identify, locate, and think about objects and ourselves in the world and the formation, inspection, transformation, and maintenance of image in the "mind's eyes" in the absence of a visual stimulus (Mathew, 1999). Kali and Orion (2004) defined spatial abilities to include the ability to recognize and comprehend the relationships between the various parts of a configuration and one's own position, the ability to generate an image and operate various mental manipulations on this image.

According to Wu (2004), spatial visualization involves the reflect processes of apprehending, encoding, and mentally manipulating spatial form. Mental manipulation of spatial visualization required chemistry problem solving. For example, to determine whether dichloromethane (CH_2Cl_2) is a polar molecule, students need to draw or show a schematized two-dimensional structure formula. However, the diagrams could lead to different conclusions unless students mentally or physically create a three-dimensional model of the molecule to indicate that dichloromethane is a polar molecule because the two polar bonds between Carbon and Chlorine do not lie along the same axis in three-dimensional space.

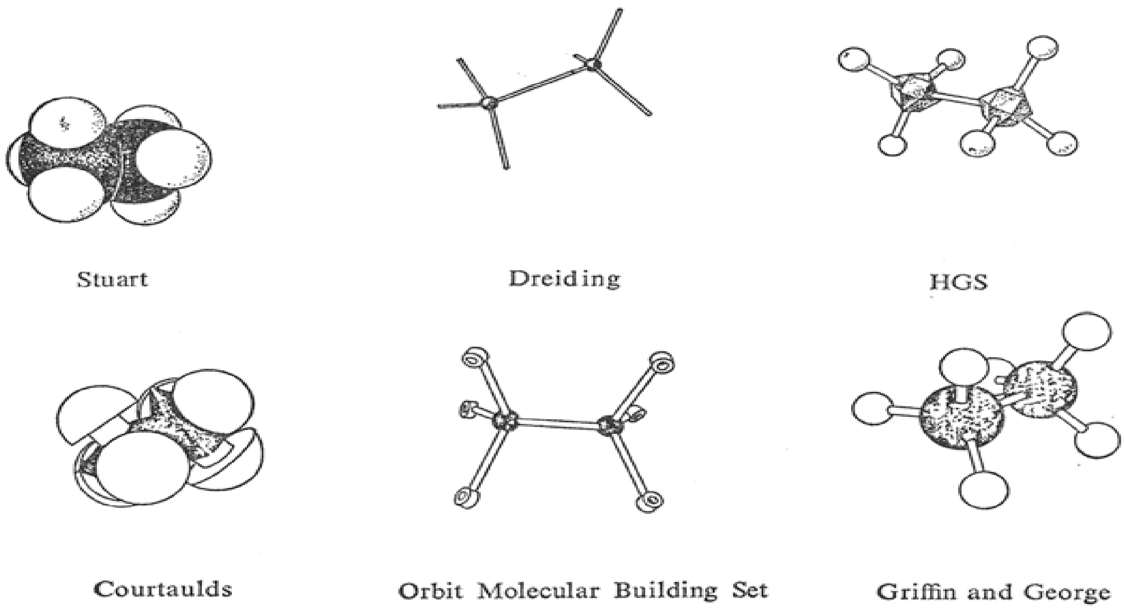
Molecular Geometry and Molecular Models

It is quite difficult to draw arrangements of atoms that make up molecules on the two-dimensional plane of paper even for considerably simple molecules such as methane, ethane and acetylene (http://www.clicktoconvert.com).

Therefore, since the latter half of the 19th century, when the importance of stereochemistry was recognized, various molecular models were devised and some of them are now commercially available to assist chemists (Bornstein, 1996).

However, previously, the molecular models were used only for research, not for education, because stereochemistry was a limited field of science regarding which only some chemists were likely to be interested.

In the 20th century, increased recognition for stereochemistry, especially among chemists studying organic chemistry, brought molecular models into education (Silberberg, 2000). Figure 3 illustrates typical molecular models of ethane which are now available on commercial bases.



(a) space-filling model (b) skeletal model (c) ball and stick model

Figure 3: Various molecular models of ethane (Petrucci, Ralph, William, Harwood, Herring, Jeffry, & Madura, 2010).

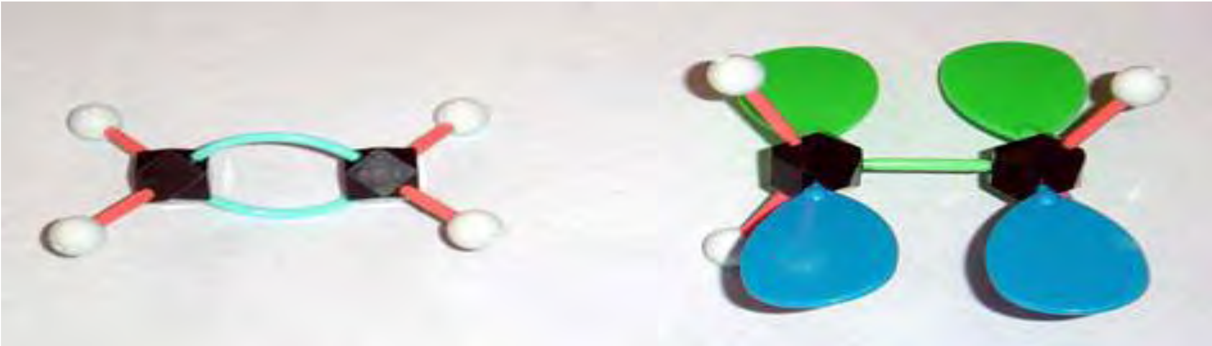
Space filling models (*e.g.* Stuart model, Courtaulds model) represent the spread of electronic clouds. However, they fail to represent atoms inside a molecule clearly. It is not always easy to understand the arrangement of atoms in a complex molecule until one has had some experience (Petrucci, Ralph, William, Harwood, Herring, Jeffry, &

Madura, 2010). Skeletal models represent a molecule only with sticks proportional to the bond length. The utility of this type of model is that it is easier to have a good idea on the bond angles, bond lengths and the shape of the whole molecule, which is not so clear in the space filling model (Berman, Westbrook, Feng, Gilliland, Bhat, Teissig, Shindyalov, & Bourne, 2000).

According to Berman, Westbrook, Feng, Gilliland, Bhat, Weissig, Shindyalov & Bourne (2000), ball and stick models can be considered as variation of (b) where the location of an atom is shown by a ball with several holes fixed with ticks of appropriate length which represent the bonds. The angle of each hole on the ball is fitted to correspond to bond angles, and the length of each stick is also made proportional to the corresponding bond length. The utility of this model often makes it easier to understand the chemical structure of a molecule since the balls are coloured as the colours of the elements they symbolize.

The HGS model consists of balls with four holes for sp3 hybridized carbon atoms, balls with five holes (two for p orbitals) for sp^2 hybridized carbon atoms, multipurpose ones with many holes including those for sp hybridization, and plastic rods of various lengths. The balls are colour coded for differentiation. There are balls with many holes to be used to construct complex molecules. For example, space filling model such as stuart model is used to emphasize electron clouds, the skeletal model like the dreiding model is use to emphasize bond length and bond angle whereas ball and stick model like HGS model emphasize atoms.

The HGS model provides the third method to solve the problem. A double bond can be represented by using balls with five holes (designated as C5) and hydrogen atoms and plates for p orbitals (Figure 4b). Since a molecule will be most stable when two pairs of p orbitals overlap most effectively, the most stable structure of ethylene can be achieved by fastening those plates (Connolly, 1983).



(a) (b)

Figure 4: Sample Molecular models

The Figure 4(a) is the model with bent bonds whereas the Figure 4 (b) is the model with plates for p orbitals. Figure 4, therefore, represents molecular models of ethylene by HGS molecular model but there remains one important problem; rotation about a single bond. When a molecular model of ethane is built up, the geometry of two methyl groups is not fixed, whichever model is chosen. In molecular models, one of the methyl groups can be rotated about the C-C bond while holding the other methyl group. As a result, the molecular shape will continuously change (Stephen, Barry, Olafson, William & Goddard, 1989).

However, even if the shape had changed, the bond angles and bond lengths would not have changed (Lagowski, 2004). What changed is the distance between hydrogen atoms of those two methyl groups. For instance, if one of the hydrogen atoms of each methyl group is named HA and the other HB, then the distance between HA and HB will be changing during the rotation about the C-C bond, and this can be portrayed by the change in the dihedral angle defined by four atoms HA-C-C-HB as shown in Figure 5.

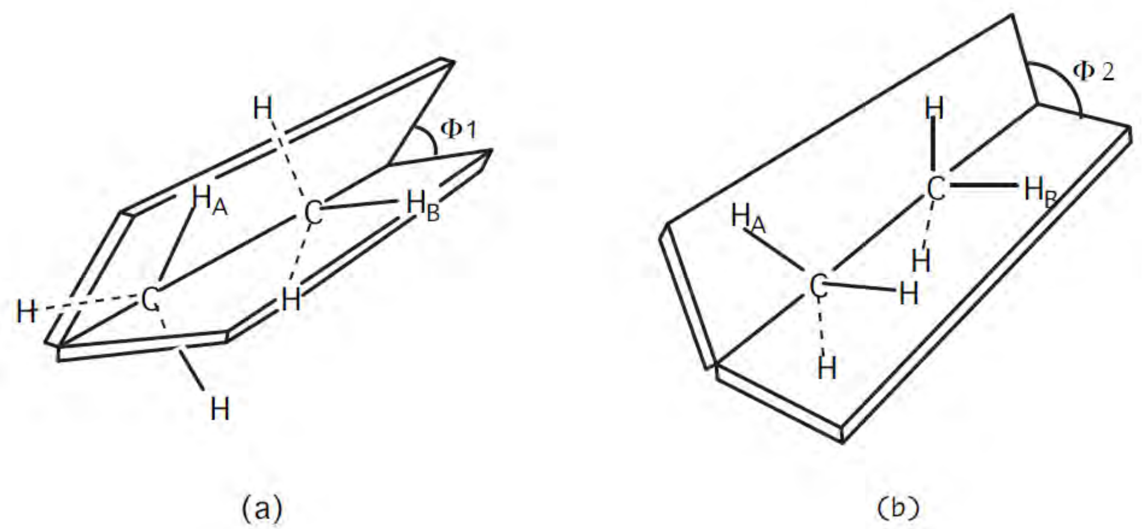


Figure 5: The shape of ethane and the dihedral angles (ϕ1as in a, and ϕ 2 as in b)

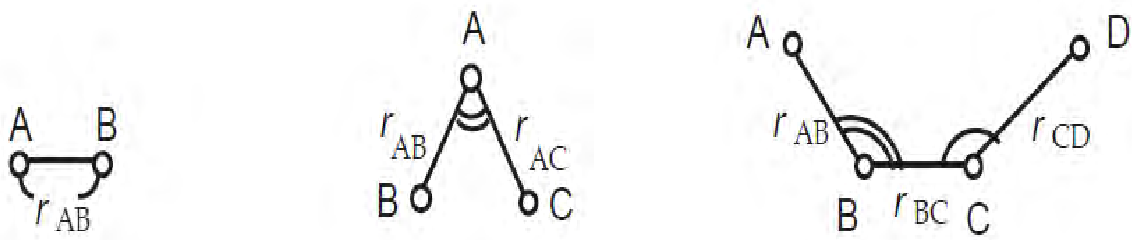
As to whether the change that takes place in molecular models correspond to the actual phenomenon is another concern raised by many chemists (Lagowski 2004). However, concern that was raised on whether a free rotation about a carbon–carbon single bond is possible was widely affirmed more than a hundred years ago. By the middle of the 20th century, however, further understanding had developed, and it was recognized that such a rotation was not completely free but restricted to some extent – restricted rotation (Lagowski, 2004).

For example, the six atoms involved in an ethylene molecule are always placed on one plane, since the overlap between the p-orbitals prevent the rotation around the double bond (Connolly, 1983). However, the first method would fail to represent this planar nature since the model allows the free rotation around the C-C bond. On the other hand, the second way can represent the planar nature among the six atoms, while there is one disadvantage: the <HCH angle is incorrect (tetrahedral

angle instead of the correct angle of 120). Furthermore, this method cannot represent the fact that a double bond is formed from two different bonds, sigma and Pi bonds (Borges & Gilbert, 1999).

Factors to determine molecular structures

Although structural formula plays a major role in the spatial orientation of a molecule, it cannot indicate the real structure of those molecules, since those formulas drawn on a sheet of paper can describe only the sequence of atoms in the molecules (Connolly, 1983). Therefore, the real structure of a molecule can be defined solely by the atomic distance *r*AB for diatomic molecules A-B as indicated in Figure 6 i, and, also by three parameters ; two atomic distances *r*AB, *r*AC and bond angle < BAC for triatomic molecules A-B-C as shown in Figure 6 ii. According to Borges & Gilbert, (1999), atomic distance and bond angle are the specific parameters for atoms that form the bonds, and they have values that can be predicted by chemical bond theory as shown in Figure 6 i, ii and iii.



i ii iii

Figure 6: Factors that determine molecular structures

For tetra-atomic molecules; A-B-C-D as indicated in Figure 6 iii, the three atomic distances *r*AB, *r*BC, *r*CD and two bond angles <ABC, <BCD are not enough to define the geometry of the molecule. Even though these parameters are specified, the

geometry is not thereby defined (Borges & Gilbert, 1999). Thus, it is not yet certain whether or not those four atoms are located in an identical plane.

If they are not in an identical plane, it must be determined which atom is not in that plane as shown in Figure 7.

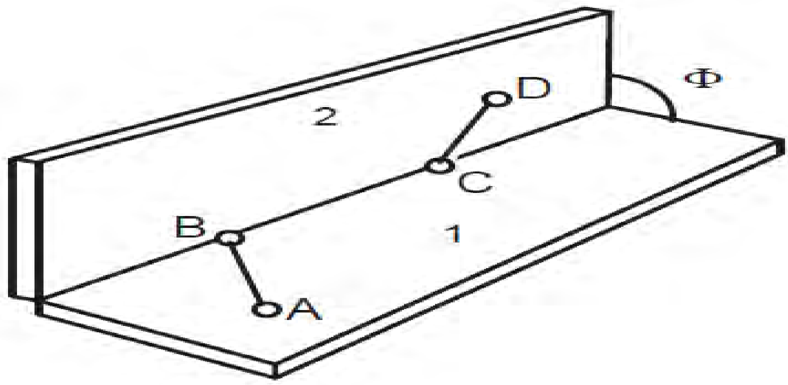


Figure 7: Relationship between molecular geometry, molecular shape and bond angle

The geometry of (ii) can definitely be defined by a sixth parameter, the dihedral angle. A dihedral angle is defined as an angle between plane 1 that includes atoms A, B and C and plane 2 that includes B, C and D. To determine the structure of a tetra-atomic molecule, it is necessary to introduce a new parameter, the dihedral angle, which is determined from neither by the atomic distance nor the bond angle. This fact suggests the following:

1) Molecules are three-dimensional, and may not always be represented on two dimensional paper.
2) Molecular structures are not defined by atoms or by types of bonding in the molecules (Connolly, 1983; Glynn & Duit 1995).

