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Enhancing Senior High School Students Understanding of Chemicai Formulae and Nomenclature of Inorganic Compounds by the Use of Improvised Conceptual Models

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Abstract
The study aimed at enhancing the understanding of SHS students in chemical formulae and nomenclature using locally constructed conceptual models. It was carried out it two Senior high schools in the Offinso district of Ashanti region of Ghana, Dwamena Akenten SHS and Namong SHS. The research instrument used was pretest and protest on an experimental and control group with 200 students as sample size. Developmental research design with cluster and purposive sampling technique were employed. Five research questions were formulated out of which four were modified into null hypothesis and was tested using 2-tailed t-test at 0.05 level of significance. The research results have showed that the use of conceptual models enhanced the understanding of SHS students in chemical formulae and nomenclature. Additionally, it was found out that the conceptual models had no influence on gender or cognitive capability. This emphasized that conceptual models should be used to assist the teaching and learning of chemical formulae and nomenclature.
Keywords: Average achiever, Conceptual Model, Control group, Experimental group, High achievers, Low achievers

Background of the Study

Most studies concerning science education centre on the content knowledge and pedagogy Ogunleye (2007).This is attributed to the strong relationship between the teachers' content and pedagogical knowledge. Teachers' knowledge is influenced by experiences of the teacher that reflect on such experiences (Onasanya & Adegbija, 2007). It is therefore logical to relate learning experiences of the learner to the influence of the teacher. Science teaching becomes effective and meaningful to the learners when science teachers have in-depth knowledge of the Science Education Curriculum. According to Entsua-Mensah (2004), without strong and efficient teacher education, the foundation of the entire educational system will be weak, and it will continue the downward decline.

Various stakeholders made a lot of efforts to address this issue in the educational system. The Ghana Association of Science Teachers (GAST) has channeled a lot of attention towards improving science education at the pre-tertiary levels. GAST focuses on promoting effective teaching and learning of science at the pre-tertiary level by organizing workshops, updating the science content of the curriculum of basic and second cycle schools, developing teaching and learning resources, writing of text books and supporting research works on science. A non-governmental organization, Japanese International Cooperation Agency (JICA), has established Science Resource Centers at three of the Colleges of Education in Ghana. These include Akropong, Akrokerri and Bagabaga Colleges of Education. The resource centers are to boost development and construction of science teaching and learning materials. The government of Ghana has over the years and in recent times made several attempts to transform science education and to enhance the quality of teaching and learning of science and mathematics at the basic education level including the provision of Science Resource Centers across the country under the 1987 Educational Reforms. The 2004 New Educational Reform Implementation Committee was made to select at least one SHS in each district across the country to serve as model SHS .The idea was to ensure that other schools within the catchment area benefit from the upgraded facilities that were provided in these model schools to enhance teaching and learning.

General Science which was a core subject prior to the 2004 New Educational Reforms is now taught as Integrated Science course. The compulsory nature of the course indicates that all topics in the course outline are equally important and should be treated as such. At present, chemical formulae and nomenclature occupy about 50% of the course content of SHS. Students' performance in chemical formulae and nomenclature aspect has been very much appalling. Inadequate resources in terms of conceptual models make the problem of teaching and learning of this aspect to persist.

The researcher's concerns have been surrounded by the following:

i. Students of SHS perform poorly on chemical formulae and nomenclature.
ii. The scientific competences and prior conceptions in Chemical Formulae and Nomenclature of students before they enter SHS are low.
iii. Teachers must be aware of the scientific competences and prior knowledge of students in Chemical Formulae and Nomenclature students.

The desire for answers to the above formed the basis of the study.

Conceptual Framework

From previous studies of conceptual understanding, theories of learning and definition of conceptual understanding amongst others, there is interrelationship amongst the student, his environment and the teaching and learning process. Conceptual understanding is entrenched in the peculiar manner the individual student perceives, processes, stores, interprets, interacts with and responds to related concepts in the learning environment. The conceptual framework is conceptualized as an interaction of several student factors and the environment (Figure 1). It indicates that student factors, prerequisite conceptions and environmental factors could possibly influence student's conceptual understanding. Conceptual understanding implies that students have the ability to use knowledge, apply it to related problems, and to make connections between related ideas (Branford, Brown & Cocking, 2000)

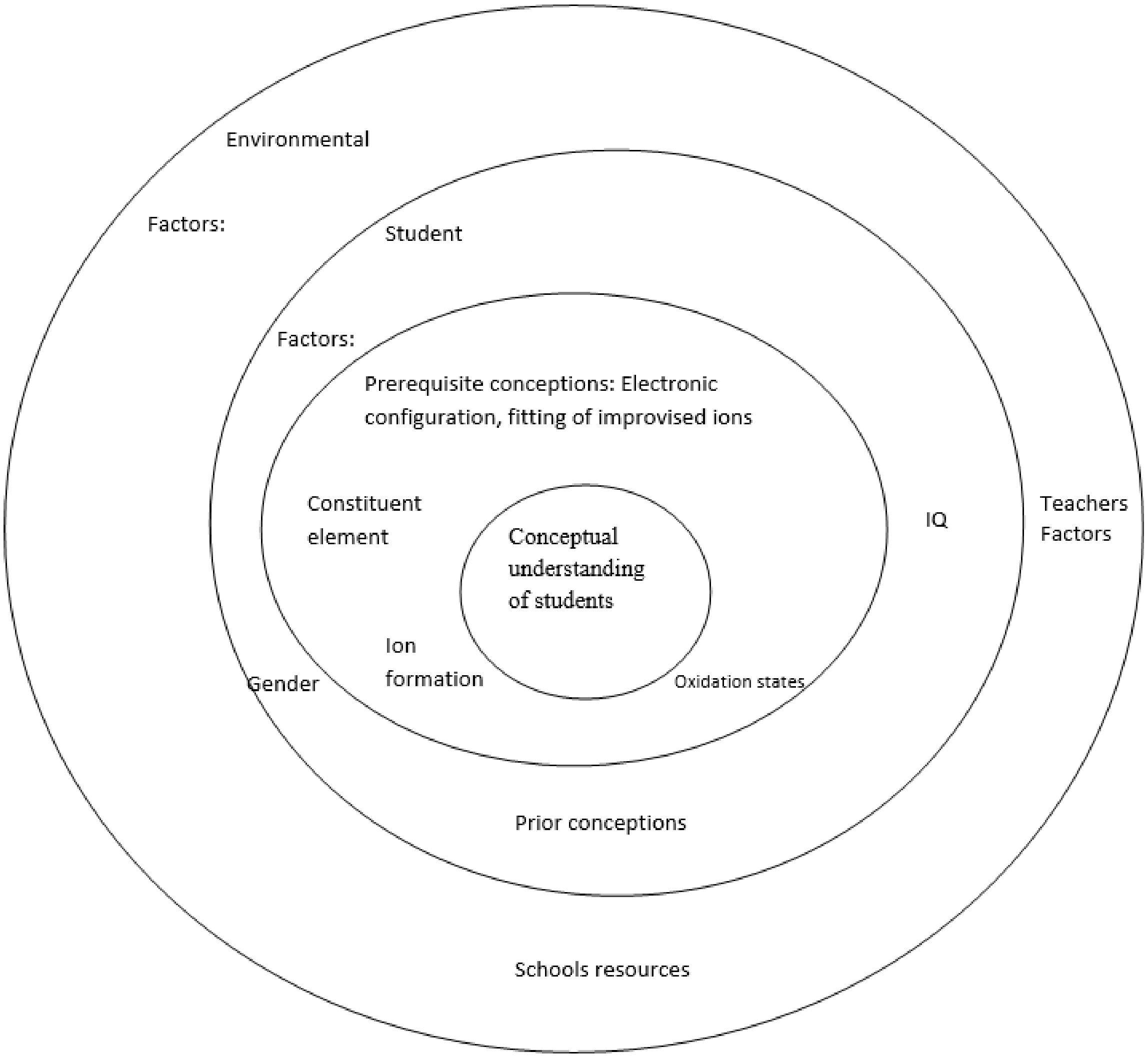


Figure 1.Conceptual Framework on Factors Influencing Students' Conceptual Understanding.

Conventionally, the sense-making involved in building conceptual understanding involves taking newly introduced information and connecting it to existing knowledge as the student builds an organized and integrated structure (Ausubel, 1968; Linn, Eylon, & Davis, 2004; Okonkwo, 2000; Taber, 2001). The conceptual framework consists of four (4) concentric circles representing different levels of influence on student's conceptual understanding. The innermost circle depicts conceptual understanding of the students. This is influenced by factors in the second smallest circle which consists of factors such as a gender, intelligence quotient (IQ) and prior conceptions (Taber, 2001). The third concentric circle influencing the second the consequently the first, represents possible prior conceptions such as oxidation states, ion formation, identification of constituent elements and electronic configuration (Trimpe, 2007). The fourth and outermost circle represents environmental factors such as teacher factors and school resources (Taber, 2005). These factors have the potential of influencing the prerequisite conceptions, student factors and conceptual understanding. The framework implies that any one of the factors or a combination of the prerequisite conceptions (oxidation states, ion formation, identification of constituent elements and electronic configuration) could have synergic influence on student's conceptual understanding. Individual characteristics selected for the study include gender, ability groups, prior conceptions and the effect of the use of conceptual models.

Historical development of molecular formula

The concept of atoms has been in existence for over 200 years when Leucupus, Demortus and Greek philosophers speculated about the ultimate constitution of matter. Some believed that it is made of atoms. However, it could not be substantiated due to lack of evidence. Supporters of this idea claimed that atoms exist as indivisible particles. According to Quaitto (2003), by the 18th Century, a lot of indirect evidence that has been gathered, strongly suggested that matter is composed of separate particle. However, Ameyibor and Wiredu (2007) stated that, Dalton was the first person to present a carefully organized atomic theory of matter that could explain the laws and facts of chemistry at that time. Dalton's theory has been modified in the light of subsequent discoveries, although the main ideas have been retained. For the purpose of this work the researcher quoted the fourth law and it goes: "Compounds are formed by the union of two or more atoms in various ratios" (Quaittoo, 2003, pp. 34).

