THE RELATIONSHIP BETWEEN STUDENTS' ACHIEVEMENT IN IDENTIFIED CHEMICAL CONCEPTS AND THE BALANCING CHEMICAL EQUATIONS

BY

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DECLARATION

I hereby declare that this thesis has been produced by me. It has not been presented in any previous submission for higher degree to the best of my knowledge. All quotations are indicated by quotation marks and sources of information are duly acknowledged by means of references.



Odoh Comfort Ojela (Mrs.)

CERTIFICATION

This thesis entitled "THE RELATIONSHIP BETWEEN STUDNETS' ACHIEVEMENT IN IDENTIFIED CHEMICAL CONCEPTS AND THE BALANCING OF CHEMICAL EQUATIONS by Odoh Comfort Ojela (Mrs.) meets the regulations governing the award of the degree of Master of Education in Science Education of Ahmadu Bello University and was approved for its contribution to knowledge and literary presentation.

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DEDICATION

This work is dedicated to my little daughter, Esther Oka Oodo who missed my motherly care and love at her tender age.

ACKNOWLEDGEMENT

I like to express my profound appreciation and sincere gratitude to all those who have in various ways been instrumental to the successful completion of this work. I am particularly indebted to Dr. A.A.M. Shaibu, my Supervisor, who despite his crowded schedule of duties, never relented in his effort to ensure that I was not handicapped at any stage of the study. His wise counselling, co-operation and constructive criticisms made possible the realisation of this work.

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ABSTRACT

Science as the bedrock of technological advancement is very important in national development. This has been pointed to in previous research studies and results of Senior Secondary Certificate Examinations. As a way to improve on the quality of Science Education, this study was undertaken to find out the relationship between students' achievements in identified chemical concepts and balancing of chemical equations.

The sample of the study consisted of 180 SS II chemistry students from six Senior Secondary Schools in Otukpo Local Government Area of Benue State. The population of the study comprised fourteen Senior Secondary Schools in Otukpo Local Government Area. The data for the study was collected by the use of test scores with a reliability coefficient r = 0.70.

The Pearsons' Product Moment Correlation Coefficient was used to test the stated hypotheses of the relationship between the understanding of chemical concepts and students' achievement in balancing chemical equations. Also t- test statistic was used. These were tested at P = 0.05 level of significance.

The findings of the study were as follows:-

(i) There was a significant relationship between the understanding of the identified chemical concepts and students' competency in

balancing chemical equations.

(2) There was significant relationship between boys' understanding of identified chemical concepts and their achievement in balancing chemical equations.

(3) There was significant relationship between girls' understanding of identified chemical concepts and their achievement in balancing chemical equations.

(4) There was significant difference in the mean score of students in the identified chemical concepts and their mean score in balancing chemical equations.

(5) There was significant difference in the mean scores of boys and girls in balancing chemical equations.

(6) The identified chemical concepts serve as pre-requisites for competence in balancing chemical equations.

Based on the findings from the study, recommendations were made that were considered useful in improving the quality of instruction and understanding in chemistry; especially in the important area of balancing of chemical equations.

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ABBREVIATIONS

SSCE	-	Senior Secondary Certificate Examination
SS	-	Senior Secondary School
WAEC	-	West African Examination Council
CCAT	-	Chemical Concept Achievement Test
CEAT	-	Chemical Equation Achievement Test

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CHAPTER ONE

INTRODUCTION

1.1 BACKGROUND TO THE STUDY

Science is a body of knowledge, a way of investigation and a way of thinking in the pursuit of an understanding (Conant (1964), Bassey (1968). Science therefore, is seen as a broadly based human enterprise. In the early 50s, educators were concerned with science curriculum reform. Educational researchers were concerned with finding better ways of 'imparting' knowledge to students, students were told what they needed to know and not how to come by it, hence they played intellectually passive role. Teachers' views focused on the issue of 'how students learn' (Ajeyalemi, 1981 and Yager, 1981). The teacher would teach but, may not attach meaning to students about the role of what he teaches. Science was then passed onto students as mere 'facts'.

The launching of Sputnik in October 1957, brought about reformation of science instruction globally which led to the discovery learning. This change undoubtedly increased the scope of science teaching/learning in schools especially in the developed countries (Driver, 1986). In pursuance of this teaching method in Nigeria, the Federal Ministry of Education (FME, 1985) adopted the use of the guided discovery approach which is strongly recommended in the National Science Curricula for Senior Secondary Schools (SSS). The approach which is activity-oriented involved practical demonstration, discussions and experimentation. The students are guided by the teacher and

materials provided. The attributes of the guided discovery as stated by Welch et al, (1987) are that:-

(i) Accurate observation provided a secure basis from which knowledge could be derived.

(ii) Science concepts will be learnt by becoming good observes.

(iii) Concept formation could flow from unbiased observation alone.

The difficulty of the approach was however underestimated (Novak, 1987). He stated that scientific concepts are imaginative constructs of the human mind and cannot be induced from mere observation. Again, the necessity of a prior 'conceptual framework' before one could 'discover' anything at all was not accounted for. Some scholars have opined that activeness of students in carrying out laboratory work do not necessarily make them to be active in the sense of actively constructing knowledge (Eckblad, 1981, and Cleminson, 1990). Novak (ibid) and Mari, (1995) contend that a fundamental reason for the failure in science of the 1970s was a failure to distinguish between a teaching approach, and a learning approach. Learning to Novak, ibid is not a mere accumulation of knowledge but an active process in which the learner engages in constructing concepts to account for novel phenomenon. Thus, there is disparity between what science educators would expect to see happening in the classroom and what actually happens (Lawson, 1982; Oguniyi, 1988 and Okebukola, 1990). This resulted in a wide spread call for ways of reforming science education in the 1980s by the British Education Council that is, 'science for all'. This move led to the establishment of a firm policy of science education for all children throughout the period of schooling in the British Education Council (HMSO, 1985). Interest in

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'science education for all' has of course extended to all parts of the world (Fensham, 1985, and Hadson and Reid, 1987). What is not always clear, however, is what form such a science curriculum should take. A common theme of many reports and recommendations contained in two documents of the Association for Science Education (ASE, 1979 and ASE, 1981) and the publications of the school science curriculum review (SSCR, 1984) is that science education for all children is necessary for economic well-being. This view is admirably expressed by a royal society working party that everyone needs some understanding of science, its accomplishments and limitations whether or not they are themselves scientists or engineers. Improving that understanding is not a luxury; it is a vital investment in the future well-being of our society (Royal Society, 1985).

In the Royal Society documents, it was argued that, if those who held positions of responsibility had at least some understanding of what science can and cannot achieve, they would be able to call for and evaluate advice on scientific issues. Hodson and Reid, (1987) and Solomon (1993) contend that all people need some science education so that they can think, speak and act on those matters related to science which may affect their quality of living. This shows that science is of great relevance to the society in numerous ways because, it has contributed immensely to the social, economic and political growth of society. These include:

- The use of fertilizers in the farming industry,
- The production and refining of petroleum,

- Medicine etc.

It is believed that increased scientific knowledge gives rise to technological advances which helps to improve the quality of life. Ozoro, (1977) and Abdullahi, (1982) agree with this view when they stated that sound education in science at lower levels of educational system plays a crucial role in the development of technological manpower. This is the main reason why Nigeria has laid down emphasis on science education (i.e. education for self-reliance) in her national goals for education (NPE, 1983). There is no doubt therefore that the continued wealth and prosperity of a nation depends partly on well-qualified and imaginative scientists. Thus, a policy of science education for all would ensure a greater pool of talent from which to recruit them. A society that educates only a minority of its citizens in science is a politically unjust society, because, in locating increasingly powerful knowledge in the hands of a few, it locates power and decision making in the hands of a few individuals. Thus, 'Science for All' is a necessary part of ensuring and maintaining a socially just democratic society.

Abdullahi, (1982) and Hodson et al, (1987) have attributed problems that influence and prompted the reform movement in science education to an increase in students' aversion towards key science concepts that they perceive as difficult leading to the growth of literature in the following topic areas:

(i) Chemical equations and the concept of the mole (Bajah, 1979; Bruces, 1983; and Schmidt, 1984, Eniayeju, 1990).

(ii) Coefficients and subscripts of chemical equations (Lazonby, et al, 1982 and Bello, 1988).

(iii) Mass ratio and Molar ratio (Artherton, 1974 and Frazer and Sleet, 1984).

They also maintained that poor understanding and application of chemical concepts results in high failure rate of chemistry students in their Senior Secondary Certificate Examination (SSCE). Result in the Senior Secondary Certificate Examination (SSCE) from most of the schools in Nigeria in recent times reveal that greater number of students fail science subjects as compared to Arts subjects. The percentage pass in science subjects at the SSCE from 1990-1995 is shown in Table 1.1.

TABLE 1.1 SSCE PERCENTAGE PASSES IN SCIENCE SUBJECTS

YEAR	SUBJECTS	NO THAT SAT	NO. THAT PASSED (1-6)	PERCENTAGE PASS (1-6)
1990	Chemistry	80,059	3282	4.10
	Biology	190,386	22,466	11.80
	Physics	63,161	13,159	20.70
1991	Chemistry	116,256	13,253	11.40
	Biology	285,690	72,850	25.50
	Physics	96,742	17,026	17.60
1992	Chemistry	140,856	26,762	19.00
	Biology	355,582	99,918	28.10
	Physics	122,809	20,140	16.40
1993	Chemistry	170,537	39,223	23.00
	Biology	481,034	43,271	18.70
	Physics	152,275	37,307	24.50
1994	Chemistry	161,262	38,212	23.70
	Biology	508,384	57,955	11.40
	Physics	146,000	21,462	14.70
1995	Chemistry	133,188	48,880	36.70
	Biology	453,353	85,683	18.90
	Physics	120,768	22,825	18.70

Source: WAEC (Statistics of entries and achievement).

Abdullahi, (1982), is of the opinion that high failure rate in chemistry could be due to lack of teaching aids and textbooks that reflect the students' environmental needs. Ali, (1982) suggested that the process of communication and prior knowledge which are the basis of learning are under-estimated by teachers. Efforts have been made to improve chemistry teaching/learning especially in the different ways by which students construct knowledge (Welch, et al 1987 and Novak, 1990). The understanding of the ways by which students construct knowledge owe some of its origin to the work of Ausubel, (1968) and Piaget, (1977). While Ausubel believes that the most important factor affecting learning is what the learner already knows, Piaget maintains that, unless a learner is of an appropriate mental age, certain concepts cannot be comprehended by them. This implies that, the chemistry teacher must ascertain this and teach the chemistry learner accordingly. Science educators (chemistry in particular) are therefore, required to elicit the existing preconceptions of the physical world that students bring to class and use them to modify students' misconceptions that these become more like the accepted "scientific conceptions of the world" (Ausubel, 1968, Piaget, 1977, Driver, et al, 1985 and Driver and Bell, 1986). Driver and Bell, (ibid), hold that the constructivits view of learning has become ideal in science education. It views learning as a process in which the learner constructs knowledge from pre-existing idea. Learning occurs not only through taking in new information, but also it involves the organisation and restructuring of the concepts that the learner already possessed. By this, the learner is actively engaged in constructing meaning.

Ajeyalemi, (1983) observed that chemistry teaching in senior secondary schools is not an easy task due to lack of teaching aids/materials. These tools assist chemistry teaching/learning in numerous ways. In most of the secondary schools, there are no standard laboratories for chemistry students to carry out laboratory work. The intention of chemistry curriculum development efforts in Nigeria is that chemistry be presented as experimental experiences for students in the secondary schools. However, research findings have shown that school chemistry (including the other sciences) teaching is extremely didactic and teacher directed, instead of being experimentally based (Ajeyalemi, ibid).

Ikoku, (1973), Ugwu, (1980), Ezenwa, (1993); and others have attributed the problems contributing to this state of affairs to:

(i) teachers' over-dependence on recommended standard textbooks and the theoretical nature of the text.

(ii) central examination system with the particularly over-loaded syllabus which requires superficial experimental teaching of chemistry.

(iii) inadequacy of basic chemistry laboratory infrastructures and technical support personnel.

(iv) language problems which compel students to memorize and regurgitate the facts and principles.

(v) large class size and heavy teaching schedule for teachers.

(vi) the negative attitudes of teachers generally, (Johnstone, 1977 and Yager, 1981).

1.2 THE MEANING AND IMPORTANCE OF CHEMICAL EQUATIONS

Chemical equation is a way of denoting a chemical reaction using the symbols for the participating particles (atom, molecules, ions etc). It is very important in chemistry because, most of the chemical concepts are embedded in it (Lee, 1988). Below is an example of a chemical equation.

$$_{x}A \quad + \quad _{y}B \quad \rightarrow \quad _{w}C \; x \; _{z}D$$

The small letters x, y, w and z refer to relative numbers of molecules reacting (ie stoichiometric coefficients), while the single arrow indicates an irreversible reaction. A chemical equation as seen above is highly symbolic. It is short hand for representing the processes involved in the conversion of reactants to products.

It is defined as a quantitative symbolic representation of the changes occurring in a chemical reaction based on the requirement that matter is neither created nor destroyed during the reaction process. Its importance cannot be over-emphasized in chemistry teaching/learning because, it embraces all aspects of chemistry (i.e inorganic, organic and physical) and it gives a detailed information about the chemical reaction that is taking place. Such information include, reactants and products, elements and radicals involved in the reaction, stoichiometry of reaction, states of matter in which the substances are present and so on (Wilkinson, 1989). This implies that ability to balance chemical equations aids chemistry learners in understanding chemical concepts. Unfortunately, chemistry teachers tend to assume that students will naturally

acquire this ability in the process of learning chemistry. Savoy, (1988) demonstrated that the ability to balance chemical equations cannot simply be picked up by students but, depends on the understanding of certain pre-requisite concepts. He contends that the ability to correctly balance chemical equations is a fundamental requirement of any chemistry curriculum. He also observed that lack of this basic skill seems to cause many students of chemistry a great deal of learning difficulty.