One would therefore not deny the fact that bond angles play the main role in determining molecular structures. Therefore, the atomic orbitals of a carbon atom, which is the factor that controls bond angles in organic compounds, should be carefully studied.

Atomic orbitals of carbon atoms; hybridization

Studies conducted by Tomita, Burian, Dore, LeBolloch, Fujii and Hayash (2000) depicted the electron configuration of a carbon atom in its ground state as $1s^2 2s^2 2p^2$. Analysis of this electron configuration and the direction of the atomic orbitals show that the bonding electrons are only two 2p electrons that occupy the 2p orbitals because 2s electrons are not involved in bond formation; these form an unshared electron pair. Consequently, hydride of carbon would be expected to be CH_2, and its bond angle should be 90^0, which is the angle between the two 2p orbitals as indicated in Figure 8 as is well known. However, the fact is that the stable hydride of carbon is methane; CH_4 and it has four covalent bonds, not two. Therefore, the electron configuration of the carbon atom should be $1S^2 2S^1 2px^1 2py^1 2px^1$.

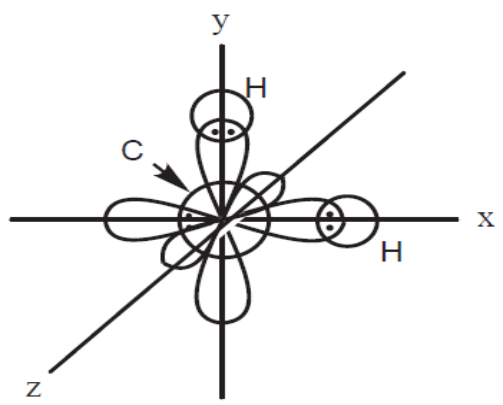


Figure 8: Illustration of hybridization geometry and bond angle (Jolly, 1984).

Moreover, studies of methane and its substituted species (*e.g.* chloroform CH_3Cl) reveal that those four hydrogen atoms in methane are identical. This means that a carbon atom must use four identical atomic orbitals with one unpaired electron in each orbital, but does not use an s orbital and the three p orbitals as such. It can be explained in terms of hybridization in which mixing an s-orbital and three p orbitals can make up four equivalent new orbitals, and the resulting orbital is called a sp^3 hybridized orbital.

On the other hand, if the four hydrogen atoms of methane are identical, the kind of structure one would expect to draw is the same situation as Figure 8. Since the three C-H bonds are orthogonal to each other. Though the fourth C-H bond has no particular direction, it should be placed on the opposite side to the other three (Glynn & Duit 1995). In any case, one of the hydrogen atoms should be different from the other three hydrogen atoms as in Figure 9 (Jolly, 1984). This is the hypothetical hydride of carbon; CH_4).

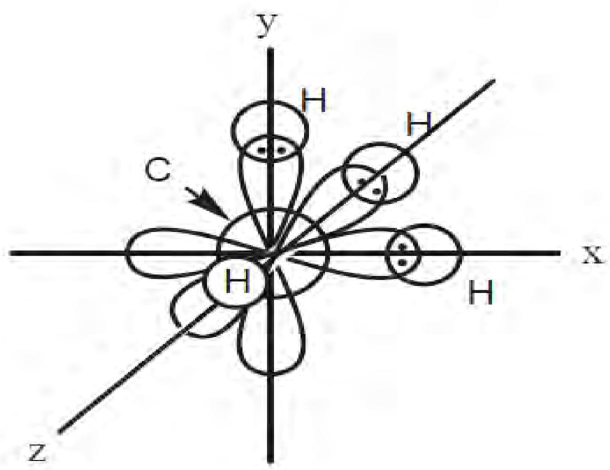
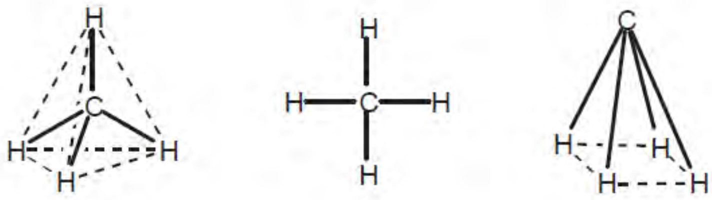


Figure 9: Illustration of hypothetical hybridization geometry and bond angle of C-H bond in Methane.

Thus, one may contend that it is impossible to decide which of those expected structures 11-13 can be the true structure of methane without some direct observations. However, if substituted methanes should have the same structure as methane, it is possible to deduce the structure of methane from the numbers of the isomers among the substituted methanes. Also in the case of methane, each of the following three structures may be possibly considered as its structure. Here structure 12 can be considered as a special case of 13 as shown in Figure 10.



11 tetrahedron

12 square

13 tetragonal pyramid

Figure 10: Proposed structures of Methane (Jolly, 1984).

Since some investigations have revealed that only one compound exists as methylene chloride, the tetrahedron should be the acceptable structure of methane. The atomic orbitals of a sp^3 hybridized carbon atom that form the tetrahedral structure are shown in Figure 10, methane is made up of four sigma bonds which are formed by the overlap of each sp^3 orbital of a carbon atom with a 1s-orbital of a hydrogen atom (Glynn & Duit 1995)

Therefore, the direction of those atomic orbitals determines the geometry of the molecule.

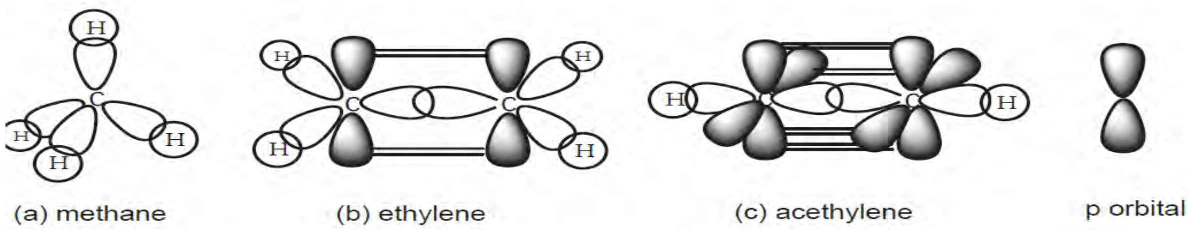


Figure 11: Molecular shapes of some compounds and their hybridized orbitals

In addition, the chemistry of a molecule that is formed by substituting for each of the three hydrogens of methane with different atoms or group, such as bromochlorofluoromethane (CHBrClF), provides more critical evidence for the tetrahedral structure of methane.

Hence, the number of isomers of CHBrClF can exist; if the structure of methane is 11 or 12 as indicated in Figure 12a.

	11	**12**
(a) CH_3Cl	1	1
(b) CH_2Cl_2	1	2
(c) $CHCl_3$	1	1
(d) CCl_4	1	1

Figure 12a: Isomers of bromochlorofluoromethane (Vollhardt, Peter, Neil, 2007).That is, two isomers (14, 15) are possible for 11 and three isomers (16-18) are possible for

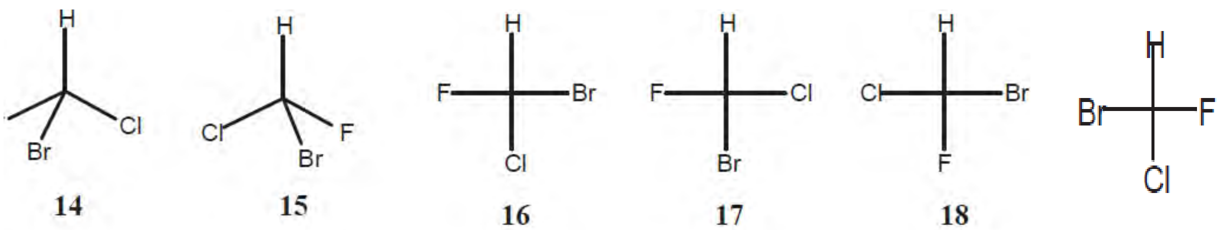


Figure 12: Proposed isomers of CHBrClF

However, there are some stipulations with regard to the answer for 12. For example, it is supposed that 19 could not be distinguished from 16. This is equivalent to assuming that there is no front or back for an atom (thus a molecule). Moreover, chemist admit that the pair of isomers 14 and 15 differ in the three-dimensional arrangement of their atoms, even though they seem to be similar

on the two-dimensional plane. Generally, isomers, though identical in their structural formulas, could differ in the arrangement of the atoms in space and are called Stereoisomers. Some classes of stereoisomers, which form a pair of non-identical images such as a right hand and a left hand or a real image and its mirror image, are called a pair of enantio isomers or simply a pair of enantiomers. Though the terms “antipode and mirror image isomer” are also used, the term enantiomer is popularly use exclusively in textbooks.

Structures 14 and 15 differ in their steric configurations around the carbon atom and this has been proven by Stereochemistry; a branch of science that involves the study of the physical and chemical properties of various compounds, especially those associated with three-dimensional structures (Jolly, 1984). Stereochemistry, which is an essential part of chemistry, has a good reason to be recognized as an important and independent field of chemistry because: the physical and chemical properties of stereoisomers are sometimes so different that it requires a great deal of information about the relation between molecular structure and properties. In addition, a definite and considerably elaborate procedure is necessary to represent information about the three-dimensional structure of a molecule on a two-dimensional sheet of paper and then to reproduce the original three-dimensional information from that representation (Connolly, 1983).

Multiple bonds

The carbon atom is not always connected to four different atoms. Carbon atoms involved in double or triple bonds combine three or two other atoms. For instance, a carbon atom with the electron configuration $2s^1 2px^1 2py^1 2pz^1$ can form three hybridized orbitals of equal energy from three atomic orbitals, 2s and two of 2p orbitals. One of the 2p orbitals (*e.g.* 2pz orbital) remains unaffected. This hybridized orbital is called sp^2 hybridized orbital from its constitution. All of the sp^2-hybridized orbitals are on the same plane that includes the carbon atom, and the remaining 2p orbital is perpendicular to the plane. Figure 13(b) shows the atomic orbital of the sp^2 hybridized carbon atom.

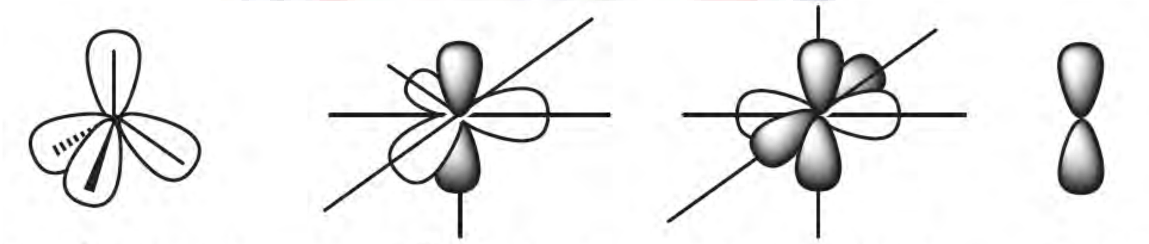


Figure 13: hybridization states of some hybridized orbitals (Jolly, 1984)

When predicting the bond angles between each of the three sp^2 orbitals, these three should be arranged symmetrically since these are on the same plane and equivalent to each other.

If a carbon atom forms a triple bond, it can be connected to only two other atoms. In this case, the carbon in the $2s^1 2px^1 2py^1 2pz^1$ electron configuration forms two equivalent sp hybridized orbitals (Figure 13c) from a 2s and one of the 2p orbitals, two 2p orbitals are left over (Vollhardt, Peter, Neil, 2007). The sp hybridized orbitals are in opposite directions. In other words, the angle between each of two sp hybridized orbitals is 180^0. In acetylene C_2H_2, a sigma bond is formed by the overlap of sp hybridized orbitals from each sp hybridized carbon, and two pi bonds are also formed by the overlap of two pairs of p orbitals, and hydrogen atoms are bonded to the remaining two sp hybridized orbitals (Connolly, 1983).

The skeleton of ethylene is formed when sp^2 hybridized orbitals of each of two-carbon atoms overlap to form a sigma bond. Overlap can take place when two p orbitals are placed parallel and the result is the formation of a pi bond. Therefore, a double bond is made up from a sigma bond and a pi bond. Ethylene C_2H_4 is completed when the hydrogen atoms are attached to each of the residual sp^2 hybridized orbitals as in Figure 14(b).

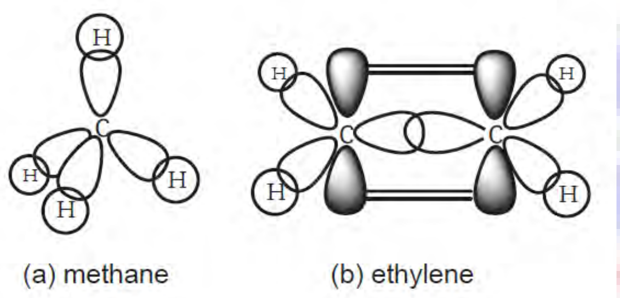


Figure 14: Hybridization geometry of methane (a) and ethane (b) molecules

Implications of the Reviewed Literature on this Study

The literature reviewed has shown that the abstract nature of molecular and hybridization geometry with associate bond angles creates a big gap between reading and visualization on the part of students. Some of the literatures that were reviewed also advocates for the need to bridge gaps in concepts when the teaching molecular and hybridization geometries (Borges & Gilbert, 1999). This suggests that teachers should start the teaching of concepts by using simple models that their students can understand and accept. It implies that the effectiveness of any model meant to be used in teaching needs to be tested. This study is a response to this suggestion, because it tested the effectiveness of physical models of molecular and hybridization geometries with their associated bond angles and a combination of models and diagrams (Visuo-spatial models) against diagrams only, which are the usual teaching aids. It thus attempts to bridge the gap between reading about atomic orbitals and visualization on the part of students. The literature has also shown knowledge of the use of models curriculum, whose development never ends (Gage & Berliner 1992).

Justification of Data Collection Methods Used in the Study

The study gathered information on what accounts for the perceived problems faced by students in studying molecular and hybridization geometry. It also investigated the effect of the intervention strategy on the academic performance of college students.

The nature of such study required the use of several methods in gathering data to make a decision. In such research work, methods like qualitative or/and quantitative can be used, however, many questions have been raised concerning the issues of ascendancy of qualitative research as opposed to quantitative research methods (Guba & Lincoln, 1994; Patton, 2002; Tashakkori & Teddlie, 1998).

According to Patton (2002), qualitative method of research emanated from constructivist point of view and uses an approach that is inductive and holistic to study human experiences within specific environment. Whereas quantitative method is derived from a positivist research paradigm and uses an experimental approach to test hypothetical – deductive generalizations.