Chemical reactions occur as a result of changes in atoms during combination (Ameyibor & Wiredu, 2007). Examination of Dalton's atomic theory reveals that it does not explain why atoms combine. Dalton suggested atoms contained something that acted like a hook and could bind atoms together. Quaittoo (2003) asserted that, Dalton's atomic theory resembled that of his predecessor, Democritus who postulated that matter was made up of atoms and suggested the properties of atoms and how they combined to form compounds. Dalton's atomic theory and its application convinced people to accept the particulate nature of matter. Many experiments were carried out to find out exactly what types of particles are in matter. These included X-ray and electrolysis experiments. The results of these experiments indicated that matter consists of atoms, molecules and ions. Again, early scientists realized that different types of matter are made up of different types of particles. Some forms consist of molecules, while others are ions.

Moreover, Harrison and Treagust (2002b) stated that properties of an atom are largely controlled by electrons. They added that interaction between the electrons of two or more atoms leads to chemical combination of the atoms. Detailed explanation about the arrangement of electrons within an atom involves interpretation of spectroscopic data and the application of the ideas of the quantum theory. However, according to Ameyibor and Wiredu (2007) before the quantum theory, scientists at the time of Dalton were interested in matter and how atoms of an element reacted with each other to form compounds. At the close of the 19th Century experiments were conducted into the inner structure of the atom, which culminated into the discovery of the subatomic particles. Based on this, the model of the atom was formed as having a center called the nucleus. The nucleus is positively charged and contains particles, namely protons and neutrons. The mass of the atom is concentrated in the nucleus. Electrons are negatively charged and move around the nucleus in orbits. The electrons have very small mass compared to protons and spread in the volume of the atom which is almost an empty space.

According to Quaittoo (2000), in 1911 Rutherford and his co-workers attempted to gather evidence about the internal structure of atoms by bombarding a tin sheet of gold foiled with a stream of alpha particles from radioactive source. They found that about 99% of the particles passed through the solid without any measurable deflection. Some deflected at large angles and a few reflected back towards their sources. To account for these observations, it was concluded that the volume of a solid is an empty space. Secondly, the mass and positive charges of an atom are concentrated in a very small region called a nucleus. To account for the volume of atom, Rutherford declared that the electrons formed a sphere with the nucleus at its center. Ameyivor and Wiredu (2007) stated that, Bohr in 1913 proposed an atomic structure in which the electrons revolved around the nucleus in circular (or elliptical) orbit of various sizes, much the same way the planets revolve about the sun. This model was called the solar system atom.

However, Harrison and Treagust (2002b) stated that Rutherford, Thompson, and Neil Bohr affirmed that, an atom consists of positively charged nucleus and that most of the mass of the atom is concentrated in the nucleus. These researchers gave the name "protons" to the basic particles making up the nucleus having a charge of +1 and a mass of 1, while the "electron" was assigned a charge of -1. A detailed study of spectra showed that an atom contains shells or orbits known as principal quantum numbers. However, the arrangement of electrons within an atom influences the interaction between the outer electrons of two or more atoms leading to possible chemical combination or the formation of chemical formulae. For example, water is a compound containing two atoms of hydrogen combined with an atom of oxygen. This is represented by H_2O. The letters H and O are the symbols for the two elements that form water, and the subscript 2 after H tells us that two hydrogen atoms combine with one oxygen atom to form water. The formula for hydrogen molecule is H_2. Similarly the formula for fluorine molecule is F_2, nitrogen molecule is N_2 and potassium chloride is KCl.

Concept and Impact of Conceptual Models in Science Education

A model is signs of objects which reproduce some essential properties of the original system. Models are used as instructional tools because they aid understanding of concepts. Creation of simplified models is an effective way of verifying the connection and fullness of theoretical concepts. The use of models is in accordance with the advice of Taber (2005). Taber opined that it is the professional capability of every teacher to find ways to make complex ideas seem accessible to his/her students. Based on this, it is not out of place on the part of the researcher to develop conceptual models to make the complex ideas with Chemical Formulae and Nomenclature accessible to his students.

This 21st Century witnessed a huge research effort into learners understanding of scientific concepts. Much of this research has been concerned with perceptions of learners' inabilities to understand scientific concepts or to develop conceptual understanding about mental models that are accord with scientific or teaching models (Pfundit & Duit, 2000). Theory-making and practice of chemistry and science is dominated by the use of mental models. This is argued by many authors that, since scientists seek to understand macroscopic properties they inevitably need to consider what is happening at the microscopic level (Oversby, 2000). However, because we cannot see what happens at the microscopic level we to develop mental images or mental models of matter and what its changes might be like at this level. This is macroscopic-microscopic link in the chemistry can be traced to the development of the atomic theory. Atomic theory, although tremendously successful, is nonetheless a theory, a mental model of how scientists view the makeup of material world that surrounds us. Scientists' current theory of the nature of matter, which explains the formation of chemical formulae and nomenclature and interests us most, as far as this research, is concerned.

Many other theories and mental models in science and chemistry build upon atomic theory and this has important implications for the teaching of abstract mental models as is discussed below. Examination of chemistry content at different educational levels, shows that mental models are deeply embedded in chemistry content, and consequently in chemistry teaching and learning (Coll, 2005; Coll, Francis & Taylor, 2005; Eduran&Duschi 2004; Justi& Gilbert, 2005). Harrison and Treagust (2002b) propose a typology of mental models which includes chemical formulae, mathematical models, analogy, physical artifacts, and diagrams such as maps. A chemistry learner will of course need to learn things other than specific chemistry models to 'understand' chemistry to the satisfaction of his/her teachers or chemistry professors (for example, chemical process and reactions, conventions for naming compounds, etc), but every feature of chemistry content and learning includes the use of at least one mental model (Harrison &Treaguest's, 2001). As a consequence, the learning of chemistry requires learners to learn about a variety of mental models, and learning about mental models dominates the learning process for this discipline (Harrison &Treagust, 2002a). This might stem from the fact that the bulk of the subject matter is at the microscopic level and without the use of the models, comprehension will not be easy. It is in line with this that Conceptual Models should be designed to facilitate the comprehension of chemical formulae and nomenclature.

Gilbert, Boulter and Rutherford (2000) point out that what researchers encounter or uncover during inquiry are in fact participants' expressed mental models; in other words, how they describe their mental models to education researchers. In some instances this results in methodological complications (Gottm & Johnson, 2003). Individuals may hold a particular mental model, but finds it difficult to express or articulate this model in manner that is clear and meaningful to a teacher (Norman, 2002). Furthermore, an individual's mental model may not be the 'neat' or consistent artifact that appears in textbooks or that researchers construct during inquiry. Glynn and Duit (2002) comment that individual mental models are 'sloppy' and 'inconsistent', irrespective of any difficulties associated with verbalization. Hence, comparison of individuals' mental models is commonly associated with inquiry that works from a deficit model in which learners' mental models are compared with scientific or 'correct' teaching mental models that appear in textbooks or lecture notes.

One of the key findings from the science education literature is that scientists and expert modelers see and use mental models in very different ways to novices or learners – and indeed many teachers (Coll, 2005). Teachers tend to use models to aid understanding, and, for example, draw upon analogy to guide learners towards a 'better' understanding of the 'correct' model (Dagher 2001a, 2001b; Gilbert &Boulter, 2001; Justi & Gilbert, 2005; Weller, 2001). Scientists understand that a model by definition has limitations (Maksic, 1990). That is, models share only some attributes with the target (what is to be modeled). As a consequence, as Taber (2002) pointed out, if a model did not possess limitations (that is, differ from the target in some way) it would in fact become the target or artifact (or process) that is being modeled. This does not mean that scientists discard models that possess limitations, indeed they continue to use models – even models that possess severe limitations; they are pragmatic about model use and clearly understand the limitations of the models they use. A simple example connected to this inquiry is the so called ligand field theory (Coll, 2005). In this model the bonding between atoms or groups of atoms surrounding a metal centre is proposed to arise from pure electrostatic interaction between an electron deficient centre (the metal) and attached electron rich groups (usually called ligands).

This electrostatic interaction results in the formation of a 'field' that attracts the ligands to the metal; even a hasty examination of this model shows clearly how simplistic and crude a model it is. The model also possesses many well-established limitations (e.g., it fails miserably to explain the spectrochemical series), but the crystal field theory is still in common use even in research chemistry (Smith, 2001). Scientists still use crystal field theory (model) in their research even though there are severe limitations, simply because it works well in certain well-define circumstances; and is helpful in understanding certain aspects of chemistry (Taber, 2000). Aufbau principle of electron configuration is similarly best explained by using models (Coll, 2005). Scientists thus see models in a functional, utilitarian capacity, and recognize that a model is intended to serve the user (Borges & Gilbert, 2001). Scientists are able to visualize mental images of abstract things rather than physical entities. So whilst learners and novices are able to conduct thought experiments and use mental models to conduct mental 'experiments' for the purpose of prediction. Another key difference between scientists and novices use of mental models is the tendency for scientists to use physical models (Coll, 2005; Coll et al., 2005, Eduran & Duschl, 2004). The scientist is commonly capable of constructing a mental model based on another mental model.