From the result of his work, he identified a number of chemical concepts, the understanding of which are essential for students to successfully balance chemical equations. He proposed a theoretical framework involving a hierarchy for chemical concepts underlying the balancing of chemical equations. The concepts are: atomicity, valency, use of brackets, subscripts and coefficient, molar ratio, atoms and molecules, radicals and the use of half moles. The hierarchy owes its origin to Gagne's broad principle of the hierarchy for knowledge where he established that the understanding of the lower-level concepts serve as pre-requisites for achieving the higher order ones. Savoy's conceptual hierarchy is illustrated in figure 1.1 below:

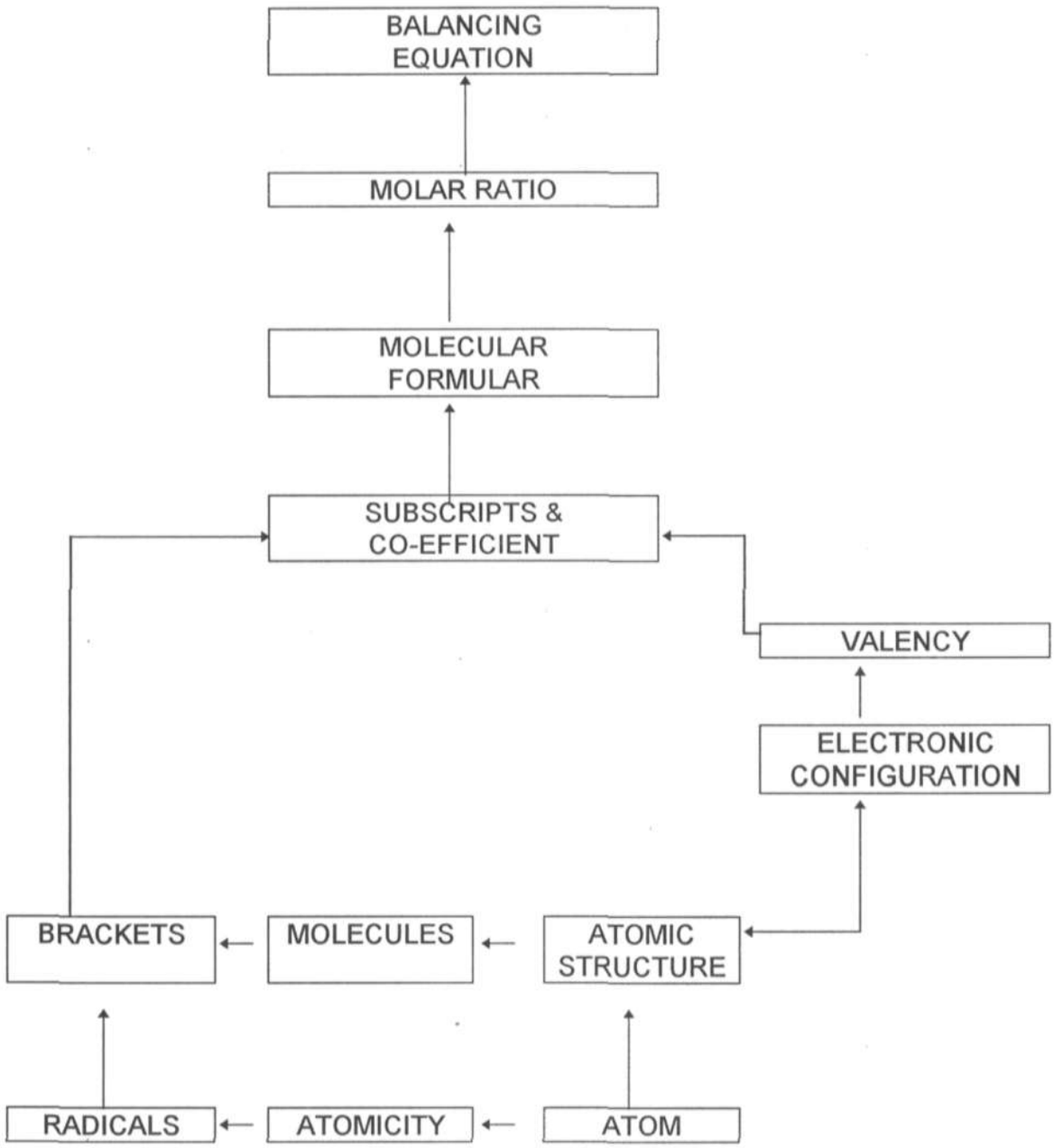


FIGURE 1: A hierarchy of chemical concepts underlying the balancing of chemical equation

From the hierarchy illustrated in figure 1.1, it follows that an understanding of all the concepts required to improve student's competence in balancing

chemical equations is dependent in the first place, on the understanding of the structure of the atom.

1.3 THE CONCEPTS FOR THE STUDY

The chemical concepts underlying the ability to balance chemical equations are stated by Savoy (1988) and they are: atoms and molecules, atomicity, valency, radicals, brackets, subscripts and stoichiometric coefficient, molar ratio and use of half moles. The chemical concepts underlying the balancing of chemical equations which the researcher has selected for purposes of this study from Savoy are: atoms and molecules, atomicity, valency, radicals, use of brackets, subscripts and stoichiometric coefficient. The use of half moles and molar ratio are purposely dropped because, they do not require an elaborate process to understand them. The use of half moles simply requires doubling the number of moles of every substance participating in the chemical reactions as symbolised by the equation. For example, the combustion of butane in oxygen (air) is seen in the equation below:

$C_4H_{10} + 0_2 \rightarrow C0_2 + H_2O$

Butane + oxygen $\rightarrow$ carbon dioxide + water

By the half moles principles, we have,

$C_4H_{10} + 6½0_2 \rightarrow 4CO_2 + 5H_2O$

By doubling the number of moles of every substance in the equation, we then have

$$2C_4H_{10} + 13O_2 \rightarrow 8CO_2 + 10H_2O$$

The researcher's selected concepts for the study are very important for any meaningful learning of balancing chemical equations because:-

(i) they serve as pre-requisites for the understanding of balancing of chemical equations. This is supported by Suderji (1983) and others who stated that to achieve a correctly balanced equation, students must be able to recognise and construct correct molecular formula which is itself dependent upon an understanding of a number of fundamental concepts (Gower et al; 1977; Lazonby, et al, 1982: Schmidt, 1984, Savoy, 1988; and Hines, 1990).

(ii) they are fundamental to the study of science in general and chemistry in particular (Owley, 1983; Adeyegbe, 1989 and Bello, 1990);

(iii) researchers have pointed out that students find this topic difficult and have misconceptions of it in some cases (Bruces, 1983; bello, 1988 and Eniayeju, 1990).

(iv) they are part of the National Chemistry Curriculum for SS 1 - 3 (Ozoro, 1977; Bajah, 1979; Yager, 1981; Ajeyalemi, 1981 and Federal Government of Nigeria, 1985).

1.4 STATEMENT OF THE PROBLEM

This study seeks to examine the relationship between the understanding of the identified chemical concepts and students' academic achievement in balancing of chemical equations. Basically from above, achievement in balancing chemical equations should depend on the understanding of related chemical concepts. The problems associated with balancing of chemical equations include:-

(a) lack of understanding of the concept of valency.

(b) inability to use brackets correctly.

(c) lack of understanding of the concepts of atomicity.

(d) misunderstanding of subscripts and coefficients.

(e) poor conception of radicals and molar ratios (Savoy, 1988 and Hines, 1990).

In the light of the above, the researcher has taken a keen interest on the topic 'balancing chemical equations' to find out if indeed Nigerian chemistry students have problems in the understanding of those concepts and consequently in the balancing of chemical equations. More specifically, the study is aimed at the following:

(1) To identify the learning difficulties that students have with the identified concepts (Savoy, 1988) underlying the competency in balancing of chemical equations.

(2) To find out the relationship between the students' understanding of the concepts and their competency in balancing chemical equations.

(3) To find out if the knowledge of the chemical concepts enhances achievement in balancing chemical equations.

(4) To find out if boys and girls differ in their competencies to balance chemical equations.

1.5 RESEARCH QUESTIONS

Based on the problem statement above, the study therefore will attempt to answer the following questions:

(1) What kinds of learning difficulties do students have with chemical concepts underlying the balancing of chemical equations?

(2) Do students have difficulties with balancing chemical equations?

(3) Do students have difficulties with identified chemical concepts and balancing of chemical equations?

(4) Is the understanding of the identified chemical concepts necessary pre-requisites to students' achievement in balancing chemical equations?

(5) Is there any significant relationship between students' achievement in the underlying identified chemical concepts and their achievement in balancing chemical equations?

(6) Is there any significant difference in the achievement of boys and girls in balancing chemical equations?

1.6 RESEARCH HYPOTHESES

The following hypotheses are formulated for testing:

(1) There is no significant relationship between students' achievement in the identified chemical concepts and their achievement in balancing chemical equations.

(2) There is no significant difference between the students' mean scores in the identified chemical concepts and their mean scores in balancing chemical equations.

(3) There is no significant difference in the mean scores of boys and girls in balancing of chemical equations.

1.7 SIGNIFICANCE OF THE STUDY

The result from the study would hopefully help in identifying the problems that are associated with balancing chemical equations in the secondary schools. This would enable teachers to pay more attention to these areas which pose problems for the students since one of the aims of teaching is for students to understand what has been taught so as to be able to pass their external examinations. Consequently, students would be helped to understand balancing of chemical equations and chemistry in general if they can follow Savoy's hierarchy of chemical concepts underlying the balancing of chemical equations. Also, it could be useful to chemistry teachers in selecting the concepts to be used in teaching balancing chemical equations since Savoy's hierarchy of chemical concepts underlying the balancing of chemical equations has established that the lower level chemical concepts serve as pre-requisites for achievement in the higher order concepts.

It is hoped that the findings from the study would be useful in the following ways as well. It could:

(1) contribute to the improvement of chemistry instruction at the senior secondary school level if both teachers and students adhere to Savoy's principles that must be followed to yield good result.

(2) help in actively involving the participation of students through discussion and demonstration whereby they are actively engaged in constructing meaning from pre-existing concepts.

(3) be used to support the existing theory of learning hierarchy by Gagné in the teaching of other related topics in chemistry and science in general since his principle of learning hierarchy maintains that concepts are ranked one above the other viz sub-ordinate, co-ordinate and super-ordinate concepts respectively.

(4) add to existing knowledge about difficulties that students encounter in the area of balancing chemical equations such as misconceptions of subscripts and coefficient, radicals and ions etc.

(5) foster new approaches in curriculum and test development especially in the area of chemical equations based on Gagné's broad principles of learning hierarchy and Savoy's hierarchy of chemical concepts.

1.8 SCOPE AND DELIMITATION

This study examined the difficulties of Senior Secondary II Chemistry students in selected secondary schools in Otukpo Local Government Area of

Benue State concerning relationship between their understanding of the identified chemical concepts and their competency in balancing chemical equations.

1.9 BASIC ASSUMPTIONS

For the purpose of this study, the following assumptions are made:

(1) The teachers are trained and that they have adopted the methods prescribed by Federal Ministry of Education (FME) for teaching chemistry.

(2) The topics under considerations have been covered by the students in all the schools selected.

(3) All the schools selected have similar facilities for effective teaching/learning of chemistry.

CHAPTER TWO

REVIEW OF LITERATURE

2.1 INTRODUCTION

Before the early 1970s, science instruction as observed by Barnes and Todd, (1977), is just transmission of knowledge from the teacher to the pupils. Students' minds were seen as empty reservoirs into which knowledge could be stored indiscriminately. The teacher provided all the facts of science to the students. The students were passive listeners because, the teacher asked and answered questions without giving the students opportunity to discover things for themselves. As scientific knowledge increased, the transmission of knowledge could no longer meet the goals of science because, this mode of instruction only encouraged memorization of information thereby making acquisition of goals of science such as retention and application of ideas, critical thinking and problem solving skills, amongst others difficult. At this point, discovery method of instruction was adopted as a possible solution.

The guided discovery learning is activity-oriented. It was expected that science concepts would be learned by observation. The approach involves experimentation, discussion and demonstration. The students were guided by the materials provided while the teachers engaged in investigations involving science processes structured to discover some concepts. Gagné, (1966), Bruces, (1983), and Frazer, et al; (1984) supported this view by stating that if students are guided to discover concepts by themselves, they may be better prepared to make wider application of the materials learned.

Despite all these efforts, investigations revealed that during the last two decades, topics perceived by students to be difficult are on the increase (Duncan and Johnstone, 1973; Lazonby, et al, 1982). In chemistry, such topics include the mole concept, stoichiometry, chemical combination, thermodynamics and chemical equation (Duncan and Johnstone, 1973; Bajah, 1976; Bello, 1990; Eniayeju, 1990 and Friend, 1994). Failure rate in science continues to increase with many studies showing that female students were achieving below their male counterparts. Moreover, this failure rate of chemistry students in senior secondary schools creates a serious concern and prompted a rethink about what should be done to improve the situation (Ameh, 1980; Becker, 1981; Clapen, et al, 1985; Bleier, 1988; and Chiral, 1992). Ajeyalemi, (1983) holds the view that several factors militate against effective chemistry teaching in Nigerian schools. These according to him, include the teaching method, language barrier, class size and pupils' weak academic background in primary science.

The importance of chemistry in the technological development of a nation cannot be over-emphasised. As a result, science curriculum developers contended that the content of science in Nigeria should be presented as experimental experiences for the students in the secondary schools. However, Ajeyalemi (ibid), in his study showed that the school chemistry (and other sciences) teaching is theoretical and extremely didactic and teacher directed instead of being experimentally-based.

A number of studies have shown that balancing of chemical equations is one of the major areas that prove difficult for students of chemistry (Lazonby et al, 1982; Savoy, 1988 and Hines, 1990). Novak, (1990) stated that a fundamental

reason for the failure of the curriculum approach of the 1970s had to do with the neglect of how humans construct and use meaning to guide their actions. The importance and practical applicability of some chemical equations thus become increasingly apparent. Consequently, efforts had continued to be made to enhance the quality of science teaching/learning; the situation of balancing chemical equations inclusive. The literature review for this study is structured under the following sub-topics.

(i) Chemical equation;

(ii) Hierarchy of knowledge

(iii) Concepts associated with balancing of chemical equations

(iv) Gender related differences and science

(v) Students' performances in balancing of chemical equations.