In a qualitative research design, the researcher does not manipulate the research environment since the purpose is to understand how phenomena occur in their natural world and records his findings without applying any treatment. Experimental (Quasi-Experimental) research of the quantitative approach on the other hand, tries to control the subjects being studied through manipulating, changing, or introducing some factors in order to measure the behavioural pattern of a set of variable (Shuttle, 2008; Shadish, Cook & Campbell, 2002).

The use of both qualitative and quantitative approaches to research provides inductive and deductive outlook. A researcher is at liberty to use any approach depending on its appropriateness to the research question(s) without necessarily being a student of that school of thought or paradigm. The method that is employed can be separated from the paradigm of which it originated (Patton, 1990).

Due to the fact that the use of qualitative and quantitative approach to research provides both theoretical and practical insight about what is being studied, both are needed to furnish holistic information on this research study.

CHAPTER THREE

METHODOLOGY

Overview

This chapter deals with the research methodology employed in the study. It describes the study site, the research design adopted for the study, population covered by the study, and sample and sampling procedures used in the study. The data collecting instruments, validity of research instruments used in the study, reliability of the research instruments and how the data collected were analysed in the study have also been discussed in this chapter.

The study site

The study was conducted at St. Joseph's College of Education (JOSCO), Bechem, which was established in 1948 and located at the Tano South District of the Brong Ahafo Region of Ghana. The College is one of the Science-Based Colleges among the 38 Public Colleges of Education in Ghana. It has students' population of (831) with permanent teaching staff of (55).

Research Design

This study was an action research that determined the effect of Visuo-spatial model on College students understanding in Molecular and Hybridization Geometries with respective Bond Angles. In action research, the researcher tries to design or organise intervention(s) and use it or them to curtail an identified situation that may be peculiar to a certain educational environment. The goal of action research is both diagnostic as well as remedial. That is, action research when conducted by a teacher, focuses on identifying problems in the classroom and then to improve classroom practices in relation to that problem by the teacher himself. Based upon these features of action research, it was appropriate for this study. However, the study was also quasi-experimental design which employed both qualitative and quantitative techniques to gather data.

Population for the Study

The target population for the study was all science students in the Colleges of Education in Ghana. The accessible population was science students in St. Joseph's College of Education, Bechem in the Brong Ahafo Region of Ghana.

Sampled population

A sample of 120 student-teachers was used for the study. This comprised two cohort groups from two different science classes with one group randomly selected as the control. The control group was taught using the traditional approach.

The other group was used as experimental group where the intervention strategies (Visuo-spatial model/symbolic means and sub-microscopic, Construction of angles and projecting three dimensional shapes with video and computer simulations as well as building molecular shapes and hybridized orbitals with locally available materials) were applied in teaching molecular and hybridization geometries with associated bond angles

Sampling Procedure

Purposive sampling and convenient sampling were used to select the respondents for the study. In purposive sampling, the researcher determines the type of respondents who are appropriate for the study and then selects them. Gray (1981) adds that this method allows the researcher to select respondents who he or she believes are appropriate for the study. Science student-teachers from colleges of education were target for this study because the topic under investigation was a chemistry topic. However, for the sake of having easy access to the accessible population, student-teachers from St. Joseph's College of Education, where the researcher works, were used for the study. This made it convenient for the researcher to gather his data since he was within the same environment. Moreover, simple random sampling was used to group the participants in the course of the exercise.

The simple random technique was used by asking the participants one at a time to pick a number written on sheet of papers folded and kept in a basket. The participants were to pick the number, show it to class for recording and fold it back into the basket for another person to also pick. The picking was done in turns till no one was left out. All those having similar counting numbers were put in one group with the group bearing the name of the counted number picked by the each of the members. Members in such groups were enrolled in course sections (construction of angles, building models and drawing of shapes) designed by the researcher, who served as instructor for the course and also assessed the performance output of the groups and individuals forming the groups. This relationship enhanced the administration and the data collection of the study.

Study Instruments

The nature of study and the level of the target group involved required the use of instruments, such as questionnaires, test item administration, non-participation observation, nominal group discussion and students' group scores, write-ups and interviews. Questionnaires, group presentation and test items were the main instruments used to gather data. The Questionnaires which were closed and open-ended were tagged as "Learning of Molecular and Hybridization Geometries with associate bond angles". The questionnaire was divided into two sections; A and B. Section A sought the demographic data, such as age, sex, class or form of the respondents, while the Section B contained 25 items developed to elicit information to measure the objectives of the study.

The questionnaire, which contained 25 items, was constructed to reflect the contents of the research questions as well as the area of study. To overcome the amount of data it represents, some of the items were purposively grouped into cluster of items that constituted a composite variable which was given an appropriate name. The name represented the common factor of the items making up the variable. This approach lifts discussion up from the items to a more general level (Schreiner & Sjøberg, 2004). However, to identify some interesting stereotypical differences between group profiles, single item analysis were done for some sections of the questionnaire. In this purposive grouping of items, the items to be included in the cluster on the basis of content (subject matter areas) and context were hand-picked. This implies that the clusters of items were not obtained from factor analyses.

However, the clusters were subjected to reliability analysis with logical reasons to measure the internal consistency within a group of items. Internal consistency is the degree to which the items that make up a scale are all measuring the same underlying attribute (that is, the extent to which the items 'hang together'). Since the items forming one composite variable may not be the best possible selection of indicators or items from the universe of indicators relevant to the name of the variable, the composite variable will not to be considered as a construct, but rather an index representing the clustered items (Anderberg, 1973).

Validity of the Instrument

Validity of the instrument deals with the extent to which an account accurately represents the social phenomena to which it refers'. (Hammersley, 1990, p.57). Validity of the data gathered were determined through triangulation, by testing the students, interviewing teachers and using end of semester results. In addition, respondent validity was also used to cross check the information given by individuals.

Reliability of the Instrument

Reliability refers to the degree of consistency with which instances are assigned to the same category by different observers or by the same observer on different occasions (Hammersley, 1992, p. 67). As a result, the reliability of the instruments used for the study was determined by testing copies of the questionnaire on two different science classes in a College which were not used for the study but whose students shared similar characteristics with the research subjects used for the study. The reliability of the pre and post tests were determined using SPSS to determine the Cronbach alpha values. The values obtained were 0.72 and 0.85 for pre-test and post-test respectively. Accordng to George and Mallery (2003), these values (0.72 and 0.85) are good estimates for determination of internal consistencies (Reliability of the instrument).

Again, the interventional strategies were also applied on some students other than those involved in the study which also helped in ensuring validity and the reliability of the results. This also helped in reviewing errors in the interventional techniques and making the necessary modifications.

Data Collection Procedure

The respondents were briefed on the questionnaire after which copies were given out to them. The answered questionnaires were collected 45 minutes after administering them to the respondents. In addition to the questionnaire, diagnostic test items were also administered to the individual students in the two cohorts. This was to identify the challenges faced by students and plan the interventions to that respect.

The experimental group was engaged in lesson activities. These activities included introduction to molecular and hybridization geometries with associate bond angles, (Appendix C), how to determine molecular geometries as shown in Appendix C and D, using locally available materials to construct given organic molecules as shown in Appendix H, drawing the two dimensional view of the designed molecules as well as observing three-dimensional shapes of molecules from PowerPoint and video presentations and transcribing them to two-dimensional forms for the researcher to observe, evidence is attached as Appendix H.

Scoring scheme design by the researcher was used to assign scores to the outcome of activities performed by individual students in both the control and quasi-experimental groups.

In addition, the test scores of the sub groups within the experimental group were also subjected to PGL5C calculation using the formulae;

$$WS = WTF + [\sum ES/TNES]$$

This was done to determine the extent to which learning with VSM through the PGL5C had enhanced College students' achievement in the learning of molecular and hybridization geometries with their associate bond-angles

Moreover, three groups within the experimental group were engaged to write group reports on the interventional strategies whiles two groups also presented a member each to be interviewed. Excerpt from the interview is attached as Appendix G.

Data Analysis

The responses to the questionnaire and the class exercises scores were analysed through descriptive statistical approach. Measures of Central Tendency and Measures of Spread were determined to ascertain the mean scores and the standard deviation as well as the range of score for the two cohorts. The mean scores and the standard deviations were determined in order the compare the level of achievements of the two cohort. Software such as Statistical Package for Social Science Students (SPSS) Version 16.0 and Microsoft Office Excel were used to analyse the quantitative data that were gathered.

Moreover, t-test analysis: Two-Sample Assuming Unequal Variances using Microsoft Office Excel was used to determine whether the treatment (Visuo-spatial model) had significant effect on student-teachers' performance on molecular and hybridization geometries with associate bond angles. Furthermore, the group works that were presented by group members as well as the responses to the interview were analysed using thematic coding with four sub-scales.

Furthermore, the group work on construction of Visuo-spatial models and presentations of models were analysed using PGL5C calculation formula. During the activities, problems were given to students to work in groups (collaboration) as they think critically, communicate, compete and create their models. This approach has been termed as PGL5C by the researcher since it is the last time.

CHAPTER FOUR

RESULTS AND DISCUSSION

Overview

This chapter deals with the demographic data of the respondents and results obtained from the instruments administered, as well as the discussions on the results.

Demographic Data of the Respondents

Four items were constructed in Section 'A' of the questionnaire to elicit responses on the demographic background of the respondents. The data collected has been presented in Tables 1, 2 and 3.

Table 1: Age Ranges of the Respondents

Age (years)	Frequency	Percentage
19-22	22	18.8
23-26	95	81.2
Total	**117**	**100.0**

Table 1 shows information about the age range of the respondents. The respondents who indicated that they were within the age range of 19 to 22 years were 22 in number, representing 19% of the total population. The other 81% consisting of 95 respondents also indicated that they were within the age range of 23 to 26years.

Sex of respondents

Question two of Section A was constructed to determine the Sex representation of the respondents. Table 2 displays the gender differences of the respondents.

Table 2: Sex of the Respondents

Sex of respondents	Frequency	Percentage
Female	55	47.0
Male	62	53.0
Total	**117**	**100.0**

According to the information in Table 2, 55 of the respondents who represent 47% were females while the remaining 62 which represent 53% of the entire sample were males.

Table 3: Type of Courses Offered by the Respondents

Courses	Frequency	Percentage
Mathematics/ science	37	31.6
Agricutural science / technical skills and drawing	12	10.3
General science / technical skills and drawing	58	49.6
Total	**107**	**91.5**

As shown in Table 3, 37 of the respondents representing 32% of the entire sample read Mathematics and Science as their major area of study. Again, 12 of them representing 10% of the population read Technical Skills and Agricultural Science as their major courses, whereas 58 of the respondents also representing 50% of the entire sample, read Science and Technical Drawing.

The remaining 13 of them representing 8.5% did not indicate their course of studies and so was treated as invalid.

Results Related to Research Questions Used

Research Question One: What are the challenges faced by the Science Students of St. Joseph's College during their studies of Molecular and Hybridization Geometries with associated Bond Angles?"

This question had a corresponding null hypothesis which was formulated to verify whether the result obtained could withstand falsification.

The Null hypothesis was stated as:

H_{01}: There are no challenges faced by the Science Students of St. Joseph's College during their studies of Molecular and Hybridization Geometries with associated bond angles".

The research question one (1) was answered with Item 20, which was structured to solicit Information from the respondents (student-teachers) on the kind of challenges faced by students in lessons involving Molecular geometries and hybridization geometries with associated bond angles. The responses obtained are presented in Table 4.

Table 4: Challenges Encountered by Students in First Year Chemistry

Responses	Frequency	Percentage
• Difficult in getting concepts	20	17.1
• Lost interest due to general poor performance	9	7.7
• Teaching was mostly lecturing	9	7.7
• Inappropriate reading materials	5	4.3
• Lack of assignments and activities	4	3.4
• Difficult in getting concept because of lecture method used	53	45.3
• The use of lecture method and no book to revise from.	7	6.0
Total	**117**	**100.0**

According to the responses obtained from the respondents (Table 4), 20 of the respondents representing 17% had difficulties in understanding the concept taught, 9 respondents representing 8% indicated that they lost interest in chemistry because of the general poor performance of students in FDC114C. Also, 53 of the respondents representing 45.3% of the entire sample studied indicated that they had difficulties in getting the concepts, because of lecturing method used by the teachers who handled FDC114C.

Moreover, five of the respondents representing 4% also indicated that they had problems with the use of inappropriate reading materials, whereas four of them representing 3% of the population studied indicated that they were neither given assignments nor engaged in activities during their studies in molecular geometries and hybridization geometries with associate bond angles. Furthermore, 10 respondents representing 9% indicated that the lessons were mostly theoretical in a large classroom, where more classes were combined.

Lastly, seven of the respondents representing 6% indicated that there were no books for them to use as revision materials.

The corresponding Null hypothesis which was formulated to falsify result research question one (result in Table 4) was tested using independent t-test analysis. The result is presented on Table 5.

Table 5: t-test Analysis of Pre-Interventional Test Score for Control and Experimental Groups

	Pre-test score for control group	Pre-test score experimental group
Mean	22.53	22.49
df	118	
t Stat	0.02	
t Critical two-tail	1.98	

Tables 5 presents mean scores of the groups after subjecting scores of the two cohorts to t-test: Two-Sample assuming unequal variances. It was observed that, the mean scores for the two cohorts were almost the same (22.53 for the control group and 22.48 for the experimental group) at the degree of freedom of 118 and for 49 observations.

This confirms that the two groups had similar conceptual understanding, for there were no differences in the ability levels of the two groups.

Again, the t-test analysis of pre-interventional test score for the two cohorts in Table 5 presents a calculated t-value of 0.02 and a tabulated t-value of 1.98. Since the tabulated t is greater than the calculated t, it means that students had challenges during their studies in molecular and hybridization geometries with associate bond angles. Therefore, the null hypothesis cannot be rejected.

Table 6: Descriptive Statistics of the Post-Interventional Scores for the Two Cohorts

	Post-Test Scores for Control Group (X)	Post-Test Scores for Experimental Group(Y)
Mean	36.9	77.6
Mode	45.0	79.0
Standard Deviation	10.3	10.6
Range	43.0	38.0
Minimum	10.0	58.0
Maximum	53.0	96.0
Confidence Level (95.0%)	3.0	3.0

In Table 6, the post-interventional mean score for the control group was 36.92 and 77.60 for the experimental group. Since the post -interventional test mean scores were higher than the pre-interventional test mean scores.

Research Question Two: What are some of the approaches used by the chemistry teachers of the college during lessons in molecular and hybridization geometries with associated bond angles?

In order to obtain information from the respondents to answer the research question two (2) (about the kind of methods used in teaching FDC114C), five items were structured (1tems 4, 9, 12, 22 and 23) to solicit appropriate information.