To illustrate scientists' mental models, chemical bonding itself' is based on another abstract mental model – the atomic theory which posits that matter is made up of small, microscopic particles of a specific nature and form. Scientists thus use mental models for a variety of purposes. They use them to understand macroscopic phenomena as described above, but they also use mental models to generate new hypotheses (Justi& Gilbert, 2005). They may go to modify or use their mental models to evaluate and expose the limitations of their own scientific inquiry

Problems Associated with the use of Science Models

The teaching and use of models in the classroom is personal and commonly involves the use of analogy. Dagher (2001a, 2001b), for example, report that teachers draw upon analogy when they feel their explanations have not been understood by learners. Analogy use has been reported to aid learners understanding of variety of models like kinetic theory to explain dissolution (Stavy, 2001, 2005; Taylor &Coll, 2007).

However, research shows that even with the use of analogy, confusion between the model and modeled abounds, and it is common for learners to confuse the model the model with reality (Lawson, Banker, DiDonato, Verdi & Johnson, 2003).The confusion arises if the teacher does not contextualize the difference between the two confusion word. There are numerous reports in the literature alluding to problems encountered in the teaching of model and numbers of themes emerge. As pointed out, learners seldom see models as mental constructions. This seems to come about because learners frequently confuse mental models with physical models, seeing models as copies of reality. This results in a number of alternative conceptions in chemical formulae and nomenclature.

Harrison and Treagust (2002a) found that secondary school learners thought of atoms as small spheres or balls. Stavy (2001) reported confusion between ball-and-stick models and mental models. Common themes about learners' alternative conceptions for chemical formulae and nomenclature emerge from the literature include confusion of intermolecular and intramolecular bonding (Coll & Taylor, 2001), confusion over polar covalent bonding and ionic bonding (Coll&Treagust, 2002, 2003), seeing ionic bonds as weak (Coll &Treagust, 2004) and that the formation of ionic bonds occurs as a result of electron transfer (Oversby, 2000; Taber & Coll, 2002). The literature points to significant difficulties in learning and teaching of conceptual models in both science and chemistry. The study of learners' conceptual models is dominated by a few conceptual themes, namely, atomic theory (Harrison & Treagust, 2001) and kinetic theory (Taylor & Lucas, 2007), with few studies on chemical bonding (Nicholl, 2001; Taber & Coll, 2002). This is a remarkable observation given that an understanding of chemical formulae and nomenclature is crucial to the understanding of chemistry as a whole, reaction chemistry, stereochemistry and industrial chemistry among others.

Students' misconceptions in Chemical Formulae and Nomenclature

According to Anamuah-Mensah and Apafo (1989), the conceptualization of the chemistry aspect of science is indeed difficult for learners of science. This was confirmed by Johnstone (1993) (as cited in Khoo & Koh, 1998) that the acquisition of scientific concepts especially the chemistry aspects poses a serious challenge to most students. The difficulty associated with the acquisition of concepts in Chemical formulae and nomenclature is as a result of the use of traditional approaches or methods in teaching concepts in Chemical formulae and nomenclature. According to Teichert and Stacy (2002), many studies conducted worldwide revealed that the traditional approach of teaching the concept of Chemical formulae and nomenclature is problematic to both low and high achievers because it leads to rote learning. According to Henderleiter (2001), students regardless of both gender and academic ability rely on rote memorization to determine which elements could be involved in forming a chemical formula because of the traditional approach used for teaching the Chemical formula and nomenclature. In many cases, it seems that students often memorise a list or a pattern but are not able to fully reason through it.

Chemical formulae and nomenclature as a concept has its own challenges. According to Taber (2001), many chemistry teachers lack both content and pedagogical knowledge to teach Chemical formulae and nomenclature.

As a result of this, such teachers easily mislead students because they lack both content and pedagogical knowledge. During the last two decades, researchers have found that students lack a deep conceptual understanding of the key concepts regarding the Chemical formulae and nomenclature and fail to integrate their mental models into a coherent conceptual framework (Taber, 2002). Chemical formulae and nomenclature are considered by chemistry teachers and chemists to be a very complicated concept (Robinson, 2003; Taber, 2001). This is attributed to the fact that learners easily form erroneous concepts during lessons due to misunderstanding or lack of understanding passed from teacher through inaccurate teaching.

Taber (2002), most alternative conceptions in chemistry are not derived from the learner's informal experiences of the world but from prior science teaching. If so, we need to ask ourselves how often can teaching strategies and pedagogy mislead students?

Also students' alternative conceptions, which are considers to largely stemming from the way they have been taught, have been labeled as pedagogical learning impediments (Taber, 2001). Strict adherence to the octet rule by teachers is part of the problem as it can lead to learning impediments. Octet rule is the idea that atoms attain stability if the valence (outer most) shell of the atom contains eight electrons. Taber and Coll (2002) suggested students should not learn by using the "octet framework," because it could lead to learning impediments. This is so because the existence of chemical formula which does not lead to atoms having full electron shells will be a mystery to many students.

Moreover, students may have difficulty accepting anything that is not clearly explicable in "octet" terms, such as a hydrogen bond as being a molecular formula. Hurst (2002) also refers to the "octet rule" as an over simplification of the electronic structure of molecules. A study carried out by Dun, (2005) revealed that students from all levels of education have difficulties in learning certain chemical concepts and this affects their ability to do well in chemistry at the tertiary level. This is confirmed by various reports of the Chief Examiner of WAEC (2004) that candidates who take part in Chemistry Examination will continue to produce poor results over the years because of poor pedagogical approaches to the teaching of the subject.

Levy-Nahum, Hofstein, Mamlok-Naaman and Bar-Dov (2004), students irrespective of cognitive ability groups posses a variety of misconceptions regarding Chemical formulae and nomenclature. Although several methods were put in place to explore and provide lasting solution to the problem, the same crucial misunderstanding regarding the bonding concept has arisen each year for the last two decades (Trimpe, 2003). Some of the methods used included "A new teaching approach for the chemical bonding concept aligned with current scientific and pedagogical knowledge" (Levy-Nahum et al, 2004) and "Fun with ionic compounds-ionic bonding games actively engage students in processing key concepts" (Logerwell & Sterling, 2007). Available literature indicates that "even if they understand atomic structure and ion formation, it is still difficult for students to visualize how ions are fitted together to form a compound" (p. 234).

Inadequate models impede Science Education

One of the activities in science is experimentation. It provides a forum for the practice of the theoretical knowledge gained in the classroom and for demonstrating the psychomotor skills of a teacher and learner. It further aids the understanding of difficult concepts in the curriculum; creates opportunity for the testing of facts and theories in science. It is believed that learners can achieve more if given the opportunity to practice what they have been taught in the classroom. Experimentation thus gives room for better attainment of lesson objectives. Experimentation in science is however dependent on the availability of science teaching and learning materials for proper understanding, development and application (Ugwu, 2008).

One of the goals of science education in Africa is the acquisition of appropriate skills, the development of mental, physical and social abilities and competencies as equipment for individual to live in and contribute to the development of the society (Asiruiwa, 2005). The realization of this goal can be impeded by non-availability of science models that can ensure effective teaching and learning. Many authors have, however, reported the issue of inadequacy of science models in educational institutions in Africa (Ogunleye, 2007; Ugwu, 2008; Ogunmade, Okedeyi&Bajulaiye 2006; Nwagbo, 2008 & Osobonye, 2002). It has also been reported that the non-availability of science models in educational institutions serve as barrier to effective science teaching (Adeyemi, 2007), which confirms the persistent poor performance of students in science in educational institutions in Africa over the years. The situation is attributed to various factors. One of the major issues is inadequate science models in African educational institutions. The issue of inadequate funding of the education sector is also a contributing factor to the inadequacy of science teaching and learning materials in educational institutions. Over the years, financial allocation to the education sector has been inadequate for the needs of the sector thus making it impossible to procure adequate models for teaching and learning.

Asiriwa (2005) regarded education in science and technology as centrally and necessarily concerned with teaching or training of individual in order to acquire systematic skills, knowledge and attitude and application of these to the society. In spite of the benefits of education to man and the society, the educational system has continually turned out products (graduates) with skills and attitudes that are neither needed in the modes of production nor saleable in the limited industrial-commercial establishments. This, according to Nwagbeo (2008) has continuously led to mass unemployment of school leavers with the attendant problem of increased economic, social and moral vices. Aggarawar (2001) declared that all knowledge a learner gains will be of no use if he or she cannot make ends meet in his life after school.

Importance of Improvisation in Science Education

Various authors have defined the concept 'improvisation' in different ways. Ogunbiyi, Okebukola and Fafunwa (2000) define it as the act of substituting for the real thing that is not available. Bajah (2002) takes it to be the use of substitute teaching and learning materials where the real one is not available. Kamoru and Umeano (2006) further define it as the act of using materials obtainable from the local environment or designed by the teacher or with the help of local personnel to enhance instruction. According to Ihiegbulem (2006), it is the act of substituting for the standard instructional materials not available, with locally made instructional materials from readily available natural resources. From these opinions, improvisation entails the production of instructional materials using available local and cheaper resources and the use of such instructional materials for effective teaching.

Improvisation serves the following purposes in the education system Bajah (2002):

i, Reduces the cost on the purchase of instructional materials in educational institutions;
ii. Ensures the realization of lesson objectives;
iii. Helps in solving problem of inadequate instructional materials in schools;
iv. Gives room for a teacher to demonstrate his creative skills;
v. Gives room for the use of cheap local materials as alternatives to the expensive foreign ones;
vi. Encourages students towards the development of creative abilities;
vii. Enables teachers to think of cheaper, better and faster methods of making teaching learning process easier for students;
viii. It exposes students to the vase resources in their environment.

There is no need doubt that science and technology plays prominent role in the development of a nation. Okeke (2007), science and technology serves as the key to modernizing or developing a society. The developed nations in the world today have achieved greatness due to the special attention given to science and technology. One of the strategies for enhancing the growth of science and technology in a nation is by paying attention to the training of children at the foundation stage. This implies that there should be more focus on science and technology at the primary, secondary levels and at the colleges of education level. Over the years, the issue of inadequate instructional materials for the teaching of students in educational institutions in Africa has been predominant. It is therefore imperative that the issues of improvisation of instructional materials are given adequate attention.