2.2 CHEMICAL EQUATION

Chambers Science and Technology Dictionary defines chemical equation as quantitative, symbolic presentation of the changes occurring in a chemical reaction based on the requirement that matter is neither created nor destroyed during the reaction process. The role of chemical equation cannot be over-emphasised because the understanding of most of the chemical concepts, are embedded in the understanding of chemical equation (Liptrot, 1984; Schmidt, 1984; Lazonby, et al, 1984, Lee, 1988; Savoy, 1988; and Hines, 1990). Chemical equations are important in the following ways:

(i) they tell us the individual elements and radicals involved in a chemical reaction.

(ii) they show the reactants and the products involved in the reaction.

(iii) they give a mental picture of the movement of the elements and radicals during the reaction.

(iv) they indicate the stoichiometry of the reaction (ie the relationship between the amounts of the reactants and the products) in terms of the mole ratio and the mass ratio of the reactants and products involved. These ratios are easily calculated since the numerical coefficient of a balanced equation represent the numbers of moles of reactants and products.

(v) they give the state of matter in which the substances are present as indicated by the state symbols - (s) for solid, (l) for liquid, (g) for gas and (aq) for aqueous solutions which are placed after the formulae of the substances in the equation.

2.2.1 BALANCING OF CHEMICAL EQUATION

Studies have shown that writing a correctly balanced chemical equation is by no means a simple process (Gower et al; 1982; Suderji, 1983; and Savoy, 1988). It has been observed that in teaching balancing chemical equation, one seemingly obvious point is often under-emphasized. It is that one cannot write an equation to describe a reaction unless one knows what happens in the course of the reaction. This means that in order to write an equation, one must know the

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formula of all reactants and products participating in the chemical reaction (Bajah, 1979; Savoy, 1988; and Hines, 1990). If we consider for example, the reaction that takes place in rocket motor which uses hydrazine as fuel and dinitrogen tetroxide as an oxidizer; the molecular formula of these two species both of which are liquids are N_2H_4 and N_20_4 respectively.

Analysis of the mixture that came out of the rocket exhaust shows that it consists of gaseous elementary nitrogen (N_2) and liquid water (H_20). To write the balanced chemical equation for this reaction one proceeds as observed by Lazonby, et al; (1982) as follows:

Step I: Write the unbalanced equation

The formula of reactants are written on the left side of the equation and those of the products on the right; i.e.

$$N_2H_4 + N_20_4 \rightarrow N_2 + H_2O.$$

Step II: Balance the Equation

In accordance with the law of conservation of mass, there should be the same number of atoms of each element on the two sides of the equation. Here, if we begin from the oxygen atoms, there are four (4) on the left and same must be on the right. We then write a coefficient of 4 for the water, thus;

$$N_2H_4 + N_20_4 \rightarrow N_2 + 4H_2O.$$

There are eight (8) hydrogen on the left, we write a coefficient of two (2) in front of N_2H_4 viz

$$2N_2H_4 + N_20_4 \rightarrow N_2 + 4H_2O.$$

Finally, we consider the number of nitrogen (N_2) atoms on the left, there are (3x2) = 6 nitrogen (N_2) atoms on the left. To have six (6) atoms of nitrogen on the right, we balance it by writing a coefficient of three (3) in front of nitrogen (N_2). Thus we have a balanced equation.

$$2N_2H_4(L) \times N_20_4(L) \rightarrow 3N_2(L) + 4H_2O(L).$$

It is easily observable that a knowledge of chemical equations therefore will guide in deciding the right proportion of fuel and oxidizer to use.

2.3 CONCEPTS

Recent philosophy of science focused on the role that concepts and conceptual framework play in the understanding of science. Concepts are the source of human understanding. There are various definitions of concepts as can be seen below. To the psychologist, thinking is a mental activity involving the use of symbols. The most important process in thinking is conceptualization, the first stage of which is perception. Bourne, (1966) states that a concept exists whenever two or more distinguishable objects or events have been classified together on the basis of some common characteristics. Pella, (1972) defines it as a summary of the essential characteristics of a group of ideas. Shalvonson,

(1974) sees it as an assemblage of identifiable elements and the relationship between them. Concept as defined by Stones, (1979) is an abstraction from objects, situations or events of the attributes these phenomena have in common. From these various definitions of concept, it is obvious that concept is a mental activity and could be described as being perceived differently by different people.

Concept is seen to occur at different levels of generalizability, one being a pre-requisite to the other and hence be represented by hierarchical relationship (Novak, 1984). The generalizability of a concept refers to its position on the hierarchical structure of concepts. The higher the concepts within the structure, the more generalizable it is in terms of the number of sub-units or sub-ordinate concepts it includes. Thus, the power (strength) of a concept refers to the degree to which a particular concept contributes to the understanding of other concepts (Gagne' 1970; and Novak, 1987). While Gagne' (ibid) dealt with the power of concept by the position it occupies in the hierarchical order of knowledge, Ausubel, (1968) dealt with it through the construct of advance organizers. Novak (1987) is of the opinion that a concept organisation that will lead to meaningful learning is one that starts from the most important. This implies that the introductory material to a lesson should include concept at a higher level of generalizability than those in the lesson so that the concepts presented in the new material could be related to those in the advance organizers.

For students to understand those concepts being taught, Novak, (1976) is of the opinion that they must first connect the new information they perceive, with the old that they know to make meaning. Goodstein, (1989) thus defined understanding as a bridge between subject matter structure and mental structure

in a way that allows them advance from static use of knowledge to flexible, dynamic and strategic mental operation. To understand therefore means that the new incoming information one perceives is connected with the old information that are already possessed to make meaning. The 'old mental structure' in turn is not the same any more due to the incorporation of the new. It is strengthened, modified and changed. The new mental structure becomes a more powerful tool for operational thought process.

Several research reports (Ali, 1983, Novak, 1988, Clemenson, 1990; and Okebukola, 1990) show that learning by understanding in science classrooms is neglected despite the fact that science teachers are aware of its importance. In Nigeria, it seems that the lack of understanding of concepts is the biggest obstacle to proper science teaching. To the scholars, more difficulties and misconceptions that students have in science (particularly chemistry) are attributed to poor understanding of science concepts.

In chemistry, studies have shown that students turn away from fundamental concepts. The use of appropriate concepts such as chemical formula and chemical equation is a common occurrence in science classroom (Bruces, 1983 and Adeyegbe, 1989). Again, students' inherent difficulties in solving stoichiometric problems are associated with the inability to write correct chemical formula and equations (Lazonby, et al; 1982 and Schmidt, 1984). For a concept to have been understood implies that the concept is attained and can be reflected in the application of new knowledge to other situations. Thus, to balance chemical equations correctly, the following lower level chemical concepts must have to be understood. They are: atomicity, atoms, valency, radicals, the use of

brackets, subscripts and coefficient (Savoy, 1988). The various literature on concepts attainment in this study is thus in line with Gagne', (1968) hierarchical order of knowledge which said that the lower level concepts serve as pre-requisite for the higher order concepts.

2.3.1 ATOMS AND MOLECULES

The ancient Greek Philosopher, Democritus was the first to use the word atom, which means indivisible, to describe the smallest particle of matter (Liptrot, 1985). Prior to the 18th century, the concept of the particulate nature of matter was based largely on speculation and intuition. It was in 1808, when the English school teacher, John Dalton, using scientific insight of a remarkable quality developed an explanation for several of the then known laws of chemistry which became known as the atomic theory (Bajah, 1984, Goodman, 1984, Lee 1984 and Ababio, 1988). As scientific knowledge increased, some of the ideas of Dalton had to be discarded as chemists learned more about the structure of matter. However, the essentials of this theory have stood the test of time (Ababio, ibid).

An atom is defined by Dalton as the smallest particle of an element which can take part in a chemical reaction. Like any useful scientific theory, the atomic theory raised more questions than it answered. Even before Dalton's idea had been generally accepted, philosophers and scientists were speculating as to whether atoms, tiny as they are, could in turn be broken down still into smaller particles. In an attempt to answer this striking question, three physicists, Thompson, J.J; Rutherford Ernest and Milikan, R.A. worked independently at different places and from their brilliant work in the 19th century, came up with the

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result that an atom is known to comprise of three basic sub-atomic particles called electron, proton and neutron (Lee, 1984; Bajah, 1986, Ababio, 1988; and Wilikinson, 1989). The characteristics of these sub-atomic particles are shown in table 2.1.

TABLE 2.1: THE THREE MAIN SUB-ATOMIC PARTICLES

PARTICLE	MASS	CHARGE	SYMBOL
Electron	1/1837 unit	- 1	e
Proton	1 unit	+ 1	p
Neutron	1 unit	No charge	n

It is known that many more sub-atomic particles exist, for example, the positron, the neutrino, the hyperon and the like, but only these three basic ones are generally considered in chemistry (Liptrot, 1984).

Most atoms cannot exist alone in nature. They generally combine with other atoms of same element or different element to form molecules. The number of atoms in each molecule of an element is called the atomicity of the element (Ababio, 1988 and Bajah, et al, 1988). It has been observed that most gaseous elements such as oxygen (0_2), chlorine Cl_2 are diatomic (ie molecule consisting of two atoms). Others like phosphorus (p) and sulphur (S) exist as polyatomic molecules (ie molecules consisting of more than two atoms). Where they exist singly, they are said to be monatomic (Lee, 1984). A molecule therefore is the smallest particle of a substance that can normally exist alone and still retain the chemical properties of that substance, be it an element or a compound (Ababio,

1988). On the other hand, some substances are not made up of atoms or molecules but are made up of charged particles which could be positively or negatively charged. Such substances are called ions. The positively charged are called cations while the negatively charged are called anions. An ion exists when a substance looses or gains an electron. A gain of electron renders it a negative charge (anion) while a loss of electron renders it a positive charge (cation) (Lee, 1984 and Liptrot, 1988).

From literature, it has been revealed that most students do not understand the concept of molecules. Many could not distinguish between diatomic atoms, mono or poly atomic atoms respectively. For example Na_2 was written in place of 2Na, 2Cl in place of Cl_2 etc. Also, they could not differentiate between atoms and molecules.

2.3.2 VALENCY AND RADICALS

Research repdorts (Schmidt, 1984; Bajah, et al; 1988 and Pearson, 1989) had shown that in chemical reactions, substances react together in definite proportions by mass. The early chemists carried out many experiment to work out the ratios of these combining powers of the various elements. From experimental evidence, they found out that hydrogen had the lowest combining power and gave its combining power a value of one (1).

The combining power of elements according to them is called valency. It is defined as the number of hydrogen atoms that can combine with or replace (either directly or indirectly) one atom of that element. The valency for an element therefore is a property of its atomic structure. It is also referred to as the oxidation

number of an element. This number may be a positive or a negative integer. Thus, knowing the valency of an element, it is possible to construct the formula of compounds from component elements. Generally, metals exhibit positive valencies while non-metals have negative valencies. Some elements show more than one valency depending on their oxidation states (Bajah and Goodman, 1984, Lee, 1984 and Ababio, 1988).

Sometimes, a few atoms of different elements may combine together and react as a single unit. Such a group is called a radical and defined as a group of atoms that function as a single unit in chemical reactions. Radicals may be charged and have valencies which are usually represented by the net number of positive or negative charges that they carry. For example, Ammonium, NH_4+ has a valency of +1, Tetraoxosulphate (vi) SO_4^{2}-, has a valency of 2-' Hydroxide, OH- has a valency of 1- etc (Lee, 1984, Bajah, et al; 1984, Liptrot 1988 and Wilikinson 1989). It has been observed from literature that most students add brackets to radicals where they were not required to do so. It is also revealed that most students lack understanding of valencies (Schmidt, 1984; Savoy, 1988 and Hines, 1990).

2.3.3 BRACKETS, SUBSCRIPTS AND COEFFICIENTS

Brackets are used in a chemical equation when a radical occurs more than once. In such cases, the radical is enclosed within brackets and the number of groups of radical (subscript) is written after the brackets. This when seen gives a clear indication that there are more than one radicals participating in the chemical reaction that is symbolised by the chemical equation (Lazonby, et al, 1982;

Suderji, 1983; Schmidt, 1984; Savoy, 1988 and Hines, 1990). However, research work have shown that students have difficulties in this concept as most of them add brackets anyhow to compounds and radicals in a chemical equation. For example, $Zn(SO_4)$ instead of $ZnS0_4$, and remove brackets where there should be one for example, ZnOH instead of $Zn(OH)_2$, CaOH for $Ca(OH)_2$ etc.

Subscripts of formula refer to the number of atoms of the component element in a chemical equation. It is usually written after the element, compound or radical. Students also found this concept confusing because literature showed that many did not know the meaning of it. For example, students wrote 20 in place of 0_2, 2Ag for Ag_2, etc. (Savoy, 1988 and Hines, 1990).

Coefficient in equations deal with the mass relations in chemical reactions. In a balanced chemical equation, the main interest lies in the information it gives about the relative masses of reactants and products involved in the reaction. From such balanced equations we may know the amount in grams of one substance that is required to react with a given mass of another or how much products can be obtained from a specified amount of reactants. Hence coefficient in equations therefore, are the number of moles of reactants and products. Also, to obtain a relation between masses of reactants and products in grams we need only to convert moles of each species in the balanced equations to grams.

The gram formula weights of the species in the equation below is:

$2N_2H_4(1) + 2NO_4(1) \rightarrow 3N_2(g) + 4H_20(1)$

(N_2H_4 = 32g, N_20_4 = 92g; N_2 = 28g and H_20 = 18g) since one mole represents one gram formula weight, we can write equation as:

$2(32gN_2H_4) + 1(92gN_2O_4) \rightarrow 3(28gN_2) + 4(18gH_2O)$

$64gN_2H_4 + 92gN_2O_4 \rightarrow 84gN_2 + 72gH_2O.$

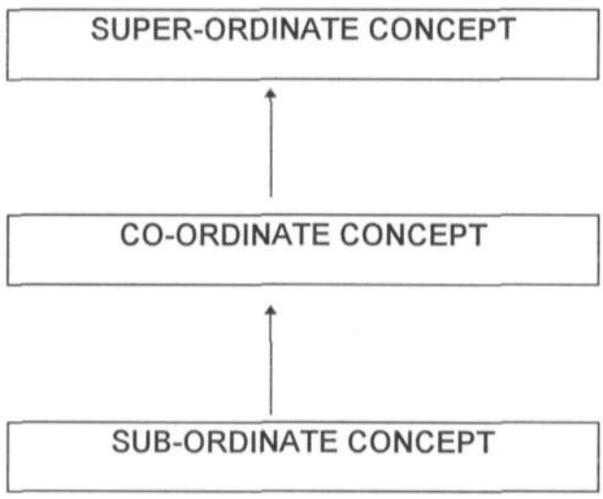
This is the general procedure for any reaction. Literature showed again that many students misunderstood coefficient for subscripts for example students could not differentiate between $(Ag)_2$ and 2Ag, Cl_2 for 2Cl etc.