Item 4

This item was structured to find out how chemistry was taught at the time that the respondents were learning molecular and hybridization geometries with associate bond angles. The results have been tabulated in Table 7.

Table 7: Teaching methods used by Tutors during lessons on FDC 114C

Teaching methods	Frequency	Percentage
Lecture method throughout	63	53.8
Lecture method with chalkboard illustrations	42	35.9
Explanations with demonstrations	12	10.3
Total	**117**	**100.0**

As shown in Table 7, 63 of the respondents representing 54% indicated that their teacher used lecture method throughout, 42 of them representing 36% indicated that their teacher used lecture method and chalkboard illustrations; whereas 12 of the respondents representing 10% indicated that their teacher used demonstrations with explanations.

Item 9

This item was used to find out from the respondents about the rate at which they were allowed to use pair of compass and protractor in constructing angles. The responses obtained have been tabulated in Table 8.

Table 8: How often were students allowed to use compass and protractors to construct angles when they were in Level 100?

Responses	Frequency	Percentage
Very often	47	40.2
Sometimes	48	41.0
Once a while	4	3.4
Seldom	18	15.4
Total	**117**	**100.0**

As shown in Table 8, 48 of the respondents representing 41% of the sample indicated that they sometimes use pair of compasses and protractors to construct angles whereas 4 of them representing 3% of the population indicated that their teachers once in a while expose them to how to construct angles with a pair of compass and protractor.

Again, 18 of the respondents representing 15% of the sample indicated that their teachers seldom exposed them to construction of angles using a pair of compass and protractor. However, 47 of the respondents representing 40% of the sample indicated that they were very often taught on how to construct angles with a pair of compasses and protractors.

Item 12

This item was structured to find out the teaching method commonly used by chemistry teachers during their lessons in FDC114C. The responses given by the respondents have are presented in Table 9.

Table 9: Teaching techniques commonly used by teachers in teaching chemistry (FDC114C)

Responses	Frequency	Percentage
Taking notes with chalkboard illustrations	24	20.5
Reading from books and given explanations	88	75.2
Power Point presentations, Videos and note taking	5	4.3
Total	**117**	**100.0**

According to Table 9, 24 of the respondents representing 20% indicated that their teachers mostly used chalkboard illustrations with notes taking, 88 of the respondents, that is 75% also indicated that their teachers used reading from text books and explained them to the students, and finally 5 of the respondents representing 4% indicated that their teachers used PowerPoint presentation, videos and note taking.

Item 22

This item was used to find out from the respondents whether organic models were used by FDC114C tutors to facilitate learning on lessons in molecular and hybridization geometries as well as the associate bond angles. The responses obtained have been tabulated in Table 10.

Table 10: Respondents' Views on whether Organic Models were used to Facilitate Learning in FDC 114C.

Responses	Frequency	Percentage
Sometimes	12	10.3
Once in a while	28	23.9
Seldom	77	65.8
Total	**117**	**100.0**

As shown in Table 10, 12 of the respondents, representing 10% of the sampled size indicated that their teachers sometimes used organic models to facilitate teaching and learning, whereas 28 of them representing 24% of the sample indicated that their teacher once a while used organic models in facilitating teaching and learning. However, 77 of them, representing 86% of the respondents, indicated that their teacher seldom use organic models to facilitate teaching and learning.

Item 23

This item was used to find out from the respondents the rate at which they were introduced to pictures of molecular shapes during their studies in FDC114C. The responses obtained from the respondents have been tabulated in Table 11.

Table 11: How often were Respondents Introduced to Pictures of Shapes of Organic Molecules?

Responses	Frequency	Percentage
Once a while	47	40.2
Seldom	70	59.8
Total	**117**	**100.0**

Table 11 gives information on the rate at which respondents were exposed to pictures of molecular shapes during their lessons on FDC114C. As noted in Table 11, 47 of the respondents, representing 40% of the sample, indicated that they were once in a while introduced to pictures of molecular shapes whereas 70 of them representing 60% of the sample, made mention of the use of pictures of molecular shapes by their FDC114C teachers.

Research Question 3: What is the effect of the instructional approaches used by the teachers in teaching FDC114C?

In order to obtain information to answer the research question 3, nine (9) items were structured in the section B of the questionnaire to solicit respondents' views and these were items: 1, 3, 13, 14, 15, 16, 17, 18 and 19.

Item 1

This item was structured to find out the impact of the methods used by teachers who handled FDC114 on the interest of the respondents in pursuing chemistry as a course. The views of the respondents have been tabulated in Table 12.

Table 12: Effects of teaching method on the interest level of students in FDC 114C

Level of interest	Number of responding individual	Percentage of responding individual
Very high	5	4
High	27	23
Moderate	37	32
Low	20	17
Lost interest	28	23
Total	**117**	**100**

From Table 12, 4% of the respondents indicated very high interest whiles 23% showed high interest in teaching the concepts.

However, 32% of them, representing the majority, indicated moderate interest and 17% of the respondents also indicated low interest whereas 24% of them indicated lost interest in studying chemistry as a course.

Also, an item was structured to find out the effect of the methods used to teach FDC114C on the grades obtained by the respondents in End of Semester Examinations. The responses of the respondents have been presented in Table 13.

Table 13: Grades obtained by Students in FDC114C

Students, Grade	Number of students with a particular grade	Percentage students' frequencies
A	14	11.5
B+	13	11.0
B	5	4.3
C+	5	4.3
C	18	15.3
D+	12	10.2
D	10	8.5
E	40	34.0

In Table 13, 14 of the respondents representing 11.5% obtained grade A and 13 of them representing 11.0% had grade B^+. Also, 25 of the respondents representing 4.3% had grade B whereas another 5 of the respondents whose percentage frequency was also 4.3 had C^+. As noted in Table 14, 18 of the respondents representing 15.3% obtained grade C while 12 of them whose percentage frequency was 10.2 obtained grade D^+. Finally, 10 of them with percentage frequency of 8.5 had grade D and those who had grade E were 40 representing 40% of the sample.

Item 13 to 19

These items were constructed to find out the impact of the methods used by the FDC114C teachers on the content knowledge of the respondents. The answers given were grouped into two categories; those who had correct answers to the questions and those who had incorrect answers. These have been presented in Table 14.

Table 14: Frequencies of students' correct and incorrect answers on test of students content knowledge on molecular and hybridization geometries with associate bond angles

Item Number	Correct Answers		Incorrect Answers	
	Frequencies	% of the frequencies	Frequencies	% of the frequencies
13	16	13.7	99	84.6
14	62	53.0	55	47.0
15	12	10.3	100	85.5
16	2	1.7	115	98.3
17	5	4.3	112	95.7
18	2	1.7	115	98.3
19	1	0.9	116	99.1

The responses in Table 14 show that the wrong answers given by the respondents were more than their correct answers in almost all the items, except item 14, where 62 of them got the answer correct, and 55 of them had it incorrect. For instance, in responding to item 13, 99 of the respondents representing 84.6% of the sample had wrong answers, whereas 16 of the respondents representing 14% had it right.

The responses to item 15 also showed that 100 of the respondents representing 86% had it incorrect whereas 12 respondents representing 10% had the correct answer. In question 16 and 18, the Table 14 shows that 115 of the respondents representing 98% of the sample had incorrect answers. Again, in either item 16 or 18, 2 respondents representing 1.7% of the sample size had the correct answer.

In responding to question 17, only 5 respondents representing 4% had correct answer. The remaining 112 representing 96% had incorrect answers.

Moreover, the respondents' answers to question 19 shows that only 1 of representing 0.9% got the correct answer while the remaining 116 representing 99% could not get the correct answer.

Research Question Four: What will be the effect of visuo-spatial models on students' performance in molecular and hybridization geometries with associated bond angles?

This research question also had a corresponding Null hypothesis which was stated as: H_{02}: Visuo-spatial models have no significant effect on student's performance in molecular and hybridization geometries with associate bond angles.

In order to determine the effect of the intervention on student's performance data was collected on the respondents' performance on molecular and hybridization geometries with associate bond-angles before using the two different approaches in teaching the two cohorts on the subject matter. This was done to ascertain college students' knowledge on the topics and whether they had similar ability levels before and after applying the two different approaches on the two cohorts.

The scores of students in the two cohorts were subjected to descriptive statistics for the purpose of obtaining information to address research question three and its corresponding Null hypotheses. The descriptive statistics results are presented in Tables 15 and 16.

Table 15: Descriptive Statistics of the Pre-Interventional Scores for the Two Cohorts

	Pre-Test Score for Control Group	Pre-Test Score for Experimental Group
Mean	22.65	22.65
Standard Deviation	10.35	10.32
Confidence Level (95.0%)	2.97	2.96

The mean scores of the two cohorts were the same, 22.65. Moreover, the standard deviations values for both cohorts showed almost the same (with a slight difference of 0.3). That of the control group was 10.34 whereas that of the experimental group was 10.32 as indicated in Table 15.

Table 16: Descriptive Statistics of Post-Interventional Scores for the Two Cohorts

	Post-Test Scores for Control Group (X)	Post-Test Scores for Experimental Group(Y)
Mean	36.92	77.55
Standard Deviation	10.37	10.64
Confidence Level (95.0%)	2.98	3.056

Moreover, similar data were collected after using the two teaching approaches to teach the Molecular and hybridization geometries with associate bond-angles to the respective groups. Table 16 shows that the mean score of the post-interventional exercise for the experimental group to be 77.6, whereas that of the control group was 36.9. Also, the values for the two standard deviations were 10.38 for the control group and 10.64 for the experimental group as indicated in Table 16.

In order to determine the extent to which the Visuo-spatial model has improved academic performance of the experimental group, data was collected during the construction and presentation of the designed models.

The result obtained from the subgroups within the experimental group after scoring their learning competitors on group members' presentations are illustrated in Tables 17 and 18.

Table 17: Working Time Fraction Table for the Groups

Group's Identity	Group's finished time in minutes (WT)	Total time given to each group divided by group's finished time (60/WT)	Working Time Fraction (WTF)
Group 1	28	60/28	2.1
Group 2	36	60/36	1.7
Group 3	34	60/34	1.8
Group 4	50	60/50	1.2
Group 5	26	60/26	2.3

According to Table 17, Group 1used 28 minutes to accomplish the task and this gave them a WTF of 2.1, Group 2 had a WTF of 1.7 because they used 36 minutes to finish the given exercise. It is also indicated on Table 17 that Group 3 finished the given task within 34 minutes with a WTF of 1.8 whereas the Group 4 spent 50 minutes to accomplish their task and so had a WTF of 1.2. Finally, in Table 17, Group 5 spent 26 minutes to achieve their result and this gave them a WTF of 2.3.

Table 18: PGL5C Score table for the Experimental Group

Participating Groups	WTF= 60/x mins	WS=WTF + [∑ES/ TNES]	Winning Positions
Scores For Group 5	2.3	48.3	1ST
Scores For Group 1	2.1	46.1	2ND
Scores For Group 2	1.7	44.7	3RD
Scores For Group 3	1.8	42.8	4TH
Scores For Group 4	1.2	42.2	5TH

Table 18 indicates that Group 5 was declared as the winning group because it had WS value of 48.3. Group 1 had the WS value of 46.1 declaring them as second winners; group two occupied the third position with WS value of 44.7. Group 3 occupied the fourth position with WS value of 42.8 whereas group 4 was declared the 5th with WS value of 42.2.

Also, in order to respond to the Null hypothesis two (H_{02}), the post-interventional test scores of the two cohorts were subjected to t-test. The mean score obtained for the Experimental group was 78.0 whereas that of the control group was 37.0. This is an indication that the Visuo-spatial model might have had a positive influence on students' academic performance than the Conventional (Traditional) teaching approach.

Moreover, the Pre-and Post-interventional scores of the experimental group were subjected to independent t-test analysis to determine the extent to which the VSM approach had enhanced the performance of the experimental group. The result has been presented in Table 19.

Table 19: t-test analysis of Post-interventional test score for Control and Experimental group

variables	Post-test scores for control group (x)	Post-test scores for the experimental group (y)
Mean	36.9	77.1
df	118	
t stat	25.24	
t Critical two-tail	1.98	

At the confidence level of 95.0% and at a degree of freedom of 96 with 49 observations, calculated t-value of 25.2 and a tabulated t-value (tabulated t) of 1.98 were obtained. Since the calculated t is larger than the tabulated t, it means there was a significant difference between the Pre and Post-interventional Scores for the experimental group. Therefore, the null hypothesis is rejected. This means, Visuo-spatial models significantly improved the academic performance of the students in the Experimental group when they were introduced to molecular and hybridization geometries with associate bond angles through VSM.

Qualitative Data

Qualitative data was collected from the students by analyzing their group reports and purposively interviewing two group leaders. The responses obtained were captured under four themes which reflects the research questions that guided the study. The responses given by the respondents' expresses students' perception to molecular and hybridization geometries with associate bond angles prior to the intervention, their attitudes and behaviour towards the interventional strategies as well as the lessons learnt from the interventional strategies.

The excerpt of the data has been presented as Appendix G.

Discussion

This session describes some characteristics of the respondents and also gives accounts on detail descriptions of findings in relation to the research questions

Demographic Data of the Respondents

The average age of the sample population is 24yrs as indicated in Table 3, which shows that they are able to take decisions on their own since people above 18years in many countries are allowed to express their opinion (Ghana Constitution, 1992; Ecuador National Constitution, 2008; Argentina National Constitution, 2012). It was therefore appropriate to solicit views from the respondents through the use of questionnaire. It was in the light of this that the respondents were allowed to express their views by either ticking an option that described their thought or by providing their own answers to questions on Appendix A.

Also, equal chances were given to all individuals; both male and female students in the targeted population to express their views. The male dominance in the samples (53% male as against 47% female) is not too strange and for that matter cannot be used to refute the opinions established since many researches have revealed that male student population outweighs that of female students, especially in science classrooms (American Association of University Women, 1998; Davies & Spencer, 2005). The composition of this sample is therefore not different from the facts already established. Therefore, the views obtained from the sampled population are worth making decisions from.

Moreover, the information obtained from Table 3 indicated that a student in any of the three classes had either studied Mathematics or Technical Drawing before and would therefore not be ignorant about construction of angles. This is because the

Mathematics Syllabus for both Junior High Schools and Senior High Schools expose learners to construction of angles (GES, 2010a). Also, at the JHS level, students are exposed to either Technical Drawing and Skills or Mathematics, where they learn construction of angles. This substantiates the fact that it would be appropriate to introduce the learners to bond angles of molecules by linking it with construction of angles which they are familiar with. This is in line with studies conducted by scholars, such as Granott (1993), Granott and Parziale (1996), which focus on bridging where students learn from known to unknown. Bridging plays a vital role in learning since it is through bridging that learners scaffold their own knowledge. It would therefore be appropriate to use construction of angles which is familiar to learners, to introduce bond angles in FDC114C.