Many factors make the call for improvisation of instructional materials in educational institutions in Africa expedient. One of these is the persistent poor funding of the education sector. Over the years, financial allocation to the educational sectors has been inadequate for the realization of educational objectives. There are therefore inadequate science instructional materials in educational institutions at all levels in the country. For instance, many authors such as (Gilbert, Boulter& Rutherford, 2000) has observed that ineffective teaching of science in educational institutions in Africa is due to non-use of science instructional materials for teaching, among other factors. Consequently, there is poor performance of students in science in both internal and external examinations (Eduran & Duschl, 2004; Justi & Gilbert, 2005).

Research Design

For every research study, the choice of design must be appropriate to the subject under investigation. In searching for appropriate design, the researcher came across various research designs such as Experimental, Quasi-experimental, Action research, Descriptive survey, Case study and Developmental research design among others. In this study, the researcher argues that developmental research design is the most appropriate when programmes or products are being developed to improve education instruction. Developmental research is a disciplined inquiry conducted in the context of the development of a product or programme for the purpose of improving either a thing being developer's capabilities to develop better things of this kind (Roget, 2003: Ary, Lacy & Asghar, 2002).

Ary*et al.* (2002) distinguish between two types of developmental research. These include Type 1 and Type 2. Type 1 is the study of specific product or programme design, development or evaluation of a project. Lessons are learnt from developing specific products and analyzing the conditions that facilitate their use. Type 2 is the study of a general design, development, evaluation processes, tools, or models. New design, development, evaluation procedures, models, and conditions that facilitate their use are generated (Aryet al., 2002). The researcher adopted the type 1 developmental research design which aimed at developing teaching and learning materials (conceptual models) to improve the teaching of chemical formulae and nomenclature that can be used by both teachers and students of science and in particular Chemistry in Ghanaian schools.

The choice of developmental research was based on:

1. Flexibility in developing an intervention step by step within the context of the problem. Developmental

research is seen as a means of influencing educational practices by experimenting with promising interventions and seeing whether they work in real classroom setting (Pimpro, 2011).
2. It is methodologically eclectic, that is, it employs a variety of research methodologies, applying any tool that meets their requirements.
3. Developmental research may include a number of component parts. Sub-studies may be conducted to analyse and define the instructional problem, to specify the content, or to determine instrument reliability and validity.
4. Sub-studies may be conducted to provide a formative and summative evaluation, or a follow-up of post instruction performance. Recent study following this line of investigation in context similar to Ghanaian SHS was in Tanzania by Pimpro (2005).

Design and Development Process of CMs Prototypes
Conceptual models were designed and developed as prototypes. A prototype is a working model of a product that is used for testing before it is produced for use (Robinson, 2001). Prototypes help designers learn about the designing process of an instructional product, how students will use the product, and how the product could fail or break. One of the advantage of building a prototype prior to full scale production is to explore design alternatives of the model with low cost in terms of time, money and materials required to manufacture a final product (Patton, 2003). A prototype is not the same as a model. A model is used to demonstrate or explain how a product will look or function. But prototype on the other hand is used to test different working aspects of a product before the design is finalized, constructed and fully put into practice. In developing conceptual models a succession of prototypes were produced in an evolutionary prototyping approach. This means that the final products were produced through a series of successive revised steps of the first prototype. (see Fig. 2)

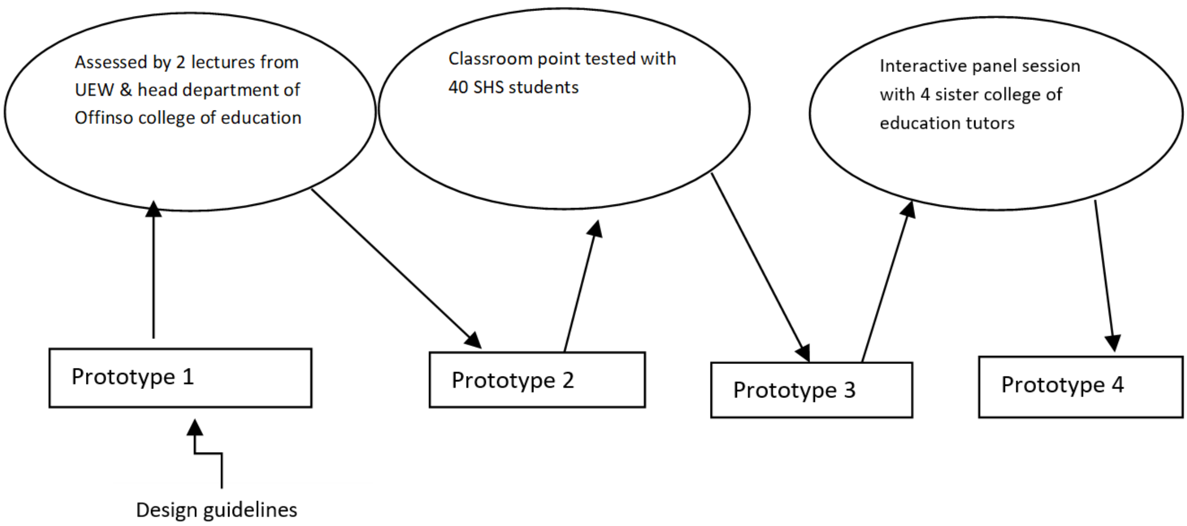


Figure 2.Procedural Development Process of Prototype Conceptual Models

The first prototype of the conceptual models was developed by the researcher based on the designed guidelines mentioned above and were assessed by two Senior Science Education lecturers from the Science Department of University of Education, Winneba (UEW) and the Head of Science Department of Offinso College of Education. Based on their comments on the first version, the second was developed and pilot-tested with 40 students from St Jerome SHS. The final version of the conceptual models was developed after incorporating the comments and recommendations from earlier models.

The final conceptual models were implemented and evaluated on a large scale. In developing the four (4) prototypes (prototype I to IV) the prime focus was to meet the intended purpose for which the prototypes were being developed. The design guidelines for the conceptual models are described below.

The following preliminary guidelines were used to guide the design of prototypes of conceptual models (CMs).

i. Active learning through conceptual model activities:- focusing on students-centred pedagogies, CMs were designed to actively engage students in the learning process through both hands-on and minds-on activities. The activities designed were simple to carry out in classrooms with more emphasis on manipulation of the materials.
ii. Rational and learning goals of Science Education at the SHS level:- to help teachers with the implementation, CMs were designed with clear learning objectives to used as a game.
iii. Content support: reflects on the challenges Ghanaian science teachers face in teaching abstract concepts.

To assess the impact of the CMs in the classroom on a large scale, pre-test intervention-posttest control group design of the quasi-experimental approach was adopted (Robinson, 2001). This means that the pretest and posttest scores of a casual experimental and control groups were compared. The quasi-experimental design was adopted because the study was to investigate a situation where intact classes were needed and therefore, random selection and assignment was impracticable.

Population

Target population is the total group to which a researcher would like to generalize the results of a study (Ary*et al.*, 2002). The target population for this study was all SHS students in the Offinso Municipality in the Ashanti region of Ghana. There are three Senior High schools in the area with a total population of 1836 students (1206 males and 630 females). The accessible population is the population of subjects that is accessible to the researcher for a study (Patton, 2002). The accessible population for the study consisted of all the 223(153 males and 70 females) and 165(100 males and 58 females) SHS1 students respectively as at 2012/2013 academic year.

Sample and Sampling Procedure

A sample is a true representation group selected from the population for observation in a study *(*Ary*et al*., 2002). The sample size in developmental research is not fixed. The sample size depends on what the researcher wants to know, what is at stake, the purpose of the research, what will be useful, credible and can be done with the available resources (Patton, 2002). Simple random sampling was used to select 200 (100 males and 100 females) selected from Dwamena Akenten SHS and Namong SHS for the study. However, St Jerome SHS was used for pilot test (Appendix M). The sample was selected through both cluster and purposive sampling techniques.

Cluster sampling is a process in which samples are chosen from pre-existing groups for study. Clusters (classes) are selected and the individuals in those classes are used for the study (Patton, 2002). This technique ensured easy access of the subjects to the researcher since most of the subjects remained in their regular classes. Statistics from the two schools indicated that the number of males outweighed their female counterparts. It was against this background that purposive sampling technique was again used to sample more females from the other clusters not selected in order to make up the differences in gender representation. In all, 200 SHS1 students (50 males and 50 females) were drawn from each of the two schools. These SHS students were sampled because they were offering the Integrated Science course within which chemical formulae and nomenclature is taught as at the time the research was to commence and they were all non-science students since they are not doing the elective science at the SHS.

Research Instrument

Achievement test was the instrument used for data collection. The instrument consisted of pretest and posttest. The test items for the pretest and posttest were made up of eighty content questions based 0n the number of test items that students are assessed upon completion. The test items were drawn from the examinations past papers set by West Africa Examination Council since 2006. The test items were parallel forms of Ionic Bonding Achievement Tests (BAT) used by Trimpe (2003). Researchers, including Robinson (2003), Taber (2003), Teichert and Stacy (2002) and Trimpe (2007), have used modified versions of IBAT to assess students and teachers' achievements on chemical formulae and nomenclature. The items were put into two sets of forty questions each. The content of the items were validated based on the existing course content on chemical formulae and nomenclature.