2.4 LEARNING HIERARCHY

Gagne', (1968) a leading theorist on learning hierarchy describes it as a representation of an ordered set of intellectual skills such that each entity generates a substantial amount of positive transfer to the learning of a not previously acquired higher order capability. It is an attempt to teach using a conceptual (hierarchy) system of grades of status ranked one above the other. This implies that learning concepts are arranged in a sequence from the simplest at the base of the hierarchy to the complex at the apex. According to him, to know what capabilities an individual must possess in order to be able to carry out an expected task involves the use of task analysis.

In learning hierarchy, Gagné states that some concepts are sub-ordinate, others are co-ordinate while some are super-ordinate concepts. The sub-ordinate concepts serve as pre-requisites for the co-ordinate concepts which in turn serve as pre-requisites for the super-ordinate concepts. This is represented in a diagram as follows:

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Source: Based on Gagne' (1968)

For learning to occur, Gagne', (1970) suggests that, the conditions of learning, the processes of learning and the types of outcomes or capabilities to be displayed after learning must be taken into consideration. The conditions of learning are divided into two namely external and internal conditions. The internal condition consists of the previous knowledge which relates to the skill and the processes that are used in order to inform the performer of the skill. The external conditions include a variety of factors such as stimulation by others to recall, inform and guide the learner.

The events or process of learning that Gagne' considers very efficient is that of information processing. To him, these processes are inferred from the behaviour of people as well as reflecting what we know of the action of the nervous system. The outcome of learning or the type of human capabilities learned have been classified into eight according to Gagne'. They are: signal

learning, stimulus-response (S-R) learning, chain learning, verbal association learning, discrimination learning, concept learning, rule learning and problem solving learning. He concludes that there are several varieties of performance that imply different categories of learned capabilities and that those varieties of performance may also be differential in terms of the conditions for their learning. He noted that, in searching for and identifying these conditions, the following steps must be followed sequentially.

(1) Look for the capabilities that are internal to the learner and

(2) Look for the stimulus situation outside the learner because the learning of each type of new capability starts from a different 'point' of prior learning and is likely also to demand a different external situation.

From literature, it has been revealed that the knowledge of learning hierarchy is very essential in balancing of chemical equations. In order for a student to correctly balance an equation he requires an understanding of relevant chemical concepts. These concepts serve as pre-requisites to the understanding of balancing chemical equations as stated by Gagne', (1968).

The educational implications of learning hierarchy centre on those issues which can be manipulated by the teacher provided that the learning hierarchy models are acceptable and can be shown to have practical outcomes. Thus, the conditions of learning especially the external ones can be controlled by teachers to some extent. Also, planning of learning and management of the learning sessions from both the learner's and the teacher's point of view are central to the learning of intellectual, motor, verbal and attitudinal characteristics, (Raghubir, 1979).

2.5 STUDENTS' PERFORMANCES IN BALANCING CHEMICAL EQUATIONS

Literature on students' performances in balancing chemical equation is scanty due to the fact that only little work has been carried out on this important topic. Savoy, (1988) in his work on balancing chemical equations stated that most of the students used for this research work found equation balancing difficult. His work revealed that most students could not differentiate between subscripts and coefficient, for example K_2 was given in place of 2K, Ca $(C0_3)_3$ and $CaC0^3$ in place of $3CacC0_3$. The work of Lazonby, et al; (1982) and Schmidt, (1984) support this result because they concluded in their work that several students misunderstood subscripts for coefficient. In another work carried out by Hines, (1990) he concluded that most students could not represent more than one atom or molecule of an element an indication of misconception of subscripts and coefficient. For example, Ag_2 was used in place of 2Ag and O and 20 were commonly written in place of 0_2. Hines, (ibid) also noted that majority of the students have a poor grasp of the concept of molecular formulae since only four (4) students out of the fifty (50) students from five secondary schools could write the formula of lead (11) oxide (Pbo) correctly. Others could not write the formula of a compound from its name, particularly those that involved complex radicals for example, $PbN0_3$, and Pb_2N0_3 were common errors in place of $Pb(N0_3)_2$. Some were unable to construct an equation from the word equation provided in the tests. The incorrect use of brackets and the omission of them when they are required was common for example, Na(OH), $ZnOH_2$, $(Ag)_2S0_4$ and $K(N0)_2$ etc (Schmidt, 1984; Savoy, 1988 and Hines, 1990).

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Literature showed that lack of understanding of the concept of atomicity was common in the sense that many students did not know the atomicity of molecules such as 0 and 20 in place of 0_2, cl and 2cl for cl_2 and N and 2N in place of N_2 (Savoy, 1988 and hines, 1990). It was revealed from the various findings that only about 35% of the students could correctly balance chemical equations with much ease, 40% could differentiate between subscripts and coefficient while about 30% could put brackets in their appropriate ways (Schmidt, 1984, Savoy, 1988; and Hines, 1990).

2.6 REVIEW OF RELATED STUDIES

Literature on studies in balancing chemical equations is scanty. Not much work seems to have been done in this area. However, studies in America and Botswana have shown some work that have been carried out in balancing of chemical equations. Savoy, (1988) carried out a study in balancing of chemical equation where he devised a short test consisting of eight chemical equations that required to be balanced by GCE O-Level or equivalent courses) students. He administered the test on sixty-two (62) GCE O-Level chemistry students and the results were analysed. From the results, a number of chemical concepts were identified, an understanding of which seems essential for students to successfully balance chemical equations. From the analysis of the result, he proposed a hierarchy of chemical concepts underlying the balancing of chemical equations. It is this proposition that is being used as the theoretical framework for this study.

In Botsawana, Hines, (1990) carried out a similar study on chemical equations. His work aimed at investigating how well students in the senior

secondary schools in Botsawana understand chemical equations within the framework of the chemical concepts underlying the balancing of chemical equations proposed by Savoy. He devised two tests on balancing of chemical equations consisting of three chemical equations of error/correction type and seven straightforward balancing of chemical equations. The tests were administered on form 5 (Cambridge Overseas School Certificate) chemistry students, ten (10) students each from the four senior secondary schools that were selected as sample schools. From his findings, he showed that the students comprising his sample had a number of difficulties in areas such as:

(a) Molecular formula of a compound from its name.

(b) Subscripts and coefficient and

(c) Atoms and molecules.

Friend, (1994) in his work in redox equations came up with a result which showed that with adjustment of redox equations, one can arrive at infinite stoichiometric coefficient which fit in some redox equations. To arrive at such infinite stoichiometric coefficient, he employed the application of the algebraic method where he observed that by the use of arbitrary values, we would obtain infinite solutions by the adjustment of the redox equation. Glaister, (1996) also worked on balancing of chemical equations in more than one way and came up with guidelines on how to determine a chemical balance in such situations (balancing of equations in more than one way). He agreed with Friend, (1994) that infinite number of stoichiometric coefficient can be arrived at when balancing chemical equations. In his work, he observed that there is some degree of

freedom in the solution where chemical reactions take place and to know the amount of degree of freedom, he formulated a formula as

degree of freedom = unknown - equations

The unknown referred to the number of reactants and products minus one and the equations referred to the umber of different elements participating in the reaction process. According to him, where the difference is 1, there is one degree of freedom and such a solution is called a one parameter family of solutions where the difference is two (2), it is called a two paramter family of solutions etc. on the other hand, if the number of unknown is less than the equation, there is usually no balance since the system is over-prescribed with the number of equations grater than the number of unknowns, for example:

$CH_4 + 30_2 + H_2$ -» $C0_2 + 4H_20$

Unknown = 4 (i.e. number of

reactants and products -1 i.e.

5 - 1)

Equations = 3

(i.e number of different elements)

Degree of freedom = unknown - Equations = 4-3 = 1.

Hence it is a one parameter family of solution.

Studies on balancing of chemical equations are virtually absent from the

experience of this researcher in the literature of science education in Nigeria. However, Bello, (1990) carried out a related study dealing with chemistry students' errors in stoichiometric problems. He found that a good working knowledge of chemical formula and equations is essential for the understanding and appreciation of stoichiometric problems in chemistry. In his work, he constructed a twenty multiple-choice items test which he administered on twenty- three preliminary science students who registered for chemistry courses at a College of Education in Oyo State of Nigeria. From his findings, he showed that Nigeria Senior Secondary Students have difficulties in writing correct chemical formula and equations and hence display inability to solve stoichiometric problems. He suggested that if students are provided with a good learning climate, they are more likely to profit from instruction.

2.7 GENERAL RELATED DIFFERENCES AND SCIENCE LEARNING

Gender related differences in science learning has become one of the topical areas of contemporary science education research. To this effect, many studies have been carried out on gender related differences and school learning (Bock, et al; 1972, Kelly, 1978; Kahle, 1983; Becker, 1989 and Chira, 1992). It has been observed in science education that girls are achieving below the boys and that the differences are pronounced in the physical sciences and Engineering (Ostad, 1981; Hall, 1982, Welch, 1985 et al; 1987; Coe, 1990; Jegede and Okebukola, 1990, Ezenwa, 1993, Casey, et al; 1995). Studies have again revealed that boys achieve better grades in science courses at high school level.

It is observed that males perceive the classroom environment to be more supportive

than do females (Bajah, 1979; Steinkam, 1982; Jegede and Okebukola, 1990). In Amercia, it was revealed that boys are better than girls at activities requiring manipulation such as balancing chemical equations regardless of the teaching method used (Babikan, 1971; Erickson and Erickson, 1984).

It is believed that several factors such as personal, social, interest, teacher, instructional and spatial abilities contribute immensely to the sex differences. Since learning basically involves internal cognitive process for the learner, it is possible that the differences in science achievement have to do with teacher interaction with students. Studies have also shown that teachers speak more frequently to boys, ask them more higher order questions, praise boys for quality work and girls for neatness (Becker, 1981; Hall, 1982; and Versey, 1990).

Casey, et al, (1995) attributes sex differences in science learning to differences in spatial abilities of males and females. On the other hand, conflicting data exist regarding the actual presence of such a gender difference (Ameh, 1980, Shuaibu, 1982; Erickson and Erickson, 1984; and Clapan, et al; 1985). They believed that sex difference could be as a result of some cultural norms. From the review of literature on gender related differences and science learning, it has been revealed that extraneous variables contribute immensely to sex differences in science achievement. Literature seems to be relatively silent on gender related differences in relation to balancing of chemical equations. Thus, it is incorporated as an aspect of the study.

Many articles in the literature reviewed suggested that students need to have certain pre-requisite knowledge of chemical concepts before they can correctly balance chemical equations. This implies that the understanding of such chemical

concepts will help students in the understanding and correct balancing of chemical equations. The literature also revealed that students who have prior knowledge of related chemical concepts to balancing chemical equations understand balancing of chemical equations better than those without prior knowledge. The implication of this is that if students are to have an understanding of balancing of chemical equations, they should have the knowledge of chemical concepts underlying the balancing of chemical equations. The literature revealed a number of instruments used in measuring students' achievement in related studies. The literature will serve as a valuable guide in the design of instrument for this study as will be described in the next chapter.

2.9 SUMMARY

This chapter has attempted to review identified chemical concepts that students need to know in order to be competent in balancing of chemical equations. Winning more students for science especially in the physical sciences has been a major professional concern for STAN because of its adverse effect on the science and technological development of the country. However, poor performances in the science by science students still persist. This poor performance especially in chemistry has been attributed to students' inability to v-correctlybalance chemicalequation, theunderstanding ofwhich depends on the knowledge of some identified chemical concepts (Abdullahi, 1982; Schmidt, 1984; Savoy, 1988; Hines. 1990 and Glaister, 1996).

There is evidence from literature that this topic could be taught meaningfully thereby making it fascinating to students. Within the limits of the available literature, it is shown that balancing chemical equation using Savoy's approach would to a large extent positively influence its understanding.

Studies on balancing chemical equations are mainly foreign relative to the Nigerian situation. The study therefore hopes to contribute to enrich the rather shallow pool of information regarding this important aspect of school chemistry teaching in Nigeria.

CHAPTER THREE METHOD AND PROCEDURE

3.1 INTRODUCTION

The purpose of this chapter is to describe the method and procedure for conducting this research. It consists of the research design, sample and sampling procedure, instrument design and procedure for its administration and the statement of procedure for analysis of data.

3.2 POPULATION

The population comprises all senior secondary schools in Otukpo Local Government Area of Benue State that offer the basic science subjects. There are a total of fourteen senior secondary schools which comprises day and boarding schools. Among these schools, there are three state government-owned schools, students intake for which covers the whole state. One is a Federal Technical College with student intake from all over the federation. Five of the schools are owned by voluntary agencies while the remaining five are owned by communities and private individuals. Also, seven of the schools are co-educational, four are only boys and three are only girls. The names of the

schools are given in table 3.1 below.

TABLE 3.1: NAMES OF SENIOR SECONDARY SCHOOLS IN OTUKPO LOCAL GOVERNMENT AREA

S/NO	NAMES OF SCHOOL	LOCATION	SEX	URBAN/RURAL
1	Govt. Model Sec. School	Otukpo	Boys	Urban
2	Govt. Comp. Sec. Sch.	Atlo	Mixed	Rural
3	Govt. Day Sec. Sch.	Otukpo	Boy	Urban
4.	Ujor Memorial College	Oglewu	Mixed	Rural
5.	St. Paul Sec. Sch.	Otukpo	Mixed	Urban
6	St. Francis College	Otukpo	Boys	Urban
7	St. Anne Sec. Sch.	Otukpo	Girls	Urban
8	St. Monica Girls. Sec. Sch.	Otukpo	Girls	Urban
9	Wesley High School	Otukpo	Mixed	Urban
10	Federal Tech. College	Otukpo	Boys	Urban
11	Ewulo College	Ewulo	Mixed	Rural
12	Holy Rosary College	Adoka	Girls	Rural
13	Opkeje Community Sec. Sch.	Adoka	Mixed	Rural
14	Ugboju Comm. Sec. Sch.	Okpanchenyi	Mixed	Rural

Figure 3.1 in appendix 1 gives the map of Benue State with Otukpo Local Government Area showing the study area.