Challenges faced by the Science Students during their studies of molecular geometries and molecular hybridization with associated bond angles

The mean score values obtained from the Pre-interventional (22.65 for the two cohorts) shows that the two cohorts were of similar ability levels. Again, the similar standard deviation values (10.34 for control group and 10.32 for experimental group) for the two groups depicts that the degree of spread of student's scores for both control and experimental groups were similar. Therefore, the outcome of the pre-interventional exercise indicates that the two cohorts had similar characteristics in terms of ability level and conceptual understanding of the molecular and hybridization geometries with associate bond-angles. However, the pre-interventional mean scores were far below the average score of the post-interventional test. This could probably suggests that students were likely to have had problems with the subject matter.

Accordingly, responses obtained from the respondents (Table 4), indicates that students had challenges in learning molecular and hybridization geometries. The kind of challenges indicated by students included having difficulties in understanding the concept taught, lost interest in chemistry because of the general poor performance of students in chemistry and having difficulties in getting the concepts, because of lecturing method used by the teachers.

Other challenges which student indicated they were facing was having problems with the use of inappropriate reading materials, lack of assignments and no engagement in hands-on activities during their studies in molecular geometries and hybridization geometries with associate bond angles.

Some students also indicated that the lessons were mostly theoretical in a large classroom, where more classes were combined with others complaining of lack of reference books for use as revision materials.

Again, t-test analysis of the corresponding null hypothesis of research question one (There are no challenges faced by the science students during their studies in molecular and hybridization geometries with associate bond-angles) presented calculated t-value of 0.02 and a tabulated t-value of 1.98 which suggested that the students had challenges during their studies in molecular geometries, molecular hybridization and associate bond angles. This confirms the reality of the problems enumerated by students. As a result, the null hypothesis could not be rejected.

Chemistry is one of the science subjects upon which technological break-through is built and is the pivot on which the wheel of science rotates. Chemistry is very essential and supportive in fields such as medicine, agriculture, transportation, housing, industries, etc. Life is made more meaningful with chemical products such as drugs, cosmetics, paints, soap, fertilizers, etc. In addition, various careers, such as the health sector, food processing industries, extractive industries, petroleum and petrochemical industries among others, take their roots from chemistry. It is therefore essential to life.

Unfortunately, Chemistry is perceived by students as one of the most challenging courses (Folayan, 1985; Ahiakwo, 2002; Sheehan; 2010). The data gathered from item 20 where 60% of the respondents complained that they had difficulties in getting the concept (Table 4) is therefore not limited to the results of this study alone. It is therefore appropriate for chemistry teachers to find appropriate means of demystifying concept in chemistry so that students can have confidents in studying chemistry as a course. It is rather unfortunate that students have reported that those teachers who facilitated FDC114C could not engaged them in series of activities that could arouse and sustain their interest in molecular and hybridization geometry with associate bond angles.

Table 4 indicates that 8% of the students even indicated that they lost interest in chemistry due to general poor performance in FDC114C. As indicated in Table 4, the challenges faced by learners were enormous ranging from inappropriate reading materials, lack of assignments and activities couple with lack of text books for revisions as well as large class size. This would adversely affect students' performance and interest in chemistry. But it could also be that teachers who taught FDC 114C had poor perceptions about chemistry which might have influenced their teaching styles. For instance, as students viewed chemistry as a difficult course the teachers might have also perceived otherwise and this could adversely affect students' conception and understanding (Iyewaran, 1985; Jimoh, 2003).

Moreover, an analysis of the pre-interventional and post-interventional means scores showed mean differences of 14.40 for the control group and 55.12 for the experimental group. Although the similar values obtained for the pre-interventional test mean scores indicated that the two cohorts had similar conceptual thoughts about Molecular and hybridization Geometries with associate bond-angles, the large mean difference between pre and post-interventional test of each group is an indication that both groups had conceptual challenges before administration of the lessons with the two approaches. Again, the larger mean difference value (55.12) for the experimental group suggests that the challenge was very significant. Moreover, the minimum score (58) of the experimental group far outweighs the maximum score (53) for the control group. This means that a student who scored low in the experimental group is likely to be the best performing student in the control group. It can also be noticed that the intervals between the scores of the experimental group are closer (38) than that of the control group (43). This means that the gap between the ability levels of the students in the control group has been widened where as that of the experimental group is closer. Again, the modal score of the experimental group (79) is one and half times more than the modal score of the control group. This also indicates that students in the experimental group performed better than those in the control group.

The result obtained is in line with studies conducted by Krajcik (1991) which pointed out that students have difficulties in learning chemical representations. A related study by Ben-Zvi, Eylon and Silberstein (1987) also pointed out that most chemistry students after receiving substantial chemistry instruction still holds misconception about chemical representations and structures.

Moreover, studies conducted by Kozma and Russell (1997) revealed that students are less capable of providing equivalent representations for a given representation. It was therefore not surprising to witness students' poor performance in the pre-interventional test because students might have received instructions on the concept without any conceptual understanding. For instance, a study has shown that large number of students was unable to make translation among formula, electron configuration, and ball-and-stick model when students' performances on translations were correlated to their understanding of underlying concepts (Keig & Rubba, 1993). Keig and Rubba (1993) attributed students' inability to make translation among formulas to lack of understanding of the underlying concept. This argument is also supported by Lesh, Post and Behr (2003) who argued that conceptual knowledge allows students to interpret the information provided by the initial representation and without it students will face difficulties in constructing the target representation.

As a result, chemistry students who are not exposed to hands and minds-on activities can easily encounter some conceptual challenges as witnessed in the case of students in St. Joseph College of Education.

Approaches used to facilitate lessons on molecular and hybridization geometries with associated bond angles

The different strategies that a teacher adopts to communicate his / her learning materials are called teaching techniques. Therefore, for effective science teaching, a teacher should have the ability to create a productive and supportive learning atmosphere for students to conceptualize information, master skills and develop their mind to optimum level (Erinosho, 2008). Lecture is one of the teaching methods where an instructor is the central focus of information transfer. Typically, an instructor will stand before a class and present information for the students to learn. Sometimes, they write on boards or use overhead projectors to provide visuals for students.

Students are expected to take notes while listening to the lecture and very little exchange occurs between the instructor and the students during that period. This method which is teacher-centered is still the most popular instructional method in the universities (Zhenhui, 2001; Wang & Farmer, 2008). During the lecture method, knowledge is transmitted from the teacher to students (Zhenhui, 2001), and this affects the rate at which a student can assimilate and comprehend concepts. Studies have also shown that most teachers are not familiar with modern teaching methods (Stitt-Gohdes, 2001), and would therefore use the lecture method in most cases (Benjamin, 2002; Rahmani, Mohajjel-Aghdam, Fathi-Azar & Abdullahzadeh 2007; Saville, 2009).

According to Brown (2003), most teachers have been taught in learning environments that were instructor-centered, therefore, they teach in the same way too. It was therefore not surprising to see most of the respondents indicating that FDC 114C teachers were mostly using lecture method in their presentations as indicated in Table 8. Even though the lecture method can be purposively used, especially in the large class size, its use normally restricts interaction between teacher and his or her students, and this is a disadvantage since the teacher may not know the extent to which learning has taken place.

Studies have shown that teacher-centered teaching methods are not appropriate to teach students in fields of training (Caudron, 2000). Some studies have also shown that training students prefer teaching methods with more student involvement (Salsali, 2005). Some conflicting results have also been reported when academic investigators compared the effects of lectures and more active teaching methods (Barnes & Blevins, 2003, Yoder & Hochevar, 2005; Riggio, 2007; Saville, 2009). Over use of lecture method will induce a hidden curriculum that teaches students to be obedient, compliant and inexpressive, and also reduce their self-confidence (Espeland & Shanta, 2001).

It can therefore be said that the various teaching methods indicated by the respondents in both Tables 7 and 9 as methods used by FDC114C teachers would be considered as not appropriate, since they are teacher-centered methods. Hence, such methods are likely to inhibit students understanding in molecular and hybridization geometries with associated bond angles. Therefore, it is not wrong to associate the challenges encountered by the respondents in FDC114C as indicated in Table 4 to the above teaching methods. Moreover, studies have shown that training students prefer teaching methods with more student involvement (Salsali, 2005), pictures and organic models which could have enhanced students understanding by getting them involved were not frequently used as indicated in Tables 11 and 12, and this is also likely to inhibit students' understanding in lessons about molecular and hybridization geometries.

Effect of the instructional approaches used in teaching FDC114C (molecular and hybridization geometries)

It is obvious that instructional methods play a major role in students' understanding of a concept. Learning atmosphere can be created from three teaching styles (instructional methods): discipline - centred, teacher – centred and student – centred (Woods, 2005). Both discipline and teacher-centered approach make learners passive and regurgitate content without making any effort to apply or transfer content to real life situations. The focus of these two teaching styles is transmission of information, and helps students in mastering of facts through illustrations, whereas lecturing and explanations are for examination purpose. In the latter, learning of concepts tends to be memorization, since student-teacher interaction is minimal (Erinosho, 2008).

Student-centred approach enhances how learners conceptualize and assimilate information by making use of learner's cognitive abilities and interest (Erinosho, 2008). It is therefore believed that lack of student-centered approach could equally be the reason why that significant number of the students failed in chemistry (FDC114C) as indicated in Table 13

The teacher who serves as a facilitator has to ensure that learners take active role in their learning by motivating the learner to conduct his own investigations, develop ideas and be ready to discuss ideas with other students for criticisms.

Moreover, in science, resource serves as teaching and learning aid. Those that support teaching are classified as teacher-centred aid, whereas those that support learning are under the category of student-centred aid. Either of them (teacher-centered or student-centered aid) is selected by the teacher based on their availability, efficiency and appropriateness for the learning context. Unfortunately, less emphasis was placed on the use of learning resources, such as organic models and pictures of molecular geometries as indicated by the respondents in Tables 9 and 10.

It is therefore, not surprising to see majority of the respondents indicating in Table 10 that they were not motivated and, hence, rating their interest from loss of interest through low interest moderate interest as opposed to the minority which indicated either high or very high.

Strangely, when the seven items (items 13-19) were constructed to find out the impact of the teaching method used in FDC114C on the content knowledge of the respondents, an average of 83.5% of respondents had wrong answers in the seven questions. For example, in item 14, 53% of the respondent had the right answer as opposed to 47% who had it wrong. During interactive discussion with teachers who taught molecular and hybridization geometries with associate bond angles on of the teachers attributed the poor performance of students in the test items to lack of teaching-learning resources which inhibited him from making things clearer to learners. The other teacher blamed students for not being serious in reading because everything was in the notes given to the students.

Contrary, to the view given by the first teacher, Erinosho (2008) argues that the non-human teaching and learning materials that are not available must either be purchased or improvised from the locally available materials. This means that for effective teaching and learning, a teacher must be innovative, and should have the ability to use the hands-on and mins-on to teach in a meager- resourced classroom environment.

It can therefore be assumed that if the teachers had combined their teaching methods with the learner-centered approach, learners would have been profitably engaged in searching for and conceptualizing knowledge in a more meaningful way that could reduce poor conceptualization of molecular and hybridization geometries with associate bond angles.

Effects of Visuo-spatial models in teaching molecular and hybridization geometries.

The findings obtained after testing the Null hypothesis two (H_{02}) revealed a significant difference between the two instructional approaches used, since the calculated t-value of 19.1 was greater than the tabulated t-value of 1.98.

Again, the findings obtained from the t-test analysis of post-interventional scores for the two cohorts reveal that the Visuo-spatial models approach enhanced students' academic achievement far better than the traditional (Conventional) teaching approach, since the mean scores of the Experimental group and the Control group were 78.0 and 37.0, respectively. This proves that the use of the Visuo-spatial models enhanced the students' conceptual understanding far better than Conventional approach. The significant difference between the mean scores of the control and the experimental group (mean difference of 41) justifies the assertion made by Snir, Smith, and Raz, 2003), when they concluded that Visuo-spatial models help students engage with fundamental ideas, especially, for students who have developed relevant macroscopic and interrelated conceptions and, therefore, can result in greater achievement in science than the Conventional instructional approach.

Furthermore, the differences in performance between the two cohorts may be attributed to many other reasons. For instance, the use of the Visuo-spatial models in teaching and learning environment gives the learner more freedom to operate. As a result, the Visuo-spatial models were likely to increase students' eagerness to study the concepts presented and this could possibly yield a good achievement scores than the Conventional approach where the teacher always 'feeds' the learner with information. The conventional approach restricts the learner from thinking without satisfying their academic curiosity. As a result of poor achievement yield of the Conventional teaching approach, Hunter (1997) downgraded the use of Conventional teaching approach on the basis that it does not permit the learner to build the necessary intrapersonal connections that are essential for learning.

Moreover, the use of Visuo- spatial models encourages learners to interact with their environment and among themselves. This is likely to enhance their communication skills, critical thinking ability, as well as ability to criticize their works and accept criticism. For instance, the groups' presentations and write ups in Appendix F clearly indicates how the learners appreciated and criticized other works by comparing their group work to others.

This is also in line with the outcome of a research conducted by Cartier, Rudolph, and Stewart (2001), which reported that curricula include sets of model representations that provide students with opportunities to learn about the conceptual subject matter of particular disciplines and the nature of scientific knowledge. It can therefore be suggested that the use of Visuo-spatial models in teaching enhanced students' ability to visualise their imaginations as well as the thoughts they had about concepts of which molecular and hybridization with associate bond-angle has no exception. Therefore, this could positively contribute to the higher performance among the experimental group. In addition to the above reasons, interacting with peers also reduces students' shyness and builds their confidence levels. These might have also positively influenced students' performance in Molecular and Hybridization Geometries with associate Bond-Angles.

Again, the low achievement scores of the Control group is also in line with studies conducted by Johnson, Aragon, Shaik, and Palma-Rivas (2000), which reported that the use of Conventional teaching approach does not support student's academic satisfaction.

Moreover, the result obtained from the comparative analysis of the post-interventional mean scores which indicated a mean difference of 40.9, in favour of the use of Visuo-spatial models in teaching also confirms that the interventional strategy was able to improve students' performance in the topic.

This is even evidenced in the PGL5C calculation in Tables 16, 17 and 18 where students in the experimental group had close scores which were closer to the total grading mark of 10. Besides the group reports presented by students, the PBL5C activity given by the individual groups in the experimental group which has been assembled as Appendix F revealed that the Visuo-Spatial models had impacted on student's achievement scores. Information in some of the reports presented by the students in the experimental group indicated that they were able to evaluate their own models and those models designed by the other groups which have been captured as plates in appendix G.

According to Burns (2007), students' correct answers are not sufficient for judging their understanding unless they include explanations of how they reason. Therefore, having students share their verbal explanations helps develop conceptual understanding (Ketterline-Geller, Jungjohann, Chard, & Baker 2007). Moreover, according to Blooms taxonomy, the highest and the most difficult level of the cognitive domain is evaluation (Bloom, 1985). Therefore, being able to evaluate Visuo-spatial models designed by other groups clearly indicates high understanding of the concepts being taught, and therefore the high achievement scores among the experimental group justifies their conceptual understanding and performance by the use of Visuo-spatial models.