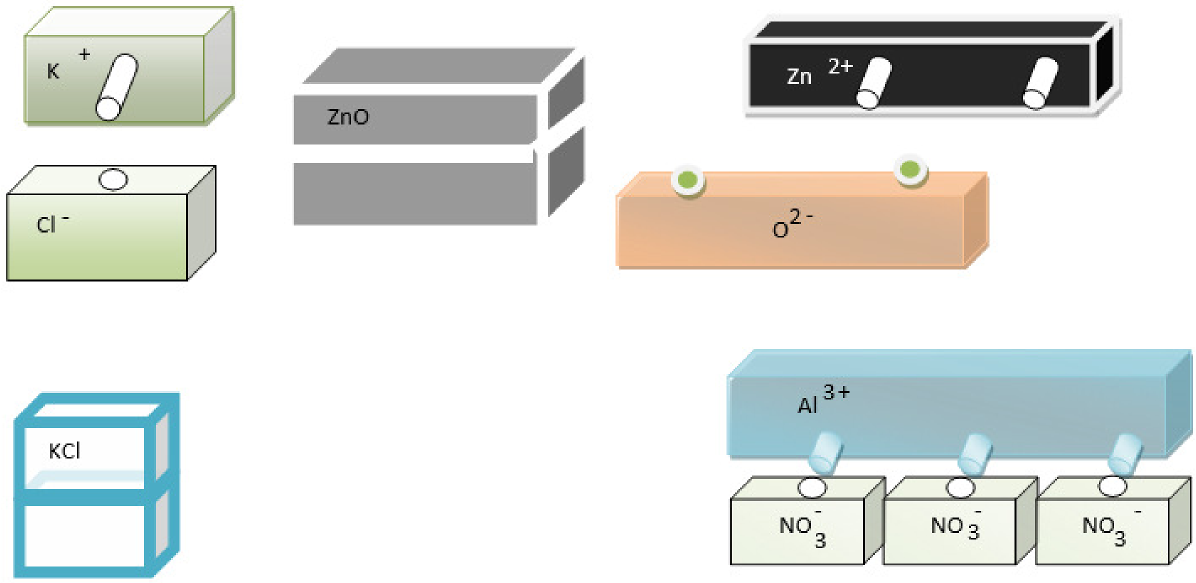
The instrument consisted of three sections, A, B and C. Section A provided general information about the purpose of the test. Section B was to collect information on the independent variables such as sex, age, college and grade level. Section C was made up of two sections, 1 and 2. Section 1 of Section C consisted of 10 test items meant to elicit prior conceptions of students in atomic structure and chemical bonding. Section 2 contained 30 test items on Chemical Formulae and Nomenclature. The pretest scripts were scored out of 40 marks. The scores were used to categorize the students into three ability groups, low, average and high achievers. The low achievers were those who scored less than sixteen (16) marks out of 40 on the pretest, while the average and high achievers were those who scored in the posttest 16 and 25; and above 26 out of 40 marks respectively.

Chemical Formulae and Nomenclature Posttest (CFNPT) was administered to the students after the intervention. The use of CFNPT avoided the effect of pretest sensitization. Pretest sensitization is the natural tendency of the subjects to perform better in the posttest due to previous experience if very same pretest is used even without any intervention (Patton, 2005). The test items increased in complexity from the first item to the last in order to cater for the thinking levels of students. The CFNPT was used for posttest to assess the effects of the intervention. Time allotted for students to respond the instrument was 50 minutes. Each correct response attracted a maximum of one mark.

Validity
Validity of a research instrument is how well it measures what is intended to measure (Patton, 2007). Face validity and content validity of the instruments were addressed. For face validity, the instrument was assessed by the researcher's supervisors in the Department of Science Education UEW. The validators determined the appropriateness of the content material, clarity of the test items and instruction. Its validity was further enhanced through pretesting and weaknesses identified remedied. The content validity of the instrument was ensured by developing a table of specification. The CFNPT and the table of specification were examined by the supervisors to identify and correct any mismatches between the test items, table of specification(Appendix E) and the course content used in the intervention. The comments of the validators were used to revise the content and the instructions.

Reliability
Joppe (2000) defines reliability as the extent to which results are consistent over time. Again, if the results of a study can be reproduced under a similar methodology, then the research instrument can be considered as being reliable. Reliability concerns the degree to which an experiment, test, or any measuring procedure yields the same results on repeated trials (Patton, 2007). Internal consistency estimate of reliability procedure was used to determine the reliability of the instrument after pilot testing. The pilot test response of students was analyzed using the Cronbach alpha. According to Aryl *et al*., (2002), for test instrument which measures intellectual achievement to be accepted, it should have Cronbach alpha Coefficient reliability of not less than 0.72. Cronbach alpha Coefficient of the instruments, CFNT and CFNPT were 0.76 and 0.82 respectively.

Figure 3. Sample Improvised Conceptual Models used



Students were taken through steps involved in writing and naming chemical formulae and using conceptual models as outlined below:

Steps Involved in Writing a Chemical Formula Using Conceptual Models

- **i.** Identifying the constituents of a chemical compound.
- **ii.** Recognizing CMs representing the constituting ions of the compound.
- **iii.** Fitting of the CMs into each other side by side.
- **iv.** Writing ratio of the number of metal ion CMs to that of non-metal.
- **v.** Reducing the ratio to its lowest term and rewriting them as subscripts. When the ratio is 1:1, subscripts are not written for them.

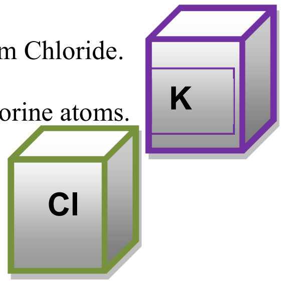
Steps Involved in Naming a Chemical Formula Using Conceptual Models

- i. Displacing the fitted CMs forming the compound from their positions.
- ii. Identifying the CMs representing cations and anions of the compound.
- iii. Writing the names of the cations and anions using their ionic names.
- iv. Finding out whether the cation has variable or fixed oxidation state. If variable, write the name of the cation, then its oxidation state in capital Roman numerals and place within a parenthesis. This is followed by the name of the anion. Where the oxidation state is fixed, write the name of the cation straight forward, followed by the name of the anion.
- v. Reducing the ratio to its lowest term and rewriting them as subscripts, and when the ratio is 1:1, subscripts

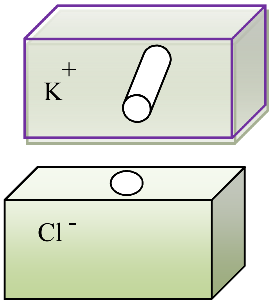
are not written for them.

Having taken the students through the steps, they were guided to use the CMs to write chemical formulae for compounds (see figures 1, 2, 3 and 4):

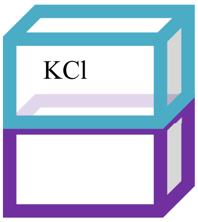
Figure 4. Example of how to use CMs in writing a chemical formula for potasium Chloride.



1. Identifying the Constituents of Potasium Chloride as Potasium and Chlorine atoms.
2. Identifying CMs constituting potasiumm Chloride as K^+ and Cl^{-1}.



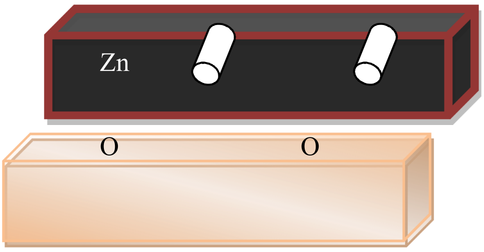
3. Fittings of the CMs into each other side by side.



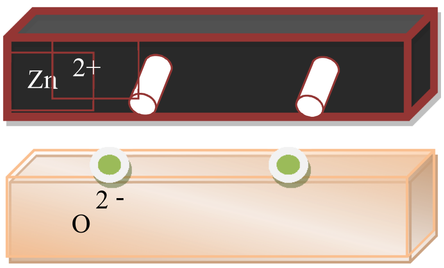
4. Writing the ratio of the metals model to that of the non-metals one as K: Cl = 1:1
5. Since the ratio 1:1, no subscripts are written for them, hence the formula is KCl.

Figure 5. Steps Involved in writing Chemical Formula for Zinc Oxide

1. Identifying the Constituents of a Zinc Oxide as Zinc and Oxygen atoms.



2. Identifying CMs representing Zinc and Oxide ions as Zn2+ and O2-.

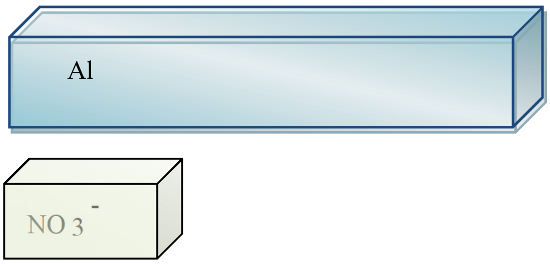


3. Fitting of Zinc and Oxide CMs into each other side by side.

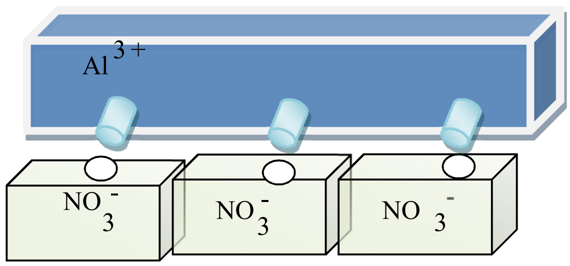
4. Writing ratio of the number of Zinc ion CMs used to that of Oxygen as Zn: O = 1:1.
5. Since the ratio is 1:1, subscripts are not written for them, hence the formula is ZnO.

Figure 6. Writing a formula for Aluminiumtrioxonitrate (V)

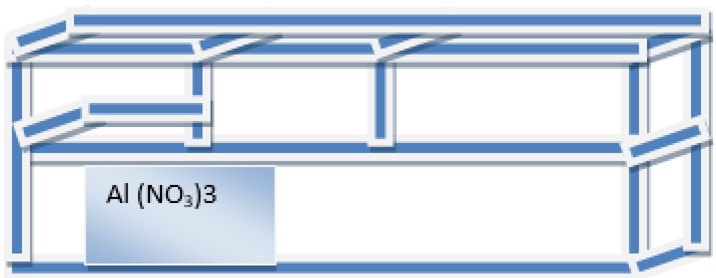
1. Identifying of the constituents of AluminiumTrioxonitrate (V) as Aluminum atoms and Trioxonitrate (V) ion.