3.3 RESEARCH DESIGN

The research design adopted for this study is Ex-post-facto research design. This design is a systematic empirical inquiry in which researcher does not have direct control of independent variables because their manifestations have already occurred or because they are inherently not manipulate. Here, inferences about relations among variables are made without direct intervention from concomitant variation of independent variables. The researcher chose this research design due to the fact that she lacks direct control of the independent variables as well as its experimental manipulation. This is because the manifestation of the independent variable had already taken place with the

researcher having nothing to do with its occurrence. The design is related to this study because it is assumed that the identified chemical concepts (independent variables) underlying the balancing of chemical equations have been taught by the chemistry teachers of the sampled schools. This study used a parametric statistical technique because the data used are continuous data. Thus, the Pearson Product Moment Correlation Coefficient (PPMC) and t-test distribution are used.

3.4 SAMPLE AND SAMPLING PROCEDURE

In order to have a proportionate number of boys and girls, students with similar classroom environment, the schools were first classified according to the type of school/sex. The schools were selected by stratified random sampling to ensure a fair representation of the various types of variables of interest of this study.

Shuaibu, (1981) and Abah, (1982) observed that stratified random sampling ensures that variabilities in subjects such as level of intelligence, social background of subjects is essential since gender is one of the variables of interest as stated in hypotheses in section 1.5.

Out of the seven co-educational senior secondary schools in the chosen Local Government Area, four were selected by the use of a table of random numbers (Kerlinger, 1973). Also one school was selected from the four male schools and one from the three female schools making a total of six schools by the same method. Based on this selection procedure, the selected schools, *y* genderand the type ofschoolsarelisted below in Table 3.2.

TABLE 3.2: SAMPLED SCHOOLS FOR THE STUDY

S/No	Names of School	Location	Sex	Urban/ Rural	No. of Students		
					Male	Female	Total
1.	Govt. Model Sch.	Otukpo	Boys	Urban	30		30
2	Ewulo College	Ewulo	Mixed	Rural	22	8	30
3.	Govt. Comp. Sec. Sch.	Atlo	Mixed	Rural	18	12	30
4.	St. Monica Girls Sec. Sch.	Otukpo	Girls	Urban	-	30	30
5.	St. Paul Secondary School	Otukpo	Mixed	Urban	21	9	30
6.	Ujor Memorial college	Oglewu	Mixed	Rural	24	6	30
Total					**115**	**65**	**180**

Thirty (30) senior secondary II chemistry students were randomly selected for the purpose of the study from each school. Thus, a total sample of one hundred and eighty (180) chemistry II students were drawn by the use of a table of random numbers from the six sampled schools.

3.5 INSTRUMENTS FOR DATA COLLECTION

The instruments used for the purpose of data collection were standardized tests. These are described in the following two sub-sections 3.5.1 and 3.5.2.

3.5.1 THE CHEMICAL EQUATION ACHIEVEMENT TEST (CEAT)

This consists of two (2) sets of tests on balancing of chemical equations.

Test 1: Unbalanced Equation Test

Test one comprised seven (7) equations of differing complexity which involved straightforward balancing. These chemical equations were written correctly but in the unbalanced form and students were required to correctly balance them. Some of the

chemical equations might not necessarily represent chemical reactions that actually occur in nature. Note that the equation Na + H_2 ->• NaH does not actually represent a natural chemical phenomenon but was used to elicit the knowledge being tested in balancing chemical equations.

Test II: Error/Correction Type Test

This section consisted of the error/correction type of test. Ten (10) *1* chemical equations, each containing a given number of formulae errors was given to the subjects. It was expected of them to:

(i) spot the error;

(ii) correct them and

(iii) rewrite the equations correctly in the balanced form.

3.5.2 THE CHEMICAL CONCEPTS ACHIEVEMENT TEST (CCAT)

This consisted of a multiple choice items on the chemical concepts underlying students' competency in balancing chemical equations. The multiple choice test comprised twenty items which covered all the identified chemical concepts that underline the balancing of chemical equations and ten items on chemical equation balancing.

3.6 RELIABILITY AND VALIDATION OF INSTRUMENTS

3.6.1 RELIABILITY OF INSTRUMENTS

The achievement tests (CEAT and CCAT) items were administered to senior secondary II chemistry students in Makurdi metropolis to ensure that they were appropriate for SS II chemistry students. This was carried out on twenty (20) SS II chemistry students in each of the two schools that were used for the pilot study. It was assumed that these students have been exposed to the topic on chemical equations. The two schools were far (about five kilometres) away from each other so as to avoid interference of extraneous variables such as subject interaction. The researcher selected twenty students randomly which brought the total to forty. The scripts were marked to check for the achievement of students in both chemical concepts and balancing of chemical equations. The reliability coefficient ® was computed using the split half method and gave the value of 0.78. the aim of this pilot study was to find out:

(i) how feasible the study would be and

(ii) how appropriate the test items were.

3.6.2 VALIDATION OF INSTRUMENTS

The Chemical Equation Achievement Test (CEAT) was adopted from the work of Savoy, (1988) and Hines, (1990) while the Chemical Concept Achievement Test (CCAT) was adapted from standard recommended chemistry texts and external examinations. To ensure the validity of the tests, each test item was examined by two university chemistry teachers, three chemistry teachers in the secondary schools and one chemistry education expert to ensure that they are

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related to the research question/hypotheses (i.e that the tests are able to produce the desired result in the study) and that they measure what they are intended to measure. The CCAT items covered questions on the various selected concepts for the study and also balancing of chemical equations.

3.7 PROCEDURE FOR DATA COLLECTION

The data for the study was collected from the six selected senior secondary schools. The researcher went personally to each of the sampled schools to administer the test so as to avoid malpractices during the tests. This approach has helped to maintain uniformity by using the same method and procedure of administration to all the students in the various schools.

First, the researcher inquired from both the teachers and the students whether the concepts and balancing of chemical equations have been taught after which the two tests (CEAT and CCAT) were administered to thirty (30) SS II chemistry students in each sampled school at a seating, one after the other. The necessary instructions needed for the successful completion of the tests were clearly stated and explained to the students before the commencement of the tests. In order to minimize test anxiety, the researcher gave the tests with the help of the class teacher. The tests were conducted in the laboratory so as to avoid interference with the normal class periods. The students were given enough time to complete the items. The fastest student finished within forty-five minutes and the slowest student in one hour, fifteen minutes. The coefficient of determination (r^2) was used to measure the effect of the independent variable on

the dependent variable. In other words, it shows the proportion of the identified chemical concept that was accounted for by balancing of chemical equation.

3.8 PROCEDURE FOR DATA ANALYSIS

Data that were analysed for this study were obtained from the two tests. Appendix II contains the instruments while Appendix III contains the scoring scheme and their answers.

3.8.1 TEST OF HYPOTHESES

The data from the two instruments were used to test the research hypotheses stated in 1.5.

Hypothesis I: There is no significant relationship between students' achievement in the identified chemical concepts and their achievement in balancing chemical equations. The statistics used are:-

(a) the mean of the two tests

(b) the standard deviation

(c) the Pearson Product Moment Correlation coefficient (PPMc)

Hypothesis II: There is no significant difference between the students' mean scores in the identified chemical concepts and their mean scores in balancing of chemical equations. The statistics used are:-

(a) the mean for each test

(b) the stand deviation

(c) t-test.

Hypothesis III: There is no significant difference in the mean scores of boys and girls in balancing chemical equations. The statistics used are:-

(a) the mean of the two groups

(b) the standard deviation

(c) t-test.

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CHAPTER FOUR

DATA ANALYSIS AND PRESENTATION OF RESULTS

4.1 INTRODUCTION

This chapter contains the analysis of the data collected. The main objective of this study was to find out the relationship between students' understanding of identified chemical concepts and their competency in the balancing of chemical equation. Three null hypotheses were stated for testing in order to find out whether any significant relationships exist between students' achievement in the identified chemical concepts and their ability in balancing chemical equations. The stated null hypotheses are as below:

(1) There is no significant relationship between students' achievement in the identified chemical concepts and their achievement in balancing chemical equations.

(2) There is no significant difference between the students' mean scores in the identified chemical concepts and their mean scores in balancing chemical equations.

(3) there is no significant difference in the mean scores of boys and girls in balancing of chemical equations.

The hypotheses were tested using the Pearson's Product Moment Correlation Coefficient and t-test statistic at 0.05 significant level for rejecting or retaining the hypotheses. The identified chemical concepts test is abbreviated as CCAT while that of balancing chemical equations is abbreviated as CEAT.

4.2 HYPOTHESES TESTING

In testing the hypotheses, the subjects' test scores in the identified chemical concepts and their corresponding scores in balancing of chemical equations were collated (see Appendix IV for the data). Pearson's Product Moment correlation coefficient was used to determine the relationship (if any) between the chemical concepts and balancing of chemical equations. The t-test statistic was used to find out whether the difference in the mean scores of the tests was significant too. The results are shown in tables 4.1 - 4.3.

TABLE 4.1: CORRELATION BETWEEN STUDENTS' SCORES IN CCAT AND CEAT

Test	N	$\bar{x}$	Std. Dev	r	r^2	df	p
CCAT		37.09	15.17				
	180			0.70	0.49	178	0.05
CEAT		19.66	18.20				

r - critical value at (df = 178)P = 0.05 is 0.11.

Table 4.1 showed that there is a correlation coefficient of 0.70. This represents a strong positive correlation. Thus the null hypothesis 1 was rejected. This implies that there is a significant relationship between students' understanding and thus achievement in the identified chemical concepts and their ability to balance chemical equations since the obtained value is much greater than the critical r value of 0.11 at df 178.

TABLE 4.2 SUMMARY OF t-TEST STATISTIC BETWEEN THE SUBJECTS' MEAN SCORES IN CCAT AND CEAT

Test	N	$\bar{x}$	Std. Dev	t-value	df	p
CCAT		37.09	15.17			
	180			9.87	178	0.05
CEAT		19.66	18.20			

t-test critical value is 1.64 at the level of significance P = 0.05 at df = 178.

Table 4.2 showed that the mean scores of students in identified chemical concepts differ significantly from their mean scores in balancing of chemical equations. The t-test calculation was done at the level of significance P = 0.05. The t-value obtained was 9.87 at df = 178 at the same level of significance P = 0.05. thus hypothesis 2 was rejected since the obtained t-value was greater than the t-critical value. This implies that the difference between the students' mean scores in the two variables (CCAT and CEAT) are statistically significant.

TABLE 4.3 COMPARISON OF BOYS AND GIRLS IN THEIR ABILITY TO BALANCE CHEMICAL EQUATIONS

CEAT	N	$\bar{x}$	Std. Dev	r	df	P
BOYS	115	20.62	18.00			
				2.28	178	0.05
GIRLS	65	14.34	17.21			

r-critical value is 1.64 at the level of significance P = 0.05 at df 178.

Table 4.3 showed the t-test statistic to test the level of significant difference between the achievement of boys and girls in their ability to balance chemical equations. From the results in the table 4.3, t-obtained is 2.28 at the significance level of P = 0-.05. the t-critical value at the same level of significance at same df of 178 is 1.64. The table showed that there was significant difference in the mean scores of boys and girls in their ability to balance chemical equations as the calculated value of t was greater than that of the critical value. Thus, hypothesis 3 was rejected. This means that the boys and girls differ significantly in their ability to balance chemical equations.

The results in tables 4.1 - 4.3. showed that,

(1) identified chemical concepts correlated positively with the balancing of chemical equations.

(2) students' mean scores in the identified chemical concepts differ significantly from their mean scores in balancing of chemical equations and

(3) Boys and girls differ significantly in their ability to balance chemical equations.

Detailed discussions of these results are found in section 4.5. The calculated values of correlation coefficient (r) and t-test distribution shown in tables 4.1 - 4.3 are consistently high which denote that the relationship between the variables (CCAT and CEAT) is high. Also that the difference in the mean scores between the variables are statistically significant. The high positive

correlation revealed from the results again agree with the views of Frank, and Althoen (1995) that strong correlation coefficient mean that the variables are statistically related.

The calculated coefficient of determination r^2 (see table 4.1) show the variance in the students' achievements in the identified chemical concepts that is accounted for by their ability to balance chemical. It is described as the percentage of the variance in the independent variable that is accounted for by the dependent variable. In this study, the dependent variable is the balancing of chemical equations while the independent variable is the chemical concepts that underlie the balancing chemical equations. For instance the percentage of students' achievement in identified chemical concepts (independent variable) that is accounted for by their ability in balancing chemical equation (dependent variable) is 49% (i.e $r^2 = 0.49$).

4.3 GENDER RELATED DIFFERENCES IN THE BALANCING OF CHEMICAL EQUATIONS

To find out whether there is gender related differences in the achievement of boys and girls in balancing chemical equations, their test scores in CEAT was computed (See Appendices VI and VII for those data).

The t-test statistic was used to know the level of difference that existed between them, the result which is shown in Table 4.3. Also t-test statistic was carried out among each sex between the identified chemical concepts and balancing of chemical equations. The results are shown in Tables 4.4 and 4.5.

TABLE 4.4: SUMMARY OF t-TEST STATISTIC BETWEEN THE GIRLS' MEAN SCORES IN CCAT AND CEAT

Test	N	$\bar{x}$	Std. Dev	r	df	p
CCAT		33.71	15.75			
	65			9.15	63	0.05
CEAT		15.30	18.24			

t-critical is 1.67 (at df = 63), P = 0.05.

Table 4.4 shows that there is significant difference in the achievement of girls in the two tests with higher achievement in CCAT than CEAT.