Discussion of the Qualitative Data

The write ups and the group members responses to the unstructured interviews were grouped under four themes which are:

Students' difficulties in learning the concept, how it was presented to them in their previous levels (SHS), the impact of the PGL5C approach and any new thing learnt. These themes relate to the research questions that were formulated for the study.

With regard to students' difficulties, student indicated in their write ups that they had difficulty representing the models with local materials. Others also indicated that they models used by their groups were not appropriate for what they intended to do. However, it was noted in the write ups that other groups were able to evaluate the models designed by another group. This shows that student had better understanding than before because according to the revised bloom's taxonomy, evaluation is the highest order of learning.

Another aspect of the difficulties encountered by students on the subject matter was based on fears in comprehending the concept. According to those who were interviewed, students had being filing FDC 114C due to their inability to conceptualise the topic. This preconceived idea discouraged students from learning about the subject matter. As a result, there was the need to arouse and sustain their interest. The used of the audio-visuals became very good intention technique for arousing students' interest as stated by some of the students who were interviewed.

In terms of the way the topics were exposed to students, students complained that the topic was presented to them in theoretical means through notes taken. Others indicated that they never knew such topics could be treated using local available materials (SLG4).

The impact of the interventional approach can be tracked from the two write-ups and the two un-structured interviews. In the write-ups, both group 2 and 3 members indicated that the activity was interesting, particularly, with the design of the models. Others also had opportunity to evaluate the models designed by others (Group 2). Therefore it can be surmised that the interventional strategy gave the students opportunity to become analytical in thinking.

Again, the interventional strategy provided the platform for students developed their speaking skills and enhanced their relationship with members in the group by discussing among themselves. The discussions session also removed shyness and fearfulness among students as stated by SGL4.

CHAPTER FIVE

SUMMARY OF FINDINGS, CONCLUSIONS, RECOMMENDATIONS AND SUGGESTIONS FOR FURTHER RESEARCH

Overview

This chapter summarizes and concludes the study as well as recommends possible ways of improving the study. It talks about the challenges faced by students when the conventional methods of teaching are used in teaching molecular and hybridization geometries. This study also elaborates on the influence of viuso-spatial models on the academic performance of college students.

Summary of Findings

The results of the study showed that student had challenges in studying chemistry. These difficulties were identified to be associated with factors such as, lack of practical approach of teaching, using lecturing method as the only method of teaching FDC 114C (chemistry). Other factors that were also identified as challenges faced by students in studying chemistry (molecular and hybridization geometries) included putting large number of students in large hall and reading pamphlets to their hearing.

The results of the study also suggest that the students who were exposed to the Visuo-spatial models performed better than their counterparts who were taught using the traditional method of teaching. Perhaps, the high performance of students in the experimental group may be due to the fact that the models used in teaching molecular and hybridization geometries describe natural processes better and offered clearer understanding to the students in the experimental group than those exposed to the conventional teaching approach. Again, the high performance scores among the experimental group showed that the use of physical manipulation and handling of objects during the construction of visuo-spatial models by the students in the experimental group was very effective. This appears to suggest that physical manipulation and handling of objects is an effective way for students to learn science and for that matter chemistry.

Moreover, in the course of the construction of the VSM and during studies using the VSM the PGL5C learning approach (through the use of VSM) was discovered by the researcher as a new way of learning. This new way of learning (PGL5C) was found to be effective way of learning because it enhanced communication skills of learners. It offered opportunity for learners to communicate ideas within groups and among groups. It also builds the sense of belongingness among learners especially, where their views were accepted within the smaller group discussion or whole class discussions. Learners also learn how to criticize opinions without attacking personalities and also how to accept criticism when they work in collaboration.

The PGL5C learning style of the Visuo-spatial learning approach encouraged hands-on learning of science as students were typically holding, touching, moving, observing, listening, smelling, and sometimes tasting objects under investigation in an approach called multiple senses in learning.

It was therefore not surprising when the members in the experimental group were able to explain concepts in molecular and hybridization geometries better than their counterparts in the control group. Moreover, the used of videos and power point presentations in the interventional approach gave students the opportunity to explore and discover concepts in real world. This also suggests that using videos in teaching is also useful for improving students' visuo-spatial skills, providing techniques for creative visualization, and allowing the use of various visual- learning modes.

Similarly, the Videos used in teaching experimental group improved their Visuo-spatial thinking and this might have influenced their Visuo-spatial skills in constructing their own models as presented in Appendix H.

Conclusions

The numerous researches done in Science Education advocate engagement of the learner in the teaching and learning processes, where the teacher acts as a facilitator through a teaching approach called learner-centeredness. In child-centred approach, the teacher only prepares and disturbs the environment for the learner who is motivated to manipulate the available learning materials in order to bring orderliness.

The study revealed that when students learn science by manipulating and interacting with their environment. The activities engaged multiple senses of these students such as sense of touch, seeing (sight), hearing, smelling as well as tasting which help them (students) to construct their own body of meaningful knowledge as they gradually moves from concrete to abstract thinking. As a result, the study encourages teachers to use the learner-centered approach, which motivates learners to become information seekers rather than empty vessels, which the teacher has to fill with knowledge.

The outcome of the study suggest that the conventional approach used in teaching FDC 114C (Chemistry) is not friendly to learners. For instance, the reading of Handouts contents by teachers and at the same time providing explanations to students were considered as one of the learning challenges faced by Chemistry students. Other complains obtained from the students included the use of only lecture method in facilitation and putting students in large groups for chemistry lessons. These observations suggest that poor and unfriendly pedagogical practices such as the use of lecture method only, or reading from pamphlet while explaining to students are some of the factors that contribute to poor performance of students in science.

The study suggest that the best options for teachers to improve student's performance in science and for that matter chemistry is to modify their pedagogical skills by shifting from any teaching approach that promote teacher centredness to that which promote complete learner-centredness. As revealed in the results of this study, the used of visuo spatial models through PGL5C approach promoted creativity, critical thinking skills, collaborative skills and effective communicative skills among group members. The use of the visuo spatial models through PGL5C also promoted the four pillars of learning advocated by UNESCO (learning to know, learning to do, learning to live together and learning to be).

There is therefore the need for science teachers, especially, chemistry teachers to integrate the use of visuo-spatial models in their teaching in order to arouse and sustain student's interest in the study of topics in chemistry; particularly, lessons involving molecular and hybridization geometries with associate bond angles. The use of VSM constructed by the students made the learning of chemistry meaningful to them and so enabled the students to easily discard the misconception that "chemistry is for particular group students who have high intelligent quotient (HIQ)". Again, the use of VSM in Colleges of Education will permit student teachers to enjoy learning of lessons in chemistry and also see chemistry as a subject that requires exploratory skills, which students can study by exploring their learning environment rather than ‘spoon feeding them’.

Recommendations

Based upon the outcome of this study, the following recommendations have been made;

1. The study suggested instructional aids such as Teaching-learning materials as well as the teaching and learning approaches to be used by facilitators should gear towards the use of Visuo-spatial models which allow learners to explore their learning environment as they construct their own knowledge. Such facilities are likely to enhance meaningful learning suggested by Ausubel (1963). Using Visuo-spatial models allows students to explore their environment and construct knowledge that makes meaning to them. When students construct their own knowledge, it can never be forgotten since learners see such knowledge as their bonafide property.

2. Moreover, provision should be made for construction of relevant Visuo-spatial models using locally available materials. This will encourage students to relate chemistry to the environment instead of imagining chemistry as a subject for students with high Intelligence quotient. This will also develop both the constructive and abstract thinking abilities of the learners as they imagine or visualize constructing or constructing to imagine how relevant and appropriate constructed model is. It will also improve upon the judgement or evaluative skills of learners since they will evaluate whatever they construct before they publicise it.

3. Finally, it is recommended that JOSCO management should organise departmental in-service training for chemistry teachers and expose them to construction of and teaching with Visuo-spatial models. This will help chemistry teachers to update their knowledge on how to make lessons more of learner-centred.

Suggestions for Further Research

The following suggestions have been made for further scientific investigations:

1. Since the study was limited to only molecular and hybridization geometries, it is suggested that Science Education Researchers should investigate whether Visuo-spatial models can also be used to improve students' performance in other chemistry topics.
2. Again since the study was limited to only students in JOSCO, it is suggested that similar study should be conducted among other science students in other Colleges of Education. This will also help to verify the reliability of the approach used.
3. Finally, the study was limited to the use of only one interventional strategy, it is therefore suggested that researchers should do a comparative study on the impact of VSM and any other well recognised learner-centred approach.

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APPENDIX A

[PRE-INTERVENTIONAL QUESTIONNAIRE]

"LEARNING OF MOLECULAR AND HYBRIDIZATION GEOMETRIES AND THEIR ASSOCIATED BOND ANGLES"

The following questions have been structured to solicit your opinion about the difficulties faced by College students in FDC114C so that some decisions can be implemented. Your contributions will be treated as confidential without disclosing your Identity to any group of persons or individuals. Kindly respond by either circling letters associated with the options that best describe your opinion or provide your answers in situations where spaces are provided.

SECTION A

Age : a. 15-18 b. 19-22 c. 23-26 d. Beyond 26

Gender : a. Female b. Male

Level : a. 100 b. 200

Programme: a. Maths/Science b. Maths/Technical c. Technical /Agric d. Science/Tech

SECTION B

1. How did you rate your interest level in Chemistry after FDC 114C end of Semester result was released?

    a. Very High, b. High c. Moderate, d. Low, e. Lost interest

2. Which of the following factors accounted for such interest level?

    i. Abstract nature of FDC 114C

    ii. Difficulty in getting the concept learnt

    iii. Instructional method and the nature of TLMs used (Note: TLM include chalkboard illustrations)

    a. I b. II c. III d. I and II e. I, II and III

3. What was your grade in EDC111?

    A B^+ B C^+ C D^+ D E

4. Which of the following best describes the way Chemistry was taught at the time you were learning FDC 114C?

    a. Lecture method throughout

    b. Lecture method with chalkboard illustrations

    c. Explanations with demonstrations

    d. Explanations with Videos, computer simulations, manipulation of objects and diagrams

5. I like watching movies.

    a. Strongly agree b. Agree c. Neutral d. Strongly disagree e. Disagree

6. I have interest in working with computer.

   a. Strongly agree b. Agree c. Neutral d. Strongly disagree e. Disagree

7. I like learning through reading and listening.

   a. Strongly agree b. Agree c. Neutral d. Strongly disagree e. Disagree

8. I have interest in learning through manipulation of objects.

   a. Strongly agree b. Agree c. Neutral d. Strongly disagree e. Disagree

9. How often did you use compass and protractors in construction of angles when you were in level 100?

   a. Very often b. Sometimes c. Once in a while d. Seldom

10. When was the last time you learnt about three-dimensional drawing?

    a. Year one b. Year two c. Both year one and two d. Not at all

11. Which of the following courses do you read at College?

    i. Mathematics ii. Pre-technical skills and drawing iii. Science

    a. i and ii b. I and iii c. ii and iii d. i, ii and iii

12. Which of the following teaching methods was commonly used during your lessons in FDC 114C?

    a. Taking notes with chalkboard illustrations
    b. Reading from book and given expiations
    c. Power point presentations, videos and note taking
    d. Combination of methods in a, b and c

13. All the carbon atoms in Ethyne are having;

    a. SP^2 hybridization state

    b. SP hybridization state

    c. SP^3 hybridization state

    d. SP^3d hybridization state

14. Ammonia has

    a. Trigonal shape with 120^0 bond angle

    b. Tetrahedral shape with 107^0 bond angle

    c. Octahedral shape with 80^0 bond angle

    d. Tetrahedral shape with 90^0 bond angle

15. Ammonia and water have;

    a. Different molecular shapes with different bond angles

    b. Similar molecular shapes with similar bond angles

    c. Similar molecular shapes with different bond angles

    d. Different molecular shapes with similar bond angles

16. Methane is a

    a. Linear molecule with bond angle of 90^0.

    b. Square shaped molecule with bond angle of 90^0.

    c. Tetrahedral shaped molecule with bond angle of 109.5^0.

    d. Bimolecular shaped molecule with bond angle of 120^0.

17. How many lone pairs of electrons are there in:

    a. Water molecules? ________________________

    b. Ammonia molecule? ______________________

18. Lone pair(s) of electron has/have no effect on the molecular shape, bond angles of and hybrization state of the central atom of molecules.

    a. Strongly agree b. Agree c. Neutral d. Strongly disagree e. Disagree

19. Determine the hybridization state of carbon atoms and the molecular shapes of the following compounds.

    a. $>C=C<$ ....hybridization and ....shape

    b. $-C\equiv C-$ ....hybridization and ....shape

    c. O=C=O ....hybridization and ....shape

20. What were some of the challenges you encountered during lessons in FDC111?

    i. ....

    ii. ....

    iii. ....

21. In your opinion, what accounted some of these challenges?

    i. ....

    ii. ....

22. How often were you allowed to use organic models in constructing molecular shapes?

    a. Very often b. Sometimes c. Once in a while d. Seldom

23. How often were you introduced to pictures of shapes of molecules by FDC114C teacher, during his/her presentations?

    a. Very often b. Sometimes c. Once in a while d. Seldom

24. How do you expert Chemistry concepts to be taught for you to appreciate the interesting nature of Chemistry?

____

____

APPENDIX B

[POST-INTERVENTIONAL TEST]

ST. JOSEPH'S COLLEGE OF EDUCATION, BECHEM

DEPARTMENT OF SCIENCE EDUCATION

FDC 114C: CHEMISTRY

1. All the carbon atoms in Ethyne are having;

   e. SP^2 hybridization state

   f. SP hybridization state

   g. SP^3 hybridization state

   h. SP^3d hybridization state

2. Ammonia has

   e. Trigonal shape with 120^0 bond angle

   f. Tetrahedral shape with 107^0 bond angle

   g. Octahedral shape with 80^0 bond angle

   h. Tetrahedral shape with 90^0 bond angle

3. Ammonia and water have;

   e. Different molecular shapes with different bond angles

   f. Similar molecular shapes with similar bond angles

   g. Similar molecular shapes with different bond angles

   h. Different molecular shapes with similar bond angles

4. Methane is a

   e. Linear molecule with bond angle of 90^0.

   f. Square shaped molecule with bond angle of 90^0.

   g. Tetrahedral shaped molecule with bond angle of 109.5^0.

   h. Bimolecular shaped molecule with bond angle of 120^0.

