Federal University of Technology, Minna

CONCEPT MAPPING: A VERITABLE TOOL IN SCIENCE EDUCATION

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DEDICATION

This lecture is dedicated to God - the Father, the Son and the Holy Spirit.

The Chairman
Vice Chancellor
Deputy Vice Chancellor
Members of Council
Senate Members
The Registrar
Other Principal Officers of the University
Deans of Schools
Distinguished Professors and Scholars
Directors of Centers
Heads of Departments
Members of the Academia
Friends of the University
Staff and Great Students of F.U.T. Minna
Distinguished Guests
Gentlemen of the Press
Ladies and Gentlemen

INTRODUCTION.

I thank the Almighty God for a day like this. It is with humility and elation that I stand before you this day to deliver this inaugural lecture titled: **"Concept mapping: A veritable tool in science education"**. This landmark and unforgettable occasion invariably comes once in the career of the academic. It is therefore with great joy and a deep sense of appreciation to the institution and indeed the entire community that I stand before you today to deliver the seventh inaugural lecture of this great institution. I have chosen the topic of my inaugural lecture to reflect and cover an area of my research interest in instructional development. My research interest and work covered three major related areas namely:

- Concept mapping,
- Misconceptions,
- Vee mapping and laboratory practices.

Education is the major issue in this lecture, it is followed by science education which is the target and concept mapping, the chief tool for getting at the target. In a world based on science and technology, it is education that determines the level of prosperity, welfare and security of people. It is a known fact that no nation can rise above the quality of its educated citizenry. In the process of education, teachers play a pivotal role. The professional preparation of teachers is therefore crucial for the qualitative improvement of education. In my view, the enterprise of science education is central to development, firstly and lastly, it is the students that matter. Educators are very much concerned with students learning and academic achievement. Research reports reveal that our students are not performing as they should and they are becoming incapable of comprehending fundamental (basic) concepts in science. Poor understanding of science concepts leads to poor performance which has serious implication for national development, future leaders and students choice of career and profession. The neglect of students-centered learning and students view have been identified as a major reason for the problems in science education. The success story of Japan and other developed countries in science and technology is based on well planned instruction. Hence, a change in instructional strategy that will enable students learn meaningfully by examining their own conceptions was sought. In search of such method, strategies based on construction of knowledge by the learner from their individual experiences were developed. These strategies are summed up as the **"constructivist view"** or using the term of von Glaserfeld (1989), the **"Generative learning Model"**. One strategy that has gained ground in the search for improving learning and performance is concept mapping. Data available to date from a variety of qualitative and quantitative research studies strongly support the value of this metacognitive tool-concept mapping, for both cognitive and affective gains. The knowledge that students are expected to learn is composed of concepts. Concept maps are representation of meaning. Concept mapping as a metacognitive strategy serves to help students organize their cognitive framework into more powerful integrated pattern.

This paper which is in four main sections, discusses education, curriculum trend in science education and evidences of declining performance of students in science in the first section. The next section introduces the emergent new approach, within the constructivist framework concept mapping, to teaching and learning that is fast gaining ground and has been shown to bring about meaningful learning. The psychological and epistemological foundations underlying the strategy are also presented here. The third section looks at the efficacy of concept mapping as a veritable tool in science education and ways of raising the performance of students in science using concept mapping instructional strategy. The collaborative role of the teacher and students in raising the standard of performance in science is given pre-eminence in the concluding section of this lecture.

On this note, Mr. Vice Chancellor sir, it is my pleasure and honor to stand before this distinguished gathering to present my inaugural lecture entitled **"Concept Mapping: A veritable tool in Science Education"**.

1.0 EDUCATION

Education is as old as man. One of the most important insights of most African states by the time they obtained their independence was the recognition that education is the greatest instrument mankind has devised for his own progress and national development. Education generally is not only profitable but a prerequisite for any meaningful and sustained national development. No wonder, the Federal Government of Nigeria adopted education as an instrument per excellence for effective national development. There cannot be any substitute for education. The essence of education in any part of the world is to assist individuals maximize their potentials for optimum self development and the development of the society. Formal education takes place in the classroom setting.

Of all the factors that determine the conduciveness of the classroom environment, the teacher is the most important. He is the pivot of teaching and learning activities . The effectiveness of a teacher is measured by the extent to which he helps his students learn. In other words, teachers' success is measured by the learning that results from their instruction. Teacher education seeks to help the individual teacher to grow and develop as a person, provide him with skills and professional abilities to motivate his students and help them in acquiring the right type of understanding, concepts, values, and attitudes necessary for survival in the society. Worldwide, countries continue to evolve educational processes or procedures for effective learning through research. Research enlivens teaching and inspires learning. Research is an essential component of teaching. There is no doubt that being a good researcher will improve a good teacher but we do question seriously whether someone who does no research can be and remain, a good teacher.

Teacher education is confined mainly to colleges of education and university levels with heavy emphasis on the professionalization of teaching. What is to be taught is determined by the philosophy of the nation. The National Policy on Education (1981) is an official document that spelt out in clear and unequivocal terms, the policies that guide government efforts in using education as a tool for the attainment of the overall national objectives. From the curriculum, syllabi are drawn up for each subject area which are closely linked to performance standard and measures of learning outcome. In Nigeria, this had been adequately done particularly in the 6-3-3-4 system of education. Education activity is centered on the learners for maximum self-development and fulfillment. The status of students is therefore a very important input into education and their number and quality are important to educational development.