TABLE 4.5: SUMMARY OF THE t-TEST STATISTIC BETWEEN THE BOYS' MEAN SCORES IN CCAT AND CEAT

Test	N	$\bar{x}$	Std. Dev	t	df	p
CCAT		39.57	14.37			
	115			15.03	113	0.05
CEAT		20.60	18.30			

t-critical is 1.65 (at df = 113), P = 0.05

Table 4.5 showed that the mean scores of boys in identified chemical concepts differ significantly from their mean scores in balancing chemical equations. The t-value obtained was 15.03 (at df = 113), P = 0.05. Tables 4.4 and 4.5 support the results in table 4.2. that both boys and girls achieve better in CCAT then in CEAT. The result in Table 4.3 implies that the boys achieve better

than the girls. This is in agreement with the findings of Erickson and Erickson (1984) and Jegede and Okebukola, 1990 that boys are better than girls at activities involving manipulation like balancing chemical equations regardless of the teaching method used.

The superiority of the boys over the girls may not be totally as a result of their intellectual endowment as shown in the test result. It may be as a result of some other factors such as the teacher, instructional and spatial abilities, social and cultural norms and the like as reported by Ameh, (1980), Shuaibu, (1982) and Versey, (1990). This is an area that needs to be looked into in the future.

4.4 STUDENTS' PERFORMANCE IN EACH CONCEPT IN RELATION TO BALANCING CHEMICAL EQUATIONS

A close examination of the scores (CCAT and CEAT) showed that students had difficulties or lack understanding of some of the identified chemical concepts and also in the balancing of chemical equations. This following results (Table 4.6) while not directly provides answers to the stated hypotheses do however answer the research question No.1 which is restated below.

What kind of learning difficulties do students have with chemical concepts underlying the balancing of chemical equations? Table 4.6 gives the details on the number of students that gained full marks in each concepts. Also, the percentage that gained full marks in each concept was stated.

TABLE 4.6: THE PERFORMANCE OF STUDENTS IN THE CHEMICAL CONCEPTS

Concepts	Number of Subjects gaining full marks	Percentage gaining full marks (%)
Atoms and Molecules	125	70.34
Atomicity	90	50.00
Valency	70	38.78
Brackets	50	27.78
Radicals	35	19.30
Subscripts	55	30.55
Coefficients	45	25.00

N = 180. The mean percentage is 37.40%

Table 4.6 showed that students' quality of performance in the chemical concepts vary from concept to concept. The table revealed that out of the 180 students (N = 180) involved in the study, 125 of them obtained full marks on the concepts of atoms and molecules, representing percentage pass of 70.34. As for the concept of atomicity, 90 students obtained the maximum mark, representing a percentage pass of 50.00, the concept of valency had a total number of 70 students that passed all the test items on valency with a percentage pass of 27.78. The concept of the use of brackets in chemical formulae had 50 students that passed all the test items with a percentage pass of 27.78%. For the concept of radicals, 35 students passed all the test items showing a percentage pass of 19.30. Those for the concepts of subscripts of formulae and coefficients in equations, 55 obtained full marks a percentage of 30.55 and 45 passed showing a percentage of 25.00 respectively.

The results in the table also indicated that some concepts are more difficult for the students than others based on their scores. This result demonstrated that the students found concept of atoms and molecules to be the least difficult on the list of the identified chemical concepts and that of the concept of radicals being the most difficult. It follows from the foregoing that table 4.6 also showed the ranking in ascending order of how difficult the students found the chemical concepts in relation to balancing of the chemical equations. They found the concept of atoms and molecules to be least difficult while the concept of radicals was found to be most difficult. This sequence demonstrates Gagne' (1968) principle of hierarchy of concepts in which some related concepts are sub-ordinates, others co-ordinates while some are super-ordinate concepts within a conceptual structure. In this regard, the concept of atoms and molecules can be said to serve as sub-ordinate concepts to the rest concepts on the list while the concept of radicals is the super-ordinate concept of the list.

TABLE 4.7: STUDENTS' PERFORMANCE IN BALANCING CHEMICAL EQUATIONS

Chemical Equation Balancing	Number Gaining Full Marks	Percentage Gaining Full Marks (%)
Error/Correction type	18	10
Straightforward Balancing	47	26.11
Multiple Choice	68	37.78

N = 180. The mean percentage score is 24.68%.

Table 4.7 showed that 18 students passed all the test items on the error/correction type with a percentage pass of 10. Forty-seven (47) students passed all the test items on straightforward balancing of chemical equations with a percentage pass of 26.11 while 68 students passed all the multiple choice items on balancing of chemical equations with a percentage pass of 37.78. the results in table 4.7 indicated that the error/correction type of balancing chemical equations was very difficult (10%) and the multiple choice items were found to be easy. This may be as a result of extraneous factors, guessing, for example. It may be observed here that while the researcher did not choose a criterion as a standard against which to judge these test scores vis-a-vis the performance of each subject, it is worthy to note that the mean scores of 24.63 did not reach 40% mark which is generally accepted as pass mark in most examinations in the secondary schools.

The rather low level of the mean scores shown in table 4.7 is an indication of a low understanding by the students of the identified chemical concepts that underlie the balancing of chemical equations. This result also does not directly provide answers to the stated hypotheses. However, it answers the research question No.2 which is restated below:-

Do Students have difficulties with balancing of Chemical Equations?

Based on the results in this table 4.7, the students' inability to correctly balance chemical equations, confirms Savoy's theory (tables 4.6 and 4.7) that the understanding of these concepts are necessary pre-requisites for balancing chemical equations. Thus, the research question No. 3 which states that, is the

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understanding of the identified chemical concepts a necessary pre-requisite to students' achievement in balancing chemical equation is answered.

4.5 SUMMARY OF DISCUSSIONS

In this chapter so far, the results obtained from analysis of data have been presented and brief discussions undertaken on them. What now follows is a summary of the discussions. The results showed that significant relationship existed between students' understanding of identified chemical concepts and their achievement in balancing of chemical equations. The achievement of boys and girls respectively in the chemical concepts relate significantly with their achievement in balancing chemical equations. Boys' achievement in CEAT differ significantly from that of the girls. Based on these critical values and the obtained values of the results (refer to tables 4.1 - 4.5) all the null hypotheses for this study were rejected.

The results also showed the average performances of the students on each concept and that on balancing of chemical equations. It revealed that the students performed best in the concept of atoms and molecules while they performed worst in the concept of radicals. Their performances in the concept of atomicity was fair (50%) when compared with those of the concepts of valency, subscripts, brackets, coefficients and radicals. On the whole, the mean percentage performance of 37.40% is considered to be poor. This connotes a lack of understanding of most of the chemical concepts underlying the balancing of chemical equation.

The results on chemical equation balancing was also poor. It showed that the students had weak ability in balancing chemical equation. The mean

percentage performance was 24.63%. The two mean percentage passes (37.40 and 24.63) gave an indication that the ability of students to balance chemical equations on their understanding of the identified chemical concepts are closely related. This observation can also be seen through an examination of the raw scores of both tests (see Appendix III).

Based on the CEAT scores for boys and girls, (table 4.3) and also the CCAT and CEAT scores for boys and girls taken separately (tables 4.4 and 4.5), it was found that there was significant difference (P = 0.05 level of significance) in their mean scores with boys achieving better than the girls. It was also inferred that the male subjects showed a better competency in balancing chemical equations than the female subjects. This result tends to support other studies in sex related difference in science achievement (Brown, 1978; and Ameh, 1980). Shuaibu and Ameh, (1982) attributed this to effects of Nigerian culture where girls are only expected to be seen but, not to be heard. This attitude makes girls shy away from active involvement in the classrooms. Also, in Nigerian culture, women are treated as the weak sex and so most science teachers being males, encourage girls on neat work rather than involve them on activities that make use of higher mental order.

The results agree with those of Savoy, (1988) and Hines, (1990) which showed that for a chemistry student to develop the necessary ability to balance chemical equations correctly, he/she must have a requisite knowledge of the chemical concepts that are related with balancing of chemical equations as highlighted in this study and discussed in this chapter especially.

CHAPTER FIVE

SUMMARY OF FINDINGS, RECOMMENDATIONS, LIMITATIONS AND SUGGESTIONS FOR FURTHER STUDY

5.1 INTRODUCTION

In this chapter, the summary of findings are stated, recommendations, limitations of the study and suggestions for further studies are outlined. This study was designed to determine the relationship between the understanding of identified chemical concepts and students' achievement in balancing chemical equations. The research was carried out using Senior Secondary II Chemistry Students in Otukpo Local Government Area of Benue State. It set out to answer the following questions:

(1) What kind of learning difficulties do chemistry students have with the concepts underlying the balancing of chemical equations?

(2) Do students have difficulties with balancing of chemical equations?

(3) Do students have difficulties with the identified chemical concepts and balancing of chemical equations?

(4) Is the understanding of the identified chemical concepts a necessary pre-requisite to students' achievement in balancing chemical equations?

(5) Is there any significant relationship between students' achievement in the underlying concepts and their achievement in balancing chemical equations?

(6) Is there any significant difference in the achievement of boys and girls in balancing chemical equations?

The instruments for this study were the Chemical concept Achievement Test (CCAT) and Chemical Equation Achievement Test (CEAT). A pilot study was conducted on twenty students to test the reliability of instruments (CCAT and CEAT) which gave a reliability coefficient of 0.59 and 0.56 (at df = 18), P ≥0.05 respectively. The coefficient of determination (r^2) was 0.35.

5.2 SUMMARY OF FINDINGS

The results from the study showed that;

(1) The correlation coefficient (r) between CCAT and CEAT was 0.70 with the critical r value of 0.11 (at df = 178), P = 0.05.

(2) There is significant relationship between students' understanding of identified chemical concepts and their competency in balancing chemical equations.

(3) There is significant difference in the mean scores of boys and girls in balancing chemical equations.

(4) There is significant difference in the mean scores of students in the identified chemical concepts and balancing of chemical equations.

(5) There is significant relationship between boys' achievement in the understanding of chemical concepts and their achievement in balancing chemical equations.

(6) There is significant relationship between girls' achievement in the understanding of identified chemical concepts and their achievement in balancing chemical equations.

This results led to the rejection of all the stated null hypotheses.

5.3 CONCLUSIONS

It could be concluded based on the findings obtained in this study that:

(1) Students have difficulties in the identified chemical concepts as shown in table 4.6. Of all the identified chemical concepts that underlie the balancing of chemical equations, results have shown that students passed in the concept of atoms and molecules and atomicity (70.34% and 50.00% respectively). The rest of the concepts (Valency = 38.785, Brackets = 27.78, Radicals = 19.30, Subscripts = 30.55 and Coefficients = 25.00) proved to be difficult as is shown by the results in the same table.

(2) Senior Secondary School Chemistry Students have difficulties with balancing of chemical equations (see table 4.7). Results have revealed that students performed worst in balancing of chemical equations especially in the area of the error/correction type of balancing of chemical equations (10%). For the multiple choice items, their performance was better (37.78). This performance may have been as a result of guess work.

(3) Students' achievement in the identified chemical concepts is related to their achievement in balancing chemical equations.

(4) Boys differ in their abilities in balancing chemical equations from the girls with the boys achieving better than the girls, the reason which is yet to be found out.

(5) A sound understanding of the identified chemical concepts theoretically perceived as underlying the ability to balance chemical equations is necessary for students' competency in balancing chemical equations.

5.4 RECOMMENDATIONS

In the light of these findings, the following recommendations are made:

(1) Teachers in the secondary schools should make deliberate effort to teach the identified chemical concepts before embarking on the teaching of balancing chemical equations.

(2) Those concepts termed as difficult in this study should be properly addressed by the chemistry teachers before teaching balancing chemical equations.

(3) An effective teaching programme should be drawn by the chemistry teachers so as to acquaint the students with the necessary skills required to balance chemical equations.

(4) The error/correction type of chemical equation balancing be given adequate attention by the teachers so as to help students acquire the necessary abilities required in the balancing of chemical equations. This when taken care of will make the students well equipped in the skills useful for correct balancing of chemical equations rather than their

usual guess work as perceived in the study. Thus, the difficulties that students have with balancing of chemical equations would be solved.

(5) A ranking order of the identified chemical concepts in their order of difficulties is necessary to alleviate students' problems in the area of balancing of chemical equations. By this sequence, those concepts termed as sub-ordinates would be learned and mastered before proceeding to the co-ordinate concepts and the super-ordinate concepts.

(6) Curriculum Planners and the Ministry of Education should organise workshop/conferences for chemistry teachers at the zonal levels on ways of improving chemistry teaching/learning in the Senior Secondary Schools especially in the important area of balancing chemical equations.

5.5 LIMITATION OF THE STUDY

The following is the limitation of the study:

The use of the equation that did not represent a real chemical phenomenon could mislead in teaching/learning situations hence a limitation.

5.6 SUGGESTION FOR FURTHER STUDY

(1) This study was limited to Senior Secondary Schools in Otukpo Local Government of Benue State, Nigeria, therefore, there is the need to replicate the study in other parts of the country in order to find out if similar or different results will be obtained.

(2) A further study on the correlation of students' achievement concept by concept with balancing of chemical equations should be carried out to see the concept that has the most effect on balancing of chemical equations (ie the concept that has the strongest correlation and the one having the weakest correlation with the ability to balance chemical equations). This would be useful in drawing out a hierarchy of concepts useful in the understanding of balancing chemical equations.

(3) The researcher suggests that further study be carried out to see if knowledge of students' performances in related chemical concepts can be used to predict their performances in balancing of chemical equations.

(4) The factors responsible for the existence of gender related differences in balancing chemical equations found in the study is not apparent. Therefore, it is suggested that further research should be carried out with the view to determining it.