5. How many lone pairs of electrons are there in:

   c. Water molecules? ________________________

   d. Ammonia molecule? ______________________

6. Lone pair(s) of electron has/have no effect on the molecular shape, bond angles of and hybrization state of the central atom of molecules.

   b. Strongly agree b. Agree c. Neutral d. Strongly disagree e. Disagree

7. Determine the hybridization state of carbon atoms and the molecular shapes of the following compounds.

   d. >C=C< ....hybridization and ....shape

   e. —C≡C— ....hybridization and ....shape

   f. O=C=O ....hybridization and ....shape

8. Determine the Hybridization and Molecular Geometries of:

   a. NH_3 b. H_2O c. CH_4 d. CO_2

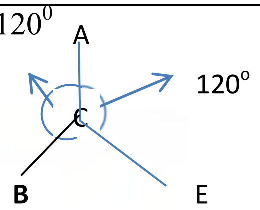
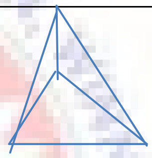
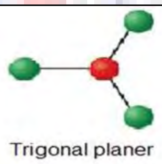
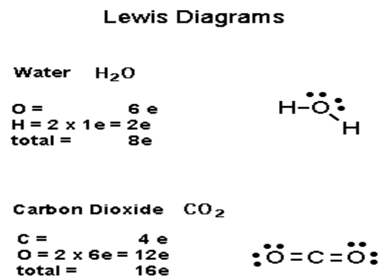
9. Determine the bond angles of the following Molecules:

   a. H_2O b. NH_3 c. CO_2 d. CH_4

10. Using structural examples, differentiate between Electron (Hybridization) and Molecular Geometries of a named compound.

APPENDIX C

HINTS FOR LESSON 1

TEACHER'S ACTIVITIES	**LESSON HINTS**
Introduction Introduce the lesson by asking students to define an angle	Angle is the meeting point of two lines.
ACTIVITY Let students construct a fan blade with three blades such that angles ACB and ACE = 120^0	120^0 
Let students measure angle ECB and write its value	120^0
Ask students to draw lines to touch the ends of the shape they have drew (from A to B, B to C and from C to A)	
Ask students to name the shape they have developed	Triangular shape
Use students' answers to discuss examples of molecules with such shapes with students.	CO_3^{2-}, O_3
using members from Alkenes, ask students identify compounds constructed from organic models with similar shapes and discuss their properties in terms of molecular geometry, hybridization geometry and bond angles with students	 Molecular Geometry is Trigonal planar, Bond angle is 120^0 Hybridization geometry is Sp^2
ACTIVITY 2 Guide students to determinine the geometric structures (molecular geometries) of H_2O and CO_2. by starting with drawing the Lewis structure:	

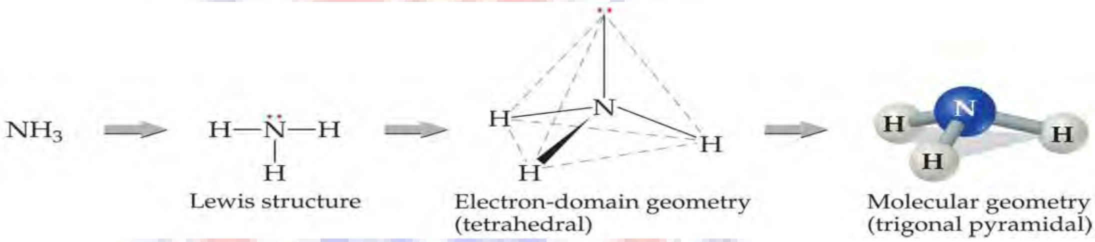
Class discussions on molecular Shape and bond angles of between O-H bonds in water	H_2O: Water has four electron groups so it falls under tetrahedral for the electron-group geometry. The four electron groups are the 2 single bonds to Hydrogen and the 2 lone pairs of Oxygen. Since water has two lone pairs, its molecular shape is bent. According to the VSEPR theory, the electrons want to minimize repulsion; so as a result, the lone pairs are adjacent from each other. CO_2: Carbon dioxide has two electron groups and no lone pairs. Carbon dioxide is therefore linear in electron-group geometry and in molecular geometry. The shape of CO_2 is linear because there are no lone pairs affecting the orientation of the molecule. Therefore, the linear orientation minimizes the repulsion forces.

APPENDIX D

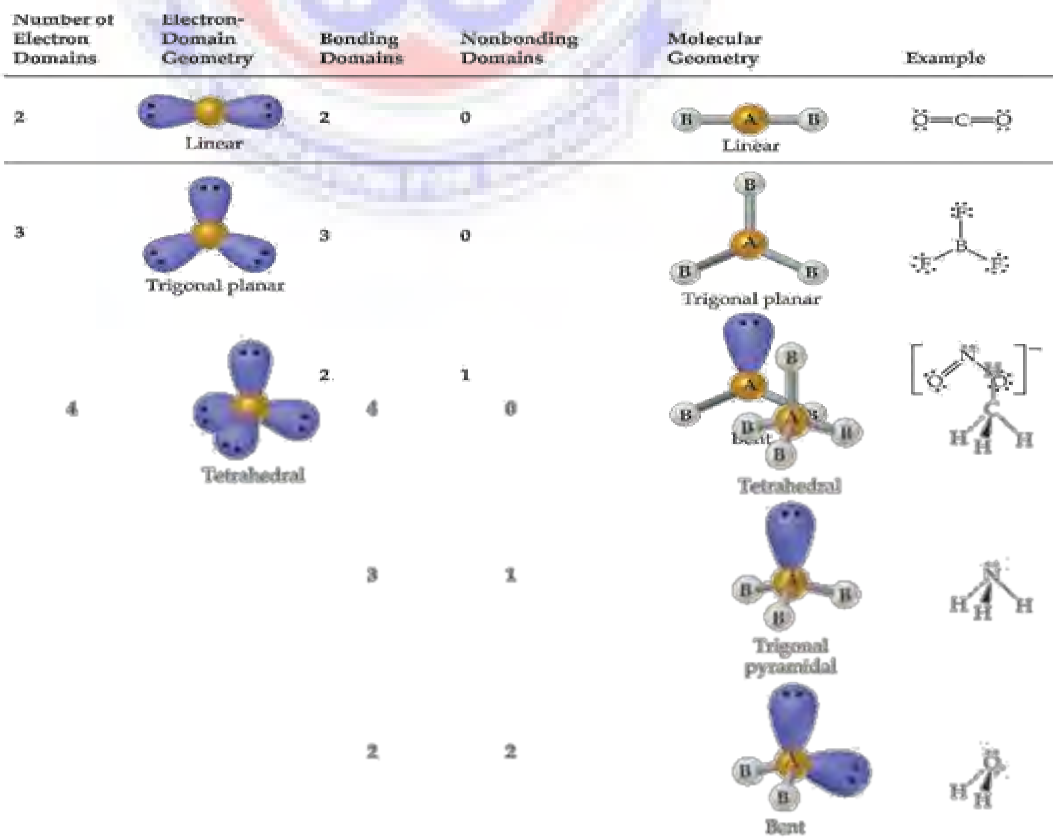
HINTS FOR LESSON 2

HOW TO DETERMINE THE MOLECULAR GEOMETRY

1. Draw the Lewis structure of the molecule.
2. Determine the electron-pair geometry (count electron domains: double and triple bonds counted as one domain.
3. Focus on bonded-electron pairs ONLY to determine the molecular geometry (MG).
4. Examples are given below;



APPENDIX E



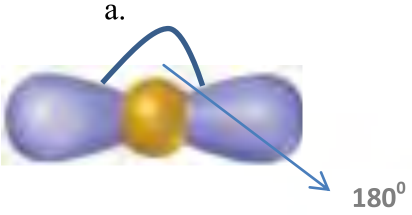
Number of Electron Domains	Electron-Domain Geometry	Bonding Domains	Nonbonding Domains	Molecular Geometry	Example
2	Linear	2	0	Linear	O=C=O
3	Trigonal planar	3	0	Trigonal planar	F, B, F, F
		2	1	Bent	[O N O]$^-$
4	Tetrahedral	4	0	Tetrahedral	C, H, H, H, H
		3	1	Trigonal pyramidal	N, H, H, H
		2	2	Bent	O, H, H

STUDENTS' GROUP ACTIVITIES

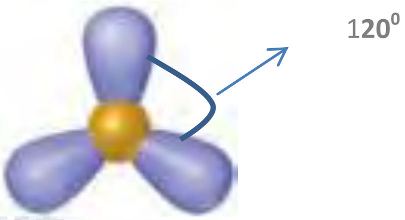
CONSTRUCTION OF MOLECULES WITH ASSOCIATE BOND ANGLES

1. Use any locally available material to construct the following molecules and determine the molecular geometry of each of them.

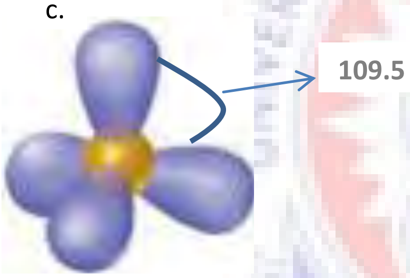
a.



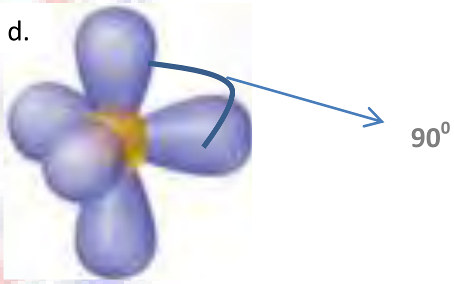
b.

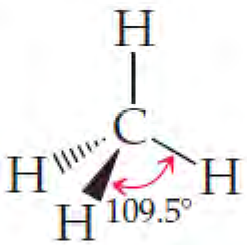


c.

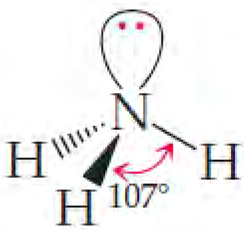


d.

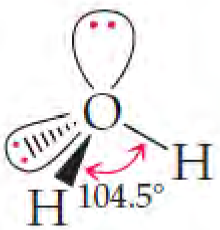




e.



f.



g.

2. Let students observe simulations and videos of molecules on the projector mat and ask them to determine;

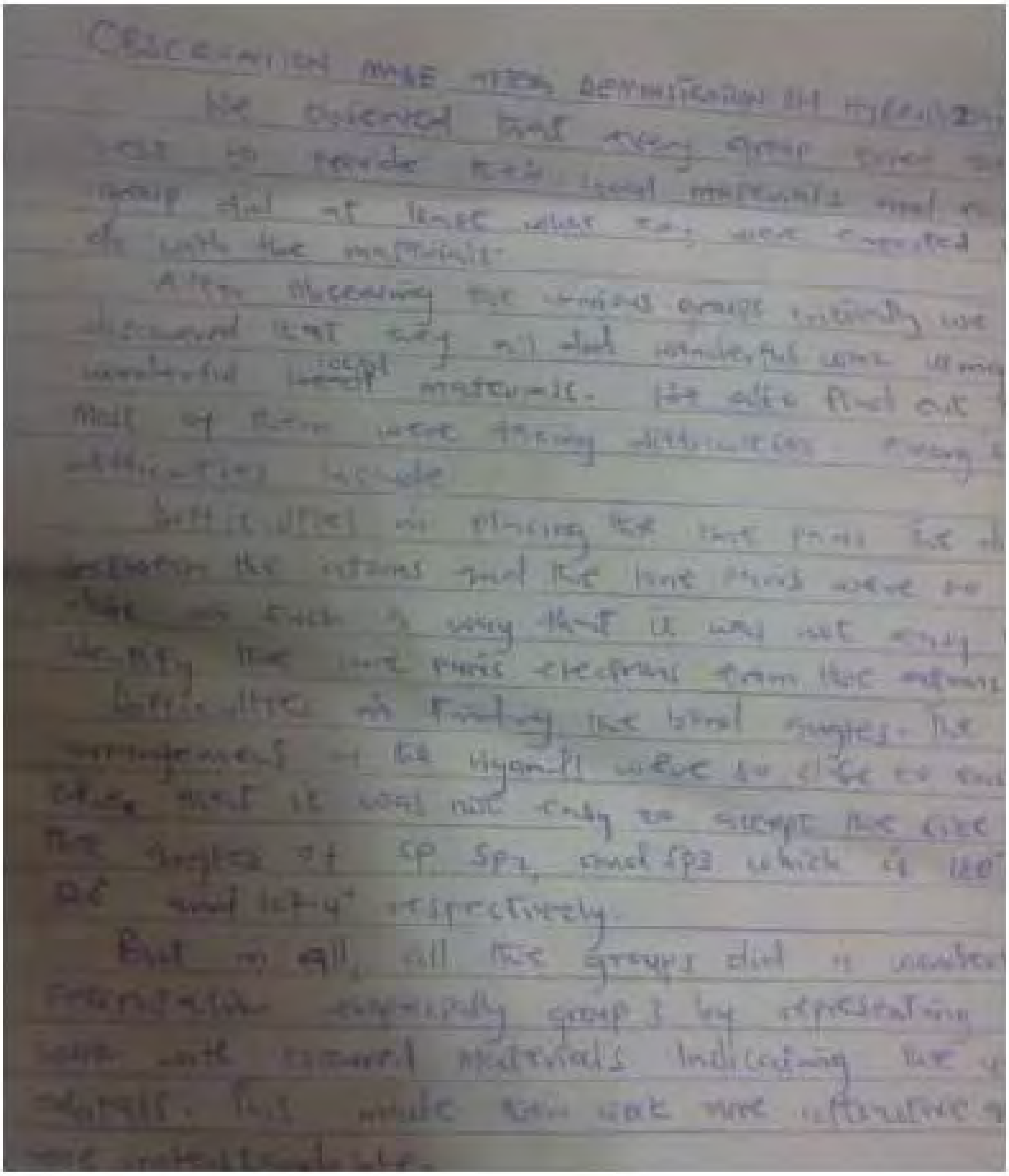
   a. Molecular geometries,

   b. Bond angles, and hybridization geometries of specific molecules.

3. As students work in groups, let them provide short notes to their answers in Q1and 2 in terms of challenges faced, their strength, the nature of the exercise and their evaluation on other groups' work.