2. Identifying CMs representing AluminiumTrioxonitrate (V) as Al^{3+} and NO^-_3.



3. Fitting of the CMs into each other side by side.



4. Writing ratio of the number of Aluminium ion CMs used to that of trioxonitrate (V) ions as Al: NO_3^- = 1:3
5. Since the ratio is 1:3, hence the formula is $Al(NO_3)_3$.

Data Collection Procedure

The researcher made two familiarization visits to the selected SHS schools with formal introductory letters obtained from the Head of Department Science of Education, University of Education, Winneba in the first week of July, 2013(Appendix F). This enabled the researcher to seek permission from the schools authorities. During this visit the researcher was introduced to both the students and members of staff. The purpose of the research was discussed with the science tutors of the schools. The time table for the integrated course was copied from the master time table to enable the researcher to plan his intervention.

The control group was taught by the science teachers of the SHS while their counterparts in the experimental group were taught by the researcher using an intervention developed for that purpose for six (6) weeks. A posttest, after the intervention was administered to the two SHS. To ensure reliability, both forms of the test were administered in the respondents own classrooms and resident teachers helped in invigilation. An equivalent form of the pretest was used for the posttest to avoid the effect of pretest sensitization. According to Aryl et al. (2002), pretest sensitization is the effect of pretest on the respondents that causes them to respond differently regardless of the treatment, from the way they would without the pretest. Pretest sensitization is a major threat to the validity of a test when very same test is repeated rather than parallel forms.

Some of students felt uneasy at the very beginning of the data collection process. For that matter, they were told that the exercise was to identify their weaknesses and determine the appropriate methodological approaches which would benefit them. Finally, students relaxed when they were further told that the exercise would not influence their Continuous Assessment or course grades, and that they need not write names or index identification number.

Data Analysis

Data were analyzed with regards to the research questions. A relationship was established between the independent variables, gender and ability groups on one hand, and performance of students on CFNPT which was the dependent variable on the other hand. Research question one was analyzed by classifying respondents' levels of understanding of chemical formulae and nomenclature using selected criteria (see Table 4) and validated schemes.

Table 1: Criteria for Classifying Levels of Understanding

Level of understanding	Criteria for selecting responses
Complete understanding	Responses that contain all components of the marking scheme.
Partial understanding	Responses that included at least one of the components of the marking scheme, but not all the components.
Misunderstanding	Responses that included complete incorrect information
No understanding	Responses that has no bearing on the question.

The students' responses reflecting each level of understanding were analyzed. The number of respondents exhibiting each degree of understanding was determined using frequency counts and percentages. Both prior and post conceptions of the experimental group in the area of basic atomic structure and chemical bonding, periodic properties and writing of chemical formulae and International Union of Pure and Applied Chemistry names (IUPAC Nomenclature) were compared. A bar chart was also used to display the percentage against the degree of understanding. However, Research Questions 2, 3 and 4 were formulated into hypotheses and analyzed using Statistical Package for Social Sciences (SPSS) version 16.0. Descriptive statistics such as mean scores and standard deviations were computed and the two groups compared. The 2-tailed t-test for independent samples was used to investigate any differences that existed between the experimental and control groups at a confidence level of 0.05. . A bar chart was also used to further compare the groups with their corresponding mean scores.

Again, the 2-tailed t-test for dependent samples was used to investigate any differences that existed between the scores of males and females and male low-achievers and their female counterparts in the experimental group. A pie chart was also used to further compare the gender with their corresponding mean scores.

Lastly, research question 5 was analyzed descriptively to determine which of the cognitive ability groups perform better. The mean gain of each ability group was calculated using the relation, mean gain = posttest means – pretest mean. The 2-tailed t-test for independent samples was employed to determine the existence of any significant difference among the various cognitive ability groups.

Results and Discussion

Interpretation of Students' Pretest Scripts Sampled Responses

To find out prior knowledge of student in writing chemical formulae and their nomenclature when they were taught with CMs, Research Question 1 was posed as:

Research Quuestion1: what knowledge do SHS students have with regard to the writing of chemical formulae and nomenclature?

The prior knowledge of the respondents were analyzed with terms of the requirement of the question and classified as partial misconception, no understanding and complete understanding using a marking scheme to the pretests.

Prior knowledge on Basic Knowledge on Atomic Structure and Chemical Bonding

Partial Understanding: These were responses that contained at least one of the components of the validated

responses, but not all components. Here the respondent assigned varied responses which were very close to the expected or validated responses not to be regarded as a correct response.
Examples are stated below.
The charge of an electron:-Negative (Sampled response to part Q4). Negative was supposed to have a numerical value attached to it, say negative 1. But some of the respondents failed to indicate as-1.

Misunderstanding: these responses contained unscientific or illogical information. Example from student' responses are shown below: Symbol for chloride ion:-cl, cl-(Sampled responses to part one Q5). The symbol does not represent the name of the ion provided. The chloride ion was wrongly taken minus cl or cl minus. The misconception may be due to inability to differentiate between ion as a charge atom and its position on the symbol. Again, the student did not understand the rule governing assigning chemical symbols to elements, hence represented Cl as cl.

Definition of atom:- It is the smallest particle of matter/ it is the smallest particle of an element/ it is a basic unit of matter. (Sampled responses to part One Q1). The definition given was incomplete. Some of the defining properties that help to make the definition complete were not stated. These include (1) the atom is the smallest particle of an element, (2) the atom should be able to take part in a chemical reaction and (3) the atom should be able to keep the properties of that element. The students could not reason that to define an atom. The two defining properties were supposed to be incorporated into any of their responses given above before scoring the required mark on that item. This lapse may be due to lack of conceptual understanding of the defining properties of an atom.

No understanding: These were made up of irrelevant or unclear responses. Responses just repeated information in the question as if it is an answer, left a blank answer space or provided unrelated validated responses. In this case respondents provided answers that were either unrelated to the marking scheme as shown below: an example of unrelated responses provided by respondents was shown below:

Definition of atomic number: - An atom of the mass number/it is the number f atoms in an atom. (Sampled response to part one Q1). The definition provided by the respondents has no bearing on the concept. The students might have mistaken the definition of atomic mass for either the mass number or atomicity of a molecule.**Complete understanding:** Responses that included all components of the validated response. The chemical symbol for Potassium:- K (sampled response to part one Q10).

IUPAC Nomenclature

Most of them left banks possibly because they had no idea on what was to be done. Again it might be due to inappropriate pedagogical approaches used IUPAC Nomenclature:

Partial understanding: Name the species, HCO_3**:-**Hydrogen carbonation/ Trioxocarbonate acid/Hydrogen, Carbon and oxygen/Hydrogen Trioxocarbonate(IV)/ hydrogen carbonate(V) Oxide. The species is actually made of Hydrogen, Carbon and Oxygen or hydrogen and carbonate ions as was acknowledge by the respondents in their responses. The respondents did not go by IUPAC convention in naming chemical substances and as such were not specific. Their inability may be due limited knowledge with regards to the naming of compounds. They should have indicated the number of oxygen atoms present in the formula by using the prefix 'trioxo'. Again, some of the respondents did not know that the oxidation state of the central atom, carbon was to be calculated before naming the compound. Even the few respondents who were aware of this convention could not calculate the oxidation state. Finally, most of the respondents did not indicate that the species is a charged unit and as such is an ion. Some of the respondents considered the species as an acid. The respondent' faulty rationalization might have been pre-empted by the mere presence of the incompletely replaced by hydrogen ion.

Misunderstanding: Name the compound, $CaC0_3$:- Calcium and Oxygen/Calcium carbon dioxide/ A combination of Calcium/Carbon and oxygen. Respondents could not recognize that the compound is made up of opposite charged particles Ca2+ and CO 2 . however, it was only the calcium which was identified.

No Understanding: Name of the compound made from Lithium and Chlorine:- Lithium /Lithium compound/ Lithium and chlorine. These responses were clearly unrelated to the validated responses. T indicated that the respondents did not understand what was expected of them.

Interpretation of Students' Post-test Scripts Sampled Responses

This segment of the research provided examples of sampled responses from the scripts of the respondents' posttest. This includes prior conceptions of students in basic atomic structure and chemical bonding, periodic properties and writing of chemical formulae and IUPAC Nomenclature Responses which include all component of the validated scheme to the posttest were accepted.

Prior conceptions of students in basic atomic structure and chemical bonding

Partial understanding: Molecular formula for lead (IV) Oxide:-PbO/PbO_4 . From the responses provided, a few of the respondents could not get it correct even though the constituting element was identified and right oxidation state not used.

Al + 3NO - $\longrightarrow$ Al NO_3 (Sampled response to part two Q 26). Few of the respondents failed to put the NO - into a parenthesis and hence did not indicate the 3 which is supposed to be a subscript after the parenthesis.

Complete understanding

The responses to Q1, Q7, Q1, Q14, Q15, Q20, Q12 and Q22 among others met the following. Correction definition of atoms and terms associated which parts of the atom, differentiations of types Chemical bond, statement of subatomic particles and their properties and writing correct ions formed from atoms. An atom become an ion: an ion is formed when an atom/ group of atoms loses or gains one or more electron (Sampled answer to Q1)

Define mass number of an element: Mass number of an element is the sum of protons and neutrons in the nucleus of the atom (Sampled answer to Q7).

Write down the electronic configuration for $_{18}$Ar: -2, 8, 8 (Sampled answer to Q8).

Isotopes:- Theses are atoms of the same element having same atomic numbers but different mass number due to differences in neutron numbers (Sampled answer to Q14).