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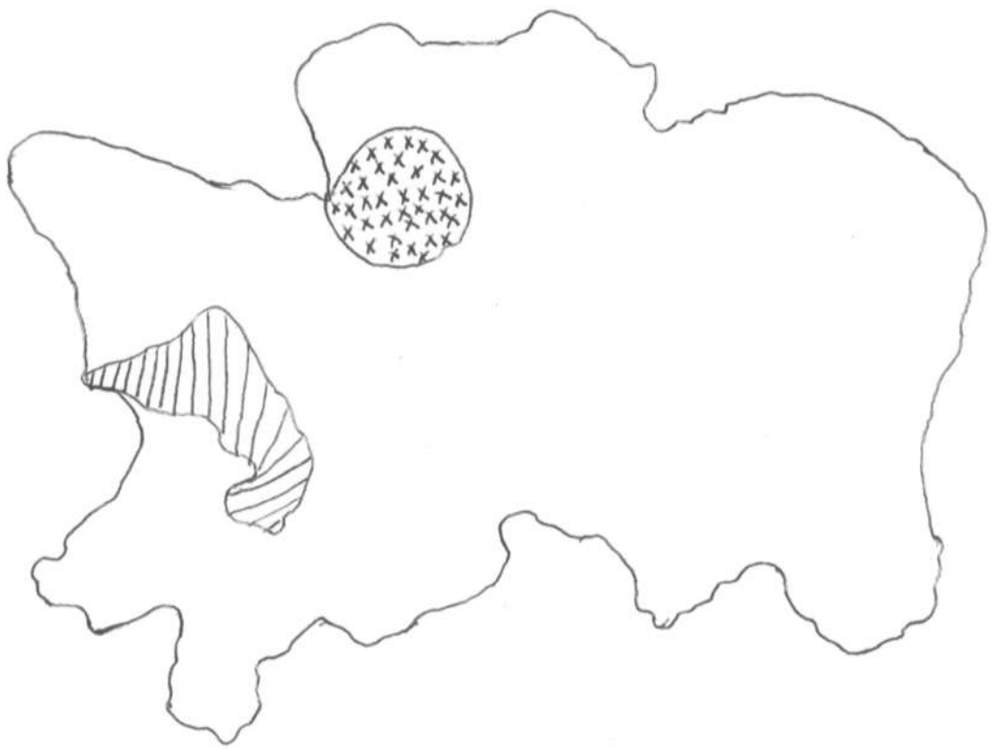
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APPENDIX I

MAP OF BENUE STATE WITH OTUKPO LOCAL GOVENRMENT AREA SHORING THE STUDY AREA



Source: Ministry of Information, Makurdi

KEY:

STUDY AREA

STATE CAPITAL

APPENDIX II

INSTRUMENTS FOR DATA COLLECTION

The instruments for data collection consisted of two tests, Chemical Concept Achievement Test (CCAT) and Chemical Equation Achievement Test (CEAT).

THE CHEMICAL EUQATION ACHIEVEMENT TEST (CEAT)

This test consisted of two sets of tests on balancing of chemical equations.

SECTION A: UNBALANCED EQUATION TEST

INSTRUCTIONS

This section consisted of seven chemical equations which needed to be balanced. *The equations are written correctly but in the unbalanced form. You* are expected to balance them correctly.

1. $Na + H_2 \rightarrow NaH$
2. $CuS0_4 + K \rightarrow K_2S0_4 + Cu$
3. $A1_2(S0_4)_3 + Bacl_2 \rightarrow BaS0_4 + A1cl_3$
4. $KOH + H_2SO_4 \rightarrow K_2S0_4 + H_20$
5. $CuS0_4 + A1 \rightarrow A1_2(S0_4)_3 + Cu$
6. $Zn + Ag_2S0_4 \rightarrow ZnS0_4 + Ag$
7. $A1_2(C0_3)_3 + Ca \rightarrow CaC0_3 + A1$

SECTION B: ERROR/CORRECTION TYPE TEST

INSTRUCTIONS

This section consisted of the error/correction type of test. Ten chemical equations each containing a given number of formulae errors are provided below. *You are expected to:-*

(i) spot the error

(ii) correct them and

(iii) rewrite them correctly in the balanced form.

To guide you, the word equation is given in each case.

Equation 1: $Pb(NO_3)_2 \rightarrow Pbo + N_20 + 40$

Word equation

Lead (II) trioxonitrate (V) → Lead oxide + Nitrogen dioxide + Oxygen

(Maximum four errors)

Spotting of error :

Correction :

Balanced equation :

Equation 2: $ZnSO_4 + Na_2OH \rightarrow ZnOH + Na_2SO_4$

Word equation

Zinc (II) tetraoxosulphate (vi) + disodium hydroxide

Zinchydroxide + disodium (II) tetraoxosulphate (vi)

(Maximum four errors)

Spotting of error :

Correction :

Balanced equation :

Equation 3: $Mg + (Ag)_2SO_4 \rightarrow MgSO_4 + Ag_2$

Word equation

Silver (II) Magnesium

Magnesium + tetraoxosulphate (vi) → tetraoxosulphate (vi) + Silver

(Maximum four errors)

Spotting of error :

Correction :

Balanced equation :

Equation 4: $K(OH)_2 + HN0_3 \rightarrow K(NO_3)_2 + H_20$

Word equation

Potassium

Hydroxide + Trioxonitrate (v) acid → Potassium trioxonitrate (v) + water

(Maximum four errors)

Spotting of error :

Correction :

Balanced equation :

Equation 5: $KC1_2 + H2S0_4 \rightarrow KSO_4 + HC1_2$

Word Equation

Potassium Chloride + Tetraoxosulphate (vi) acid → Potassium hydrogen tetraoxosulphate (vi) + chloride

(Maximum four errors)

Spotting of error :

Correction :

Balanced equation :

Equation 6: $H + Cl \rightarrow HCl$

Word equation

Hydrogen + Chlorine → Hydrochloric acid

(Maximum four errors)

Spotting of error :

Correction :

Balanced equation :

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Equation 7: $Na_2NO_3 + H_2SO_4 \rightarrow 2NaSO_4 + HNO_3$

Word equation

Disodium Tetraoxo Disodium Trioxonitrate

trioxonitrate (v) + sulphate (vi) acid → tetraoxosulphate (vi) + (v) acid

(Maximum four errors)

Spotting of error :

Correction :

Balanced equation :

Equation 8: $C_20 + H_20 \rightarrow HCO_3$

Word equation

Carbondioxide + water → Trioxocarbonate (v) acid

(Maximum four errors)

Spotting of error :

Correction :

Balanced equation :

Equation 9: $CaOH + NH_4Cl \rightarrow CaCl + H_20 + 2NH_3$

Word equation

Calcium Ammonium Calcium

hydroxide + chloride → chloride + water + Ammonia

(Maximum four errors)

Spotting of error :

Correction :

balanced equation :

Equation 10: $MgO_2 + HNO_3 \rightarrow MgNO_3 + H_2O$

Word equation

Magnessium Trioxo Magnesium

oixde + nitrate (v) acid → trioxonitrate (v) + water

(Maximum four errors)
Spotting of error :
Correction :
Balanced equation :

THE CHEMICAL CONCEPT ACHIEVEMENT TEST (CCAT)

This test consisted of two units (2a and 2b). Unit 2a consisted of twenty multiple choice test items on chemical concepts with five options labelled A- E. The options are carefully selected to highlight possible chemical concepts errors. Unit 2b comprised ten multiple choice items on balancing of chemical equations. The options are also selected to highlight possible chemical equation balancing errors.

Unit 2A: Multiple choice items on Chemical concepts

Instructions: Attempt all questions

Each question is followed by five options, circle the correct letter corresponding to the correct answer.

1. The substance with atomic number 12 is likely to be:
   (a) A compound (b) An element (c) A radical (d) An ion
   (e) A mixture

2. The element with atomic number 5 is likely to be:
   (a) Covalent with a valency of 5
   (b) Electrovalent with a valency of 5
   (c) Inert with zero (o) valency
   (d) Electrovalent with a valency of 3
   (e) Covalent with a valency of 3.

3. The formula of oxygen molecule is:
   (a) 0 (b) 20 (c) 02 (d) 3/20 (e) ½ 02

4. Chlorine exists freely in nature as:
   (a) A diatomic element
   (b) A monoatomic element
   (c) A triatomic element
   (d) A polyatomic element
   (e) Tetra-atomic element

5. The formula of magnesium sulphate is:-
   (a) $Mg(SO_4)_2$ (b) Mg_2SO_4 (c) $(Mg)_2SO_4$ (d) $MgSO_4$ (e) $Mg(SO_4)_3$

6. The valency of iron in $FeSO_4$ is:
   (a) 1 (b) 2 (c) 3 (d) 0 (e) 4

7. Neon has a valency of:
   (a) 2 (b) 4 (c) 8 (d) 0 (e) 1

8. the numerical coeficient in a balanced equation give:
   (a) the numbers of moles of reactants and products.
   (b) the numbers of moles of reactants only
   (c) the molar mass of reactants and products.
   (d) the mass ratio of the reactants
   (e) the number of molecules and atoms of products only.

9. When the equation $A1(OH)_3 + HN0_3 \rightarrow A1(NO_3)_3 + H_20$ is balanced, the coefficient of HNO_3 is
   (a) 1 (b) 4 (c) 2 (d) 6 (e) 3

10. What is the subscript of A1(OH)3 in equation 9 above?
    (a) 6 (b) 4 (c) 2 (d) 1 (e) 3

11. The subscripts of formulae in a balanced chemical equation represent:
    (a) the number of molecules and atoms in a chemical equation.
    (b) the molar mass of reactants only
    (c) the numbers of atoms of the component elements in a chemical equation.

(d) the numbers of moles of reactants and products
(e) the number of elements in a chemical equation.

12. Brackets are used in a chemical equation when:
    (a) A molecule occurs once
    (b) An atom occurs more than once
    (c) A compound occurs more than once
    (d) A radical occurs more than once
    (e) A radical occurs once

13. The formula of Zinc phosphate is:-
    (a) $Zn(PO_4)_2$ (b) $Zn_2(PO_4)_3$ (c) $Zn_3(PO_4)_2$ (d) $ZnPO_4$ (e) $Zn_4(PO_4)_3$

14. Which of the following is a molecule?
    (a) Na (b) Ne (c) O (d) Fe (e) Cl_2

15. Which of the following contains the greatest number of atom?
    (a) 5.4g of carbon (b) 5g of calcium (c) 8g of hydrogen (d) 2.2g of aluminium (e) 3.5g of phosphorus

16. What is the coefficient of the compound (HCl) in the equation below?
    $NaOH + Hcl \rightarrow Nacl + H20$
    (a) 1 (b) 2 (c) 0 (d) 3 (e) ½

17. A radical is defined as:
    (a) a group of molecules that function as a single unit.
    (b) a group of metals that function as a single unit.
    (c) a group of atoms that function as a single unit.
    (d) a group of acids that function as a single unit.
    (e) a group of gases that function as a single unit.

18. Which of these substances below is a radical?
    (a) H_2SO_4 (b) NH_4+ (C) $Bacl_2$ (d) H_2O (e) Zn^2+

19. The three basic sub-atomic particles are:
    (a) Photon, Electron and Proton.
    (b) Neutron, Photon and Electron

(c) Neutron, Proton and Electron
(d) Positron, Neutrino and Electron.
(e) Proton, Neutron and Hyperon

20. What is the subscript of A1 in $A1_2(C0_3)_3$?
(a) 1 (b) 3 (c) 4 (e) 0

Unit 2(b): Multiple Choice Items on Equation Balancing

Instruction: circle the letter corresponding to the correct anwer

(1) $Ca(P0_4)_2 + K \rightarrow K_3P0_4 + Ca$

(A) $Ca_3(P0_4)_2 + K \rightarrow 3K_3(P0_4)_2 + 3Ca$
(B) $Ca_3(P0_4)_2 + 4K \rightarrow K_3(P0_4)_2 + 3Ca$
(C) $Ca_3(P0_4)_2 + 6K \rightarrow 2K_3(P0_4)_2 + 3Ca$
(D) $Ca_3(P0_4)_2 + 6K \rightarrow 3K_3P0_4 + 3Ca$
(E) $Ca_3(P0_4)_2 + 6K \rightarrow 2K_3P0_4 + 3Ca$

(2) $H_2S0_4 + Ca(0H)_2 \rightarrow CaS0_4 + H_20$

(a) $H_2S0_4 + Ca(0H)_2 \rightarrow Ca_2S0_4 + H_20$
(b) $2H_2S0_4 + 3Ca(0H)_2 \rightarrow Ca_3S0_4 + 4H_20$
(c) $H_2S0_4 + Ca(0H)_2 \rightarrow Ca_2S0_4 + 2H_20$
(d) $H_2S0_4 + Ca(0H)_2 \rightarrow 2CaS0_4 + 3H_20$
(e) $H_2S0_4 + Ca(0H)_2 \rightarrow Ca(S0_4)_2 + H_20$

(3) $A1_2(S0_4)_3 + N_aOH \rightarrow Na_2S0_4 + A1(OH)_3$

(a) $A1_2(S0_4)_3 + N_aOH \rightarrow 3Na_2S0_4 + A1(OH)_3$
(b) $A1_2(S0_4)_3 + 6N_aOH \rightarrow 3Na2S04 + 3A1(OH)_3$
(c) $A1_2(S0_4)_3 + 2N_aOH \rightarrow Na_2S0_4 + A1_2(OH)^3$
(d) $A1_2(S0_4)_3 + 2NaOH \rightarrow Na_2S0_4 + A1_3(0H)_3$
(e) $A1_2(S0_4)_3 + 3NaOH \rightarrow 2Na_2S0_4 + 2A1(OH)_3$

(4) $Fe + 0_2 \rightarrow Fe_20_3$

(a) $2Fe + 30_2 \rightarrow 2Fe_20_3$

(b) $3Fe + 30_2 \rightarrow 3Fe_20_3$

(c) $4Fe + 20_2 \rightarrow 2Fe_20_3$

(d) $4Fe + 30_2 \rightarrow 2Fe_20_3$

(e) $8Fe + 30_2 \rightarrow 4Fe_20_3$

5. $Ag_2S0_4 + Nacl \rightarrow AgC1 + NaS0_4$

(a) $Ag_2SO_4 + Nacl \rightarrow 2AgCl + NaS0_4$

(b) $Ag_2S0_4 + 2Nacl \rightarrow 2AgCl + NaSO_4$

(c) $Ag_2S0_4 + 3Nacl \rightarrow 3AgCl + NaS0_4$

(d) $Ag_2SO_4 + 2Nacl \rightarrow 3AgCl + NaS0_4$

(e) $Ag_2SO_4 + Nacl \rightarrow (Ag)_2\ Cl + NaS0_4$

6. $A1(NO_3)_3 + k \rightarrow k(N0_3)_3 + A1$

(a) $A1(N0_3)_3 + 3K \rightarrow K_3(NO_3)_3 + 3A1$

(b) $A1(NO_3)_3 + 3K \rightarrow K_3NO_3 + A1$

(c) $A1(N0_3)_3 + 3K \rightarrow (K)_3N0_3 + 3A1$

(d) $A1(N0_3)_3 + 3K \rightarrow KN0_3 + 3A1$

(e) $A1(N0_3)_3 + 3K \rightarrow K_3(NO_3)_3 + A1$

7. $C_6H_{12}0_6 \rightarrow C_2H_50H + C0_2$

(a) $C_6H_{12}0_6 \rightarrow 3C_2H_50H + C0_2$

(b) $C_6H_{12}0_6 \rightarrow 2C_2H_50H + C0_2$

(c) $C_6H_{12}0_6 \rightarrow 2C_2H_50H + 2C0_2$

(d) $C_6H_{12}0_6 \rightarrow 3C_2H_50H + 2C0_2$

(e) $C_6H_{12}0_6 \rightarrow C_2H_50H + 4C0_2$

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8 $CH_4 + CO_2 \rightarrow CO + H_2$