APPENDIX F

GROUPS' WRITE-UPS



OBSERVATION MADE AFTER DEMONSTRATION ON HYBRIDISATION

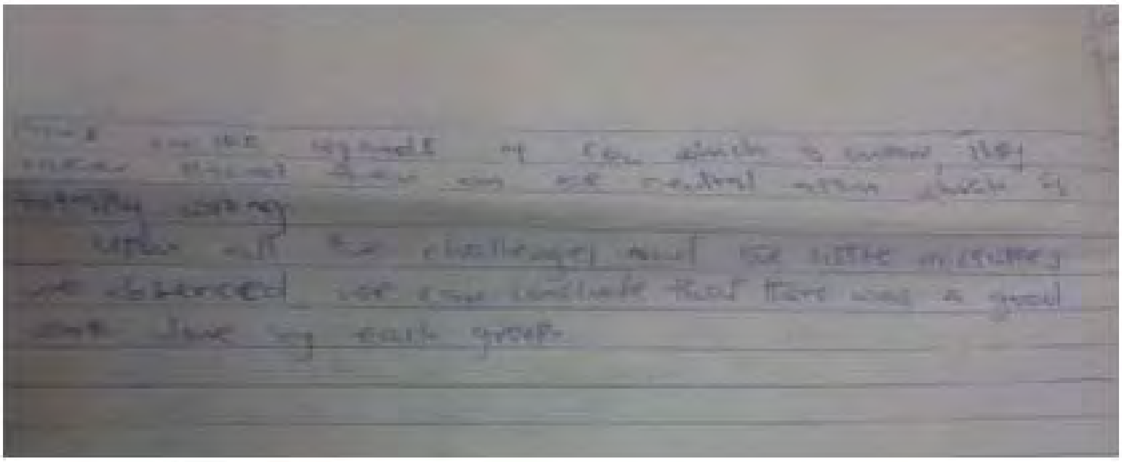
We observed that every group tried its best to provide their local materials and each group did at least what they were expected to do with the materials.

After observing the various groups critically we discovered that they all did wonderful work using wonderful local materials. We also find out most of them were facing difficulties. Among the difficulties include:

Difficulties in placing the lone pairs ... between the atoms and the lone pairs were so close in such a way that it was not easy to identify the lone pairs electrons from the atoms.

Difficulties in finding the bond angles. The arrangement of the hybrids were so close to each other that it was not easy to accept the size of the angles of sp, sp2, and sp3 which is 180°, 120° and 109.4° respectively.

But in all, all the groups did a wonderful presentation especially group 3 by representing their work with coloured materials indicating the orbitals. This made their work more attractive and more understandable.



[illegible]

Upon all the challenges and [illegible] we [illegible] we can conclude that there was a good [illegible] by each group.

Group 5

Many Students find it difficult to understand [illegible] concept of hybridization in terms of [illegible] [illegible] [illegible] [illegible] [illegible] and [illegible] and [illegible] [illegible] using local materials [illegible] [illegible] [illegible] [illegible] it better.

Hybridization is the mixing of [illegible] orbitals [illegible] [illegible] energies and shapes to form a new orbital of [illegible] shape and energies.

We are going to limit ourselves to 3 types of hybridization

sp hybridization
sp^2 hybridization
sp^3 hybridization

sp hybridization

[illegible] CO_2 [illegible] instance carbon has [illegible] [illegible] [illegible] [illegible] oxygen has 6 valence electrons [illegible] [illegible] [illegible]

[illegible] [illegible] [illegible]

[illegible] [illegible] = [illegible]

[illegible] [illegible] [illegible]

[illegible] [illegible] [illegible] [illegible] [illegible] [illegible] [illegible] [illegible]

[illegible] [illegible] [illegible]

[illegible] [illegible] [illegible]

[illegible] [illegible] from [illegible] [illegible] are [illegible] [illegible] [illegible] [illegible]

[illegible] [illegible] [illegible] [illegible] [illegible] [illegible] [illegible] [illegible]

[illegible] [illegible] [illegible] [illegible] [illegible] [illegible] [illegible]

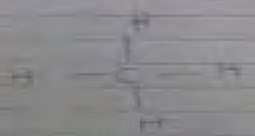
[illegible] [illegible] [illegible] [illegible] [illegible] [illegible] [illegible]

[illegible] [illegible] [illegible] [illegible] [illegible] [illegible] [illegible] [illegible]

[illegible] [illegible] [illegible] the [illegible] [illegible]

[illegible]

[illegible] illustrated below



[illegible]

[illegible]

[illegible] trigonal shape with [illegible] bond angle of 120°

[illegible] sp² [illegible]

[illegible]

GROUP 3

Owusu Dapaa Williams	SJCE/0040/2017
Damalabua Domanaangment Bennett	SJCE/[illegible]/2017
Yeboah Evans Dankwah	SJCE/0049/2017
Dufei Josephine	SJCE/0029/2017
Amankwaa Solomon	SJCE/0009/2017
Asantoa Dorina	SJCE/0017/2017
Umar Abdul-Hadi	SJCE/0048/2017
Oberg Micheal	SJCE/0025/2017
Gyamp Collins	SJCE/0031/2017

The whole exercise was very interesting. Every body participated in the exercise.

Our challenges ~~was~~ were that, our materials didn't help such that the broom stick couldn't stick into the chewing gums very well. This is because we used hollow gums. We couldn't get appropriate materials to represent the lone pair.

We overcame our challenge by using chewed gums to glue the broom sticks and the unchewed gums (bond atoms). We also used some of the chewed gums to represent the lone pairs.

~~Our work~~ Comparing our work to other groups, we used different colours of materials to represent different atoms but the other groups used identical materials for both central and bond atoms. ~~Than~~ The bond angles of other groups were better than ours because their structures were firmer due to the materials they used which were better than our hollow gums.

APPENDIX G

EXCERPT FROM THE INTERVIEW AND THE GROUP REPORTS

In all, the experimental group was put into five groups for the PGL5C exercise. Students in three groups after the exercise were selected to write their reports on their findings about the impacts of the techniques in the interventional strategy used. These groups were selected using random sampling technique. A member each from the other two remaining group was interviewed. The following are the group reports:

Presentation by group 2:

We observed that each group tried their best to provide their local materials and did what they were expected to do with the materials. After observing the various group critically we discovered that they all did wonderful work using wonderful local materials. We also found out the most of them were facing difficulties. Among such difficulties include:

Difficulties in placing the lone pairs: the distance between the atoms and the lone pairs were so close in such a way that it was not easy to identify the lone pairs of electrons from the atoms.

Difficulties in finding the bond angles: the arrangements of the ligands were so closed to each other that was not easy to accept the size of the angles of sp, sp^2 and sp^3 which were $i80^0$, 120^0 and 107.5^0 respectively.

But in all, all the groups did wonderful presentations especially group 3 by presenting the work with coloured materials indicating the various orbitals. This made their work more attractive and understandable.

In group 2, instead of placing the lone pairs on the upward of the oxygen in CO_2, which is linear, they rather placed them on the central atom.

Upon all the challenges and the little mistakes we observed, we can conclude that there was a good work done by each group.

GROUP 5

Many students find it difficult to understand the concept of hybridization in terms of theory. In view of this, Group 5 members discover and understand the concept by using local materials such as garden eggs to explain it better. Hybridization is the missing of atomic orbitals with different energies and shapes to obtain new orbitals with identical shape and energy. We are going to limit ourselves to the three types of hybridization; SP, SP^2 and SP^3.

SP hybridization: Considering CO_2 for instance, Carbon has 4 valence electrons and Oxygen has 6 valence electrons.

Adding their valence, C= 4 *1 = 4e. O = 6 * 2 = 12. Total electron = 16e

The hybridised atom has molecular geometry of linear shape; O=C=O with each oxygen having hybridization geometry of Trigonal planer. The bond angle between Carbon atom and each oxygen atom is 180^o.

NH_4 has a molecular geometry of Trigonal pyramidal with hybridization state of tetrahedral. Also, methane has either molecular or hybridization geometry of tetrahedral.

Group 3

The whole exercise was very interesting, everybody participated in the exercise. Our challenges were that our materials didn't help such that the broom sticks couldn't stick into the chewing gums very well. This is because we used hollow gums. We couldn't get appropriate materials to represent the lone pairs. We overcame our challenge by using chewed gum to represent the lone pairs.

Comparing our works to other groups, we used different colours of materials to represent different atoms while the other groups used identical materials for both central and other bonded atoms. The bond angles of other groups were better than ours because their structures were firmed due to the materials they used which were better than our hollow gums.

Data on the Interview session

Un-structure interview between a group one member and the researcher

The researcher (TR): How did you find the exercise on the model construction? Student leader in group 1 (SLG1): It was interesting though we faced challenged at the initial stage.

TR: Interesting?

SLG1: Yes sir, ha ha ha; errm yes please

TR: What made it interesting?

SLG1: The way some of us were able to construct our models to represent what we wanted to do made it interesting. We didn't know how to go about it but as a group we worked together after watching the videos on hybridization and molecular geometries.

TR : And how challenging was the exercise?

SLG1: Sir; hmm, this topic (hybridization) is a topic we didn't want to hear of. Every science student is afraid about it.

TR: Why didn't you want to hear about it? Afraid? Why?

SLG1: The way we were exposed to it at SHS was different and hmm, difficult to understand so when we so it in the course outline we were all afraid. Again, the seniors have been complaining that people get referred in FDC 114 because of the organic part such as hybridization and bond angle.

TR: I see so how did you overcome that fears and do you now see the topic as interesting?

SLG1: Sir, the videos and the group discussions helped us a lot but when you asked us to present our own models using local materials we did a lot of research from the net.

TR: What have you learnt from the lesson so far?

SLG1: Sir, you see ooo. We thought the topic was difficult but working as a group and the Competition in the groups helped all of us to do a good job. Ahaa, sir; the group discussion also help us because there were certain things some of us were afraid to ask in the class but in the groups we were able to discuss our difficulties.

TR: Do you think other group members will share similar opinion with you?

SLG1: yes sir, I think so because even other group members are also happy about the way this topic was taught. We have learnt a lot.

Another interview session between a member in the group 4 and the researcher is presented in this session.

TR: how are you?

SLG4: I am fine sir, thank you.

TR: Tell me some of the difficulties you had with molecular and hybridization geometries and how they were resolved.

SLG4: Sir, the name of the topic alone was scary because we knew of it from SHS and how difficult it was. I never knew we could use things around us like pawpaw, garden eggs and clay to teach it.

TR: why were you thinking that the topic could not be treated with things around us?

SLG4: Sir; in my school at the SHS, our teacher gave us notes and we didn't even know that the bond angles were the ordinary angles in mathematics. Even the names of the shapes were confused. Sir in our group, we did not know that geometry was the same as shapes but when we watched the videos for about four times things became clearer.

TR: Any lessons learnt from what you did as a group and the models that were built by the various groups?

SLG4: Yes sir. Sir, practical lessons and group works are very good way of learning because some of us are the shy type but we were able to ask questions and discussed things among ourselves.

APPENDIX H

PLATES

Plate 1: Students in the experimental group watching video of molecular shapes to determine geometries

Plate 2: Students in the experimental group watching video of molecular shapes to determine geometries

Plate 3: Students in the experimental group watching video of molecular shapes to determine geometries

Plate 4: Students in the experimental group watching video of molecular shapes to determine geometries

Plate 5: Students in the experimental group watching video on Hybridization Geometries

Plate 6: Students in the experimental group watching video on Hybridization Geometries

Plate 7: construction of Visuo-spatial models from locally available materials by students in the experimental group

Plate 8: construction of Visuo-spatial models from locally available materials by students in the experimental group

Plate 9: Determination of Hybridization Geometry, Molecular Geometry and Bond Angle of Carbon (IV) Oxide from locally constructed Models designed by some students in the experimental group

Plate 10: Determination of Hybridization Geometry, Molecular Geometry and Bond Angle of Carbon (IV) Oxide from locally constructed Models designed by some students in the experimental group

Plate 11: Determination of Molecular Geometry, Hybridization Geometry and the Associate Bond-Angles of Visuo-spatial models constructed from Pawpaw buds by some members in the experimental group

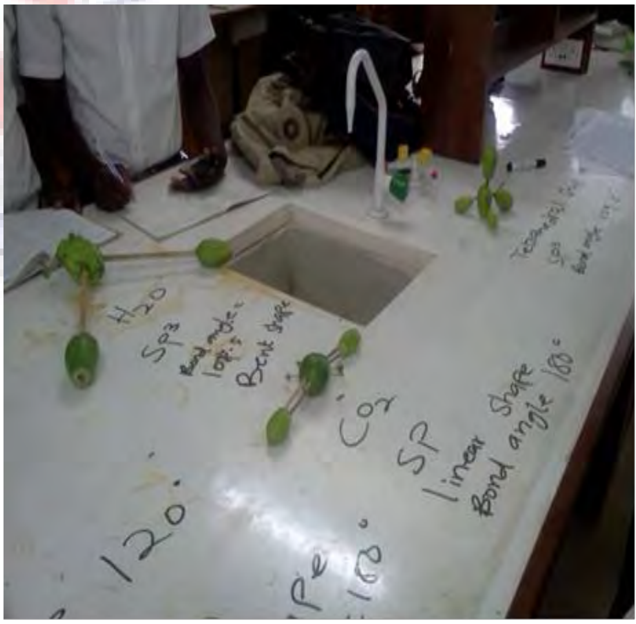


Plate 12: Visuo-spatial models of water, Carbon (IV) Oxide and Methane constructed from Pawpaw buds by some members in the experimental group

Plate 13: Visuo-Spatial models constructed from clay by some members in the experimental group.

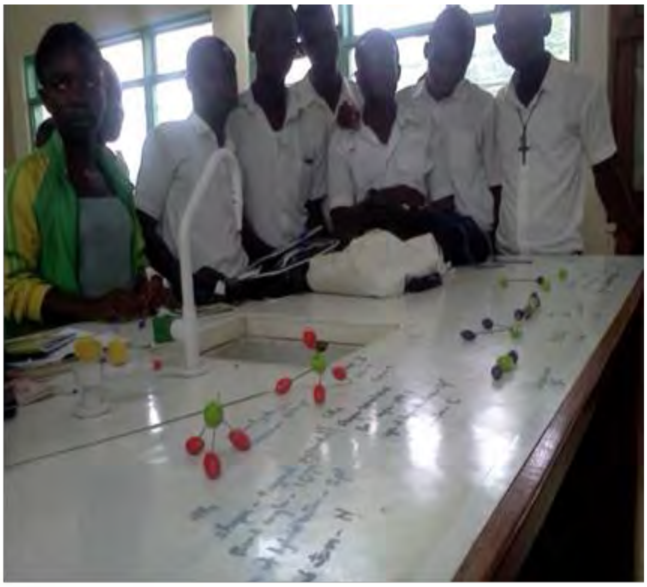


Plate 14: Visuo-Spatial models constructed from rubber (gum) by some members in the experimental group.

Plate 15: Visuo-Spatial models constructed from vegetables (garden eggs) by some members in the experimental group.

Plate 16: Visuo-Spatial models of Methane, Ethyne and Water molecules constructed from Clay by some members in the experimental

Plate 17: Students from the experimental group are evaluating Visuo-spatial models constructed by other group members

Pllate 18: Students from the experimental group are evaluating Visuo-spatial models constructed by other group members.

Plate 19: Students from the experimental group are evaluating Visuo-spatial models constructed by other group members

Plate 20: Students from the experimental group are evaluating Visuo-spatial models constructed by other group members