The group of chemicals substances that has a high melting points and conducts electricity when melted:- Ionic/Electrovalent bond (Sampled answer to Q14). The type of bond is formed when pairs of electrons are equally shared by atoms:- Ionic/Electrovalent bond (Sampled answer to Q21). Determines the chemical properties of an element:- Valence/Outcome electrons (Sampled answer to Q22)

Writing of IUPAC Nomenclature - The responses to Q9. Q27, and Q30 among others met the following criteria:- The oxidation number of

- An element in its uncombined, atomic or molecular form is zero (0)
- An ion of a single atom is equal to the charge on the ion.
- An oxygen atom is -12 except in peroxides (H_2O_2) and superoxides (KO_2) where it is -1 and -1/2 respectively.
- Hydrogen is -1 in metal hydrides.

Oxidation number of N_2: Zero (0) (Sampled answer to Q9).

The chemical formula, KCl is a formula unit Explain:- It means that one potassium ion combines with chloride ion to form KCl (Sampled answer to Q29).

The….number of a compound is equal to the sum of the oxidation numbers for each atom in the compound:- Oxidation (Sampled answer to 30)

Writing of chemical formulae and periodic properties:- The students' responses to Q11, Q12, Q15, Q17, Q19, Q24 and Q29 among others showed:- correct identification of groups and periods, correct indication of symbols of each element, charge of an acceptable chemical compound formed is zero. The name of the Compound made from lithium and fluorine:- (LiF) (Sampled responses to Q11). The formula of Aluminum Sulphide:- $(Al)_2S_3$ (Sampled responses to Q12). Which group of element form only negative ions:- Group V, VII and VII (Sampled responses to Q15). Identify the group of element that never form compounds:- Rare/ Inert/ Noble gases. (Sampled response to Q17).The formula of Magnesium Carbonate:-$MgCO_3$ (Sampled response to Q19). Write down the molecular formula for ammonia:- NH_3 (Sampled response to Q24). The chemical formula for Iron (III) tetraxosulphate (VI) acid:- H_2SO_4 (Sampled response to Q29).

Statistical Presentation of Results

Respondent's prior and post conceptions of chemical formulae and nomenclature after the intervention was classified. Frequency counts and percentage were used to tabulate the number that exhibited each degree of understanding in both tests (see Table 5 and Figure 7). A total 70 (70%) and 25 (25%) of the students showed sound and partial understanding of chemical formulae and nomenclature respectively after the intervention as against 7(7%) and 23 (23%) in the pretest. Thus, there was an increase of 63% in the number that showed sound understanding.

Table 2. Frequency Distribution of the Experimental Group Understanding Level in both Types of Test

Degree of	Posttest		Pretest	
Understanding	Frequency	percentage	Frequency	percentage
Complete understanding	70	70	7	7
Partial understanding	25	25	23	23
Misconception	5	5	30	30
No understanding	0	0	40	40

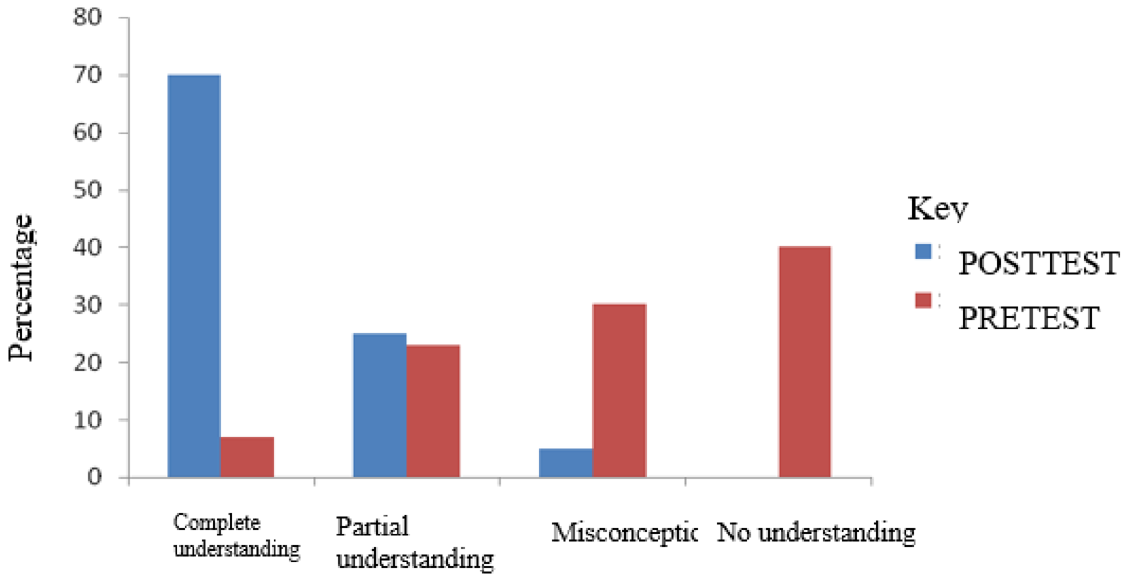


Fig. 7: A Bar Chart Showing Percentage Distribution of the Experimental Group Understanding Level in both Types of Test

Again, the number that showed misconception in the pretest decreased from 30(30%) to 5(5%) at the end of the intervention. Finally, no respondent showed no understanding after the posttest as compared to 40(40%) in the pretest. It was clear from the results that, the performance of students in writing chemicals formulae and their nomenclature were largely influenced by their alternative conceptions. These conceptions ranged from partial understanding, misconception to no understanding. Despite the seemingly improved sound understanding from the pretest (7%) to Posttest (70%) (Table 5 and Figure 7), the inability to write chemicals formulae and their nomenclature still persist among few students.

To find out whether the performance of students was enhanced in writing chemical formula and their nomenclature when they were taught with CMs, Research Question 2was posed as:

Research Question 2: What is the difference in the differences in performance between the control and experimental group in writing chemical formulae and their nomenclature?

Descriptive statistics such as mean, mode and standard deviation for both tests were computed (see Table 6 and Figure 8). The mean score for the control group was 9.85, (SD= 4.50) and a mode of 7 indicating the most frequent scored mark, while the mean score in the experimental group 9.83, (SD= 4.90) and a mode of 5. The mean score of the pretest in the control group was slightly higher that of the experimental group before the intervention. However, the posttest results indicated that the mean score for the control group was 10.63, (SD=4.27) and a mode of 8, while the mean score in the experimental group appeared to do better than the control group after the intervention.

Table 3. The 2-tailed t-test for independent samples analysis of Pretest and Posttest scores of the Experimental and control Groups.

Groups Compared	Test	Mean Test Scores	Standard Deviation	t-valued	p-Value
Experimental	Pretest	9.83	4.90	1.501	0.43612
Control	Pretest	9.85	4.50		
Experimental	Posttest	20.21	6.05	-12.93	1.6602
Control	Posttest	10.63	4.27		

A= Not Significant, $p > 0.05$. *= Significant; $p < 0.05$

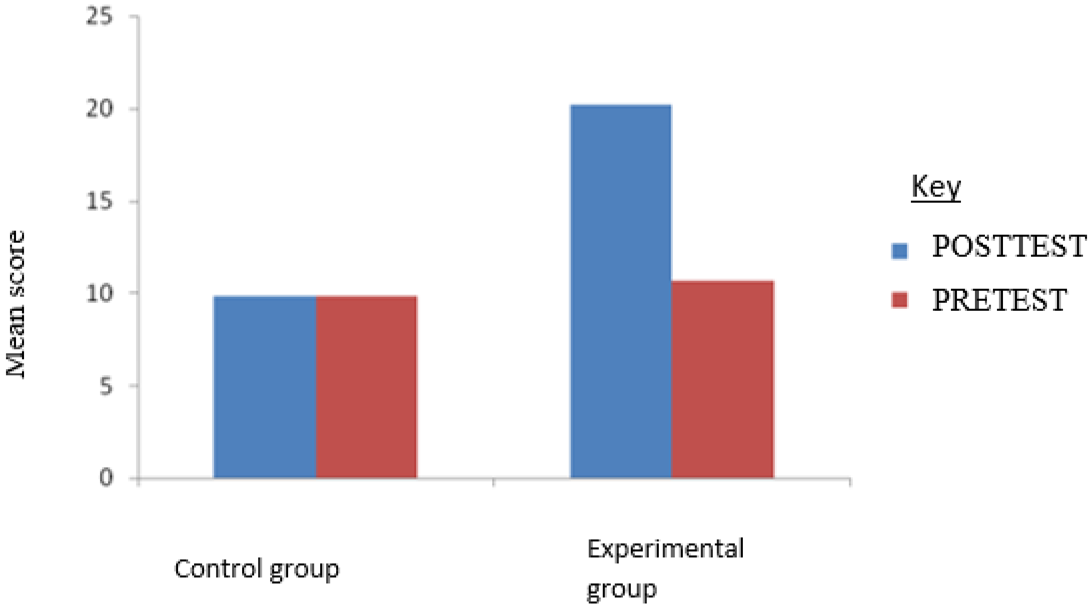


Figure 8.A Bar Chart Showing Independent samples analysis of Pretest and Posttest scores of the Experimental and control Groups.

Research Question 3: What is gender difference in the performances of students in writing chemical formulae and their nomenclature when they are taught with CMs?

Descriptive statistics was used to determine the differences in performances between females and males in writing chemical formulae nomenclature. Descriptive statistics such means, mode and standard deviation for both types of test were compound (see Table 7 and Figure 9). The mean score for the males was 10.42, (SD=4.93) and a mode of 9, while the mean score for the females was 7.4, (SD=3.56) and a mode of 7. The mean score of the males in the pretest was slightly higher that of the females before the intervention. However, the posttest results indicated that the means score for the males was 20.76, (SD=6.33) and a mode of 21, while the mean score for the females was 21.36, (SD=5.92) and a mode of 23. The females appeared to have done better than the males after the intervention.