(a) $CH_4 + CO_2 \rightarrow 2CO + 2H_2$

(b) $CH_4 + CO_2 \rightarrow CO + 2H_2$

(c) $CH_4 + CO_2 \rightarrow 3CO + 2H_2$

(d) $CH_4 + CO_2 \rightarrow 4CO + 2H_2$

(e) $CH_4 + CO_2 \rightarrow 2CO + H_2$

9. $N_2 + H_2 \rightarrow NH_3$

(a) $N_2 + 2H_2 \rightarrow 2NH_3$

(b) $N_2 + H_2 \rightarrow 4NH_3$

(c) $N_2 + 4H_2 \rightarrow 2NH_3$

(d) $N_2 + 3H_2 \rightarrow 2NH_3$

(e) $N_2 + 3H_2 \rightarrow 3NH_3$

10. $H_2S04 + LiOH \rightarrow Li_2S0_4 + H_20$

(a) $H_2S0_4 + 3LiOH \rightarrow 3Li_2S0_4 + 4H_20$

(b) $H_2S0_4 + 2LiOH \rightarrow Li_2S0_4 + 2H_20$

(c) $2H_2S0_4 + 2LiOH \rightarrow Li_2S0_4 + 3H_20$

(d) $3H_2S0_4 + 2LiOH \rightarrow Li_2S0_4 + 4H_20$

(e) $H_2S0_4 + 4LiOH \rightarrow 2Li_2S0_4 + 2H_20$

APPENDIX III

SCORING SCHEME FOR THE TESTS

The scoring scheme for the tests are as follows:

A. **Scoring Scheme for CEAT**

This test comprised two sections; the error/correction type and the straightforward balancing of chemical equations.

(i) Error/Correction Type

Spotting of error	=	1 mark
Making a correction	=	2 marks
Balancing	=	3 marks
Total for each question	=	5 marks
10x 6	=	60 marks.

(ii) Equation balancing

Addition	=	1 mark
Correct use of bracket	=	1 mark
Appropriate subscript	=	½ market
Appropriate coefficient	=	½ market
Balancing	=	2 marks
Total for each question	=	5 marks
Total mark allocation	=	40 marks

B. **Scoring Scheme for CCAT**

This test comprised two units (i.e. 2a and 2b). Unit 2a consisted of twenty (20) multiple choice items covering the chemical concepts underlying the balancing of chemical equations. Unit 2b was made of ten (10) multiple choice items on equation balancing. For unit 2a, three (3) marks are awarded for choosing the correct option and there are twenty (20) multiple choice items for this

unit i.e. 20 x 3 = 60 marks. Unit 2b consisted of ten (10) multiple choice items with four (4) marks awarded for each question i.e. 10 x 4 = 40 marks.

c. **Answer to the Tests**

Below are answers to the two tests (CEAT and CCAT) used for the study.

(i) **Answers to CEAT**

Error/Correction Type

Equation 1: $Pb(NO_3)_2 \rightarrow PbO + N_20 + 40$

Error spotting: N_20 and 0

Correction: NO_2 and 0_2

Balancing: $2Pb(NO_3)_2 \rightarrow 2Pb) + 4NO_2 + 0_2$

Equation 2: $ZnSO_4 + Na_20H \rightarrow ZnOH + Na_2SO_4$

Error spotting: Na_2OH and ZnOH

Correction: NaOH and $Zn(OH)_2$

Balancing: $ZnSO_4 + 2NaOH \rightarrow Zn(OH)_2 + Na_2SO_4$

Equation 3: $Mg + (Ag)2SO_4 \rightarrow MgSO_4 + Ag_2$

Error spotting $(Ag)_2$ and Ag_2

Correction $(Ag)_2SO_4$ and 2Ag

Balancing $Mg + Ag_2SO_4 \rightarrow MgSO_4 + 2Ag$

Equation4: $K(OH)_2 + HNO_3 \rightarrow K(NO_3)_2 + H_20$

Error spotting $K(OH)_2$ and $K(NO_3)_2$

Correction KOH and KNO_3

Balancing $KOH + HNO_3 \rightarrow KNO_3 + H_20$

Equation 5: $KC1_2 + H_2S0_4 \rightarrow KSO_4 + HC1_2$

Error spotting $KC1_2$, $KS0_4$ and $HC1_2$

Correction $KC1_2$, K_2S0_4 and HC1

Balancing $2KC1_2 + H_2S0_4 \rightarrow K2S0_4$ and 2HCl

Equation 6: $H + Cl \rightarrow HCl$

Error spotting Hand Cl

Correction H_2 *and* $C1_2$

Balancing $H_{2(g)} + C1_2 \rightarrow 2HCl_{(g)}$

Equation 7: $Na_2N0_3 + H_2S0_4 \rightarrow (Na)_2S0_4 + HN0_3$

Error spotting Na_2NO_3 and $(Na)_2S0_4$

Correction $NaN0_3$ and Na_2S0_4

Balancing $2NaNO_3 + H2S0_4 \rightarrow Na_2S0_4 + 2HN0_3$

Equation 8 $C_20 + H_20 \rightarrow HC0_3$

Error spotting C_20 and $HC0_3$

Correction $C0_2$ and H_2C0_3

Balancing $C0_{2(g)} + H_20(L) \rightarrow H_2C0_{3(ag)}$

Equation 9: $CaOH + NH_4cl \rightarrow CaC1 + H_20 + NH_3$

Error spotting CaOH and CaC1

Correction $Ca(OH)_2$ and $CaC1_2$

Balancing $Ca(OH)_2 + 2NH_4cl \rightarrow CaC1_2 + 2NH_3 + 2H_20$

Equation 10: $Mg0_2 + HN0_3 \rightarrow MgNO_3 + H_20$

Error spotting $Mg0_2$ and $MgN0_3$

Correction Mg0 and $Mg(N0_3)_2$

Balancing $Mgo + 2HN0_3 \rightarrow Mg(NO_3)_2 + H_20$

Equation Balancing

Note: The number of atoms of participating elements in the reaction must be equal on the two sides (right and left) of the equation for an equation to be balanced correctly.

(1) $2Na + H_2 \rightarrow 2NaH$

(2) $CuS0_4 + 2k \rightarrow K_2S0_4 + Cu$

(3) $A1_2(S0_4) + 2Bac1_2 \rightarrow 3Ba_3S0_4 + 2A1C1_3$

(4) $2KOH + H_2S0_4 \rightarrow K_2S0_4 + 2H_20$

(5) $3cuS0_4 + 2A1 \rightarrow A1_2(S0_4)_3 + 3cu$

(6) $Zn + Ag2S0_4 \rightarrow ZnS0_4 + 2Ag$

(7) $A1_2(C0_3)_2 + 3ca \rightarrow 3CaC0_3 + 2A1$

(ii) **Answers to CCAT**

1. B
2. E
3. C
4. A
5. D
6. B
7. D
8. A
9. C
10. E
11. C
12. D
13. A
14. E
15. B
16. A
17. C
18. B
19. D
20. E

Unit 2b multiple choice items on Balancing of chemical equation

1. E
2. C
3. A
4. D
5. B
6. E
7. C
8. A
9. D
10. B

APPENDIX IV

RAW SCORES FOR THE TESTS

S/NO	CCAT (X)	CEAT (Y)
1	30	30
2	38	06
3	36	00
4	29	00
5	35	03
6	03	00
7	75	65
8	40	33
9	51	44
10	37	30
11	30	17
12	72	28
13	35	10
14	20	00
15	22	03
16	21	38
17	23	00
18	45	10
19	20	01
20	18	38
21	49	12
22	24	00
23	33	09
24	28	10
25	33	00
26	39	05
27	47	00
28	20	00
29	15	00
30	15	00
31	23	00
32	36	05
33	31	05
34	19	00

S/NO	X	Y
35	31	00
36	35	31
37	64	43
38	34	08
39	09	01
40	21	02
41	15	00
42	33	14
43	40	10
44	80	73
45	31	58
46	09	03
47	45	26
48	36	33
49	18	10
50	63	49
51	33	16
52	41	46
53	12	04
54	26	18
55	56	34
56	47	18
57	46	43
58	49	14
59	33	06
60	29	00
61	30	01
62	53	03
63	32	00
64	29	17
65	19	11
66	24	07
67	12	02
68	48	32

S/NO	X	Y
69	50	43
70	33	20
71	23	15
72	48	41
73	44	26
74	52	36
75	53	48
76	38	21
77	14	04
78	48	32
79	52	29
80	40	47
81	53	38
82	20	07
83	36	47
84	45	34
85	21	12
86	29	22
87	51	41
88	40	27
89	44	22
90	12	03
91	18	10
92	26	14
93	40	34
94	43	38
95	43	31
96	43	31
97	43	32
98	32	35
99	46	32
100	56	35
101	56	35
102	43	31

103	49	38
104	50	30
105	51	46
106	56	37
107	28	06
108	09	00
109	21	00
110	12	04
111	21	00
112	23	00
113	34	05
114	34	01
115	24	00
116	50	17
117	34	00
118	41	01
119	47	00
120	41	01
121	46	00
122	27	02
123	36	00
124	25	05
125	45	16
126	26	00
127	16	03
128	67	32
129	42	00
130	57	27
131	42	18
132	74	64
133	66	51
134	34	34
135	61	32
136	54	48

137	45	09
139	28	-2
139	36	02
140	51	24
141	49	61
142	48	28
143	61	74
144	25	05
145	56	60
146	56	60
147	37	07
148	57	52
149	57	33
150	35	25
151	28	02
152	49	29
153	44	31
154	35	03
155	67	39
156	49	27
157	26	19
158	48	28
159	15	00
160	13	00
161	35	00
162	35	00
163	28	01
164	47	27
165	36	15
166	33	15
167	27	18
168	29	14
169	41	05
170	50	05

171	38	12
172	26	00
173	50	16
174	54	26
175	28	01
176	21	01
177	38	05
178	42	07
179	19	05
180	67	58

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APPENDIX V

RAW SCORES FOR THE PILOT STUDY (CCAT)

S/NO	(X)	(Y)
1	30	38
2	36	29
3	40	51
4	49	35
5	51	44
6	56	53
7	44	48
8	59	66
9	57	55
10	67	49
11	36	22
12	16	20
13	34	40
14	53	48
15	21	17
16	48	32
17	60	70
18	10	30
19	25	17
20	70	60

APPENDIX VI

RAW SCORES FOR BOYS ONLY

S/NO	CCAT (X)	CEAT (Y)
1	24	07
2	12	02
3	48	32
4	50	43
5	33	20
6	23	15
7	48	41
8	44	26
9	52	36
10	53	48
11	38	21
12	14	04
13	48	32
14	52	29
15	40	47
16	53	38
17	49	38
18	20	07
19	36	47
20	45	34
21	21	12
22	29	22
23	51	41
24	40	27
25	44	22
26	12	03
27	18	10
28	26	14
29	40	34
30	43	38
31	43	31
32	43	32
33	32	35
34	46	32
35	56	33
36	56	35
37	43	31
38	49	38

S/NO	X	Y
39	59	39
40	51	46
41	56	37
42	28	06
43	09	00
44	21	00
45	12	04
46	21	00
47	23	00
48	34	05
49	34	01
50	24	00
51	50	17
52	34	00
53	41	01
54	47	00
55	41	01
56	46	00
57	27	02
58	36	00
59	25	05
60	45	16
61	26	00
62	16	03
63	67	32
64	42	00
65	57	27
66	42	18
67	74	64
68	66	51
69	34	34
70	61	32
71	54	48
72	45	09
73	28	02
74	36	02
75	51	24
76	49	61

S/NO	X	Y
77	48	28
78	61	74
79	25	05
80	56	60
81	34	10
82	37	07
83	57	52
84	57	33
85	35	25
86	28	02
87	49	29
88	44	31
89	35	03
90	67	39
91	49	27
92	26	19
93	48	28
94	15	00
95	13	00
96	36	00
97	35	00
98	28	01
99	47	27
100	36	15
101	33	15
102	27	18
103	29	14
104	41	05
105	50	05
106	38	12
107	26	00
108	50	16
109	54	26
110	28	01
111	21	01
112	38	05
113	42	07
114	19	05
115	67	58

APPENDIX VII

RAW SCORES FOR GIRLS ONLY

S/NO	CCAT (X)	CEAT (Y)
1	34	08
2	09	01
3	21	02
4	15	00
5	33	14
6	40	10
7	80	73
8	31	58
9	09	03
10	45	26
11	36	33
12	18	10
13	63	49
14	33	16
15	41	46
16	12	04
17	26	18
18	56	34
19	47	18
20	46	43
21	49	14
22	33	06
23	29	00
24	30	01
25	53	05
26	32	00
27	29	17
28	19	11
29	30	30
30	38	06
31	36	00
32	29	00
33	35	03
34	03	00
35	75	65

S/NO	X	Y
36	40	33
37	51	44
38	37	30
39	30	17
40	72	28
41	35	10
42	20	10
43	22	03
44	21	38
45	23	00
46	45	10
47	20	01
48	18	38
49	49	12
50	24	00
51	33	09
52	28	10
53	33	00
54	39	05
55	47	00
56	20	00
57	15	00
58	15	00
59	23	00
60	36	05
61	31	05
62	19	00
63	31	00
64	35	31
65	64	43