Table 4.The 2-tailed t-test for dependent samples analysis of Scores according to Gender in the Experimental Group.

Gender	Number of Respondents	Test Scores	Mean	Standard Deviation	t-value	p-Value
Male	50	Pretest	10.42	4.93	0.029	0.007 [a]
Female	50	Pretest	7.40	3.56		
Male	50	Posttest	20.76	6.23	0.250	0.804 [*]
Female	50	Posttest	21.36	5.92		

A= Not Significant at 0.05; p > 0.05.   *= Significant at 0.05; p < 0.05

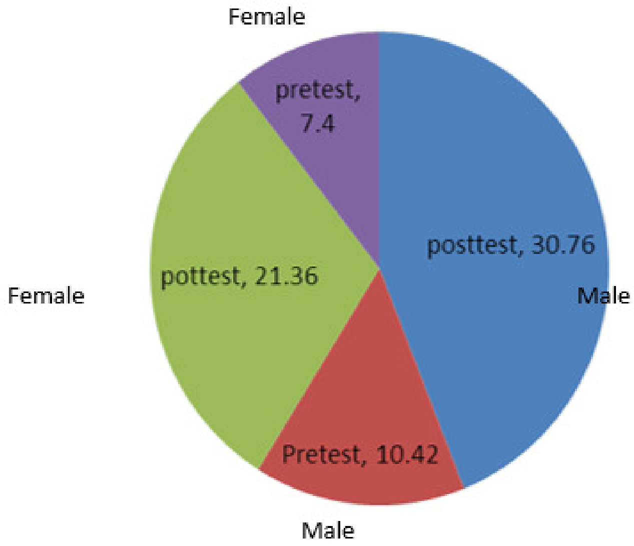


Fig. 9: Pie chart for independent sample analysis of pretest and posttest mean scores according to Gender in the experimental group

Summary of Findings

The study revealed that most students lack a scientific and complete conception of basic concepts in atomic structure. Further analysis revealed that some to the most frequent difficulties students had with this concept included the use if unscientific or incomplete definition which does not include all the defining properties of the concepts. In most situations definition of terms like atom, element and ions were interchanged. For instance some students defined an atom s the smallest particle of a matter, charged species or a piece of an element. Other forms misconceptions include the definition of an ion as negatively charged particle or an atom with a positive charge. It is clear that many students have no sound understanding of these basic concepts. The common problems that emerged from the students' responses included

- Misconception of the definition of the atom, ions and elements
- Wrong conception of the meaning of mass number, atomic number and proton number
- General weak arithmetical background
- Wrong conception of the charges of the subatomic particles such as elements, protons and neutron.

Again, it is clear from the sampled answers that students have various conceptions on the writing of chemical formulae and nomenclature. Serious alternative conceptions on chemical symbols expressed by respondents include writing the symbols of

- Fluorine as Fl instead of F
- Chlorine as cl or Cl instead of Cl
- Bromine as br B (which is for boron) instead of Br
- o for oxygen instead of O and carbon, c which in many cases were too small to be considered as C.

The following accounted for respondents' partial, misconception or no understanding in writing IUPAC names.

1. The use of wrong prefixes like mono, di, tri, tetra, to indicate the number of oxygen atoms in the given compounds.
2. Inability to identify the constituting ions presented in the given compounds and naming each accordingly.
3. Lack or inadequate skills in determining the oxidation states or valencies of central atoms with respect to polyatomic ions or oxoanions present in a compound
4. Lack or inadequate knowledge using capital Romans numerals to designate oxidation state for central atom and placing these in parenthesis.

From the study and the review of literature, it appears the problem of poor conception of chemical formulae and nomenclature can also be explained by three facture related to instruction;

i. First, chemical formulae and nomenclature are abstract concepts like the atom itself and if appropriate mental models are not used in teaching, the subject matter becomes incomprehensible.
ii. Second, it seems that previous instructions have failed to help students make meaning of the concept and assimilate it into their knowledge structure. This resulted in compartmentalization of knowledge.
iii. Third, students tended to use unrelated correct ideas from their conceptual structure to answer questions related to the chemical formulae and nomenclature.

Conclusion

One purpose of science education is to ensure that every learner acquires such a good grasp of science as to be able to apply it to man's need. This has to be pursued through active participation of the learners. The present study revealed that student from OCE did not develop an appropriate conceptual understanding of chemicals formulae and nomenclature, and therefore possessed a lot of misconceptions about chemical formulae and nomenclature. The student's conceptual understanding of writing chemical formulae and nomenclature ranged from partial understanding to no understanding. The results lend credence to various report of institute of education (chief Examiner's report, 2004-2009), (Taber, 2003) and dun (2005) that colleges of education students perceive chemical formulae and nomenclature to be difficult and therefore possess a lot of misconceptions about it.

However, the integration of conceptual models into science lessons illustrated how improvisation techniques can be integrated into a learning environment where student are given effective opportunity to visualize, explore, analyze and manipulate scientific concepts. The result of this study demonstrates that conceptual models are appropriate for the development of activity-based environments in science lessons and have the potential to provide science teachers with effective exploration and the necessary pedagogical approaches incorporate existing local resources and materials to bring the active process of learning chemical formulae and nomenclature to the students. As a result, more learner-centered learning environment can be created to enhance learners' ability for inquiry and discovery learning. The conceptual models have been found to be useful in this respect.

The results indicated clearly that conceptual models greatly influence students learning and widen the scope of learning skills and knowledge. This conceptual model mode of learning provides an alternative to the other teacher-centered learning approaches and enables students to enjoy a richer learning environment. It empowers students to become active learners and display their ideas their ideas and information in acceptable scientific terms and use their higher order thinking skills like analysis, synthesis, evaluation, reflection and manipulation while solving authentic problems. This learning mode also makes the teacher flexible in presenting learning materials in various innovative ways and become a co-learner, facilitator, consultant or guide and at the same time helping students to access, organize and obtain information to provide solutions to the problem rather than the one supplying and prescribing solutions to the learners as in the classical behaviours learning mode. In this learning mode, student learning, in particular, the learning process becomes the main focus, not the content, teacher or the conceptual models used, which only play supportive roles, thus creating a student-centered learning environment using conceptual models can contribute substantially towards enhancing student learning and the learning processes. Onasanya and Adegbija (2007) recommend that students, especially those who are in Arts bias institutions should receive a fair amount of support as well as encouragement in using conceptual models. Additionally, instructors need to be aware of effective listening skills and be ready to discuss them with learners. Since students' performance in chemical formulae and nomenclature showed that students who were taught using the conceptual models generally had higher mean scores than counterparts, it can conclude that the use of the models enhanced students understanding of chemical formulae and nomenclature Hence, it will be of great value if the technology behind the preparation of these models be made available to more teachers.

Furthermore, the general contention is that the nation stands a better chance of achieving the vision 2020 by pursuing science and technology. In response to developing countries demand for instructional materials to prepare youth to compete in a world driven by scientific knowledge, the role of conceptual models in science education should be emphasized when teaching chemical formulae and nomenclature. Learning cycle approach asserts that learning in the active process of constructing rather than passively acquitting knowledge directly from the teacher. The use of conceptual models increase instructional effectiveness and also reduces the time and cost needed for learning.

Recommendations

Based on the findings of the study, the following recommendations were made to enhance the teaching and learning of chemical formulae and nomenclature

1. Conceptual models should be used to enhance students' performance in chemical formulae and nomenclature of inorganic compounds in both mixed gender and ability classrooms.
2. Conceptual models be designed and developed by experts to help students develop alternative ways of learning difficult concept such as chemical formulae and nomenclature of inorganic compounds. In this way students will be helped to learn chemical formulae and nomenclature inorganic compounds meaningfully. This will help students to be actively involved in constructing and organizing knowledge in a way that can help them solve problems in real life situations.
3. Ministry of education and Ghana education service should include the use of conceptual models as an instructional aid in teaching and learning of chemical formulae and nomenclature of inorganic compounds and other related topic such as qualitative analysis, balancing of chemical equation among others.

Implication for science Teaching and learning
The result of this study indicate that many student in SHS have difficulty with the learning of chemical formulae and nomenclature due to difficulty associated with the conceptualization of the concept and difficulty in fitting ions or atoms together to formulae and nomenclature, the designed and developed conceptual models are intended to help teachers and students with the teaching and learning from compounds. It appears this problem is common to other concepts in chemistry. As a result, many students resort to the memorization of concept in chemicals formulae and nomenclature and thus find it difficult applying the concepts to solve problem or relating the concept to real life situation. It is therefore necessary that innovative ways of teaching chemicals formulae and nomenclature have to be developed to make learning meaningful. Conceptual models have been proven to be a useful method of diversifying the teaching and learning of chemical formulae and nomenclature. With the introduction of conceptual models in all Ghanaian Junior and senior high schools, better method of teaching can be explored in our schools as an innovation in the teaching and learning not only chemical formulae and nomenclature but in other abstract concept in chemistry. When this is done in teaching and learning of integrated science and chemistry as well as other science subject will become meaningful and interesting and students will be able to apply the concepts learnt in solving problems academically

Contributions of the study to Science in Education
Despite it numerous limitation, the strength of the study lies in its contribution to science education in Ghana. It is envisaged that the success of science education depends mainly on the methodologies used by the science teachers, and curriculum developers to enhance understanding of various scientific concepts. Coll and Taber (2003) asserted that the method of teaching employed by a potent factor in motivating students to learn. The president method of teaching science through listening, looking and learning have not been successful. If anything, it has culminated in making student dislike science. Therefore, reflecting on the challenges Ghanaian SHS teachers and students face in teaching and learning of chemical formulae and nomenclature in science and chemistry classes.

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