Secondary school students form the major population of my research work. Secondary education in the overall national education system is both dual and strategic. It commands both the consumer and producer status. Secondary education dictates the pace of education at the primary and tertiary levels of the educational system. It consumes the products of the primary schools, on one hand, and yields input for the tertiary level on the other. The broad aims of science education are:

i. preparation for useful living within the society and
ii. preparation for higher education (NPE, 1981:16).

The objectives of secondary education for Nigeria as stated in the National Policy on Education (FRN, 1981) include the following:

i. to equip students to live effectively in our modern age of science and technology.
ii. to raise a generation of people who can think for themselves.
iii. to inspire the students with a desire for achievement and self improvement both at the secondary and in later life (Section 4, Pg 16).

In order to meet the objectives; Federal Government included Biology, Chemistry and Physics as core subjects in the secondary schools.

At the secondary school level, we have the following grade of teachers:

i. NCE holders.
ii. University graduates with professional training.
iii. University graduates without professional training.
iv. University graduates who hold postgraduate Diploma in education.
v. University graduates with Masters degree.

Today, more than half of the teachers in our secondary schools are B.Ed/B.Tech (Ed) graduates. These are trained by the various departments, faculties/schools, in Colleges of Education and Universities. These departments and schools/faculties teach the pedagogy of education. Student teachers are given:

i. good understanding of what teaching is all about.
ii. good understanding of subject area.
iii. good understanding of the students.

Teacher education, thus develops in the recipients the required ability to effectively facilitate learning.

Education at whatever level aims at developing the individual who in turn is expected to contribute to the development of the society. When an individual is developed, by extension a nation is developed. An adage says 'change the individual and you change the society'. People, therefore become educated not merely by attending schools but by the acquisition of useful experiences. In many areas of human existence, we learn from parents, friends, institution, church, mosque, library, clubs, TV, press, radio and so on. Of course, we cannot be carried away by any illusion that mere supply of books and increased student population are enough to bring about desired education. Only nations that are prepared and equipped with meaningful teaching and learning will be part of the dynamic world and all its evident benefits including rapid socioeconomic development.

1.1 SCIENCE AND INSTRUCTIONAL PROBLEMS

Modern world is permeated by the consequences of science and technology. "Science" is generally conceived as the source of knowledge and "Technology" as the application of that knowledge to a particular sphere of product. Science is concerned with understanding of natural phenomena and creating conceptual framework for its explanation.

Science education is a dual concept-science and education. Science education remains the precursor to acquiring the scientific know-how. Science educators train students for teaching science at the secondary school or tertiary levels. Science curriculum is built around basic science concepts with varying degrees of magnification to the level of specific science lesson. The relationship of classroom methodology and teacher education to performance is an issue that concerns the whole curriculum. Industrialised countries like Europe and America have increasingly come to realize and recognise that curriculum at whatever level must be accompanied by appropriate teaching strategy.

One of the main aims of research in science education is to provide data in order to answer the question "what curriculum and instructional method are most appropriate for learners". Hence the research in science education aims at developing better ways of teaching to help our students learn science and perform well in schools. Performance (how well an individual is able to demonstrate desired abilities) is a cardinal concept in education. The centrality of the concept is derived from the goal of instruction which is to bring about desired changes in knowledge, skills and attitude of students. Children are sent to schools in order to acquire certain competencies. Their performance in the attributes of interest provides an indication of the degree of efficiency of the machinery of education. A decline in students' performance in the sciences, therefore, becomes a matter of grave concern to the nation and science education in particular. Contemporary research works have probed into cognitive processes of learning. This is known as metacognitive strategy of learning. An example of a metacognitive strategy is concept mapping. We shall look at the genesis of this cognitive process.

1.2 HISTORICAL FACTS ON THE DEVELOPMENT OF INSTRUCTIONAL PRACTICES

In the early fifties, educators were concerned with getting knowledge into the heads of their students and educational researchers were concerned with finding better ways of "imparting" or "transmitting" this knowledge to the students. The students were told what they needed to know. They were seen as empty-headed and they played an intellectually passive role. Teachers did not regard students pre-existing ideas as important. Teachers' views rarely focused on the issue of "how students learn". The teacher, for instance, might ask "why do things fall" but might not attach meaning to students argument about the "role of air". Science was therefore presented as a catalogue of facts. Evaluation of learning emphasized summative assessments on whether knowledge had been transmitted or not. As science knowledge increased, the transmission mode of instruction was found to be deficient in meeting the goals of science. Moreover, it encouraged memorization of facts. The result was that students could not retain and apply ideas/concepts. If experiences in schools are such that learning is seen as impersonal and mechanical storage of facts, we should not be surprised if students entering science in higher education, albeit, with reasonable grades lack an inventive and personally committed attitude towards their study and become unquestioning members of the society. In order to avoid a situation where our students become conformist, a change of teaching method was sought. The then Soviet Union sent Sputnik 1, the first earth satellite, into space in October, 1957. This event drew attention to the disparity between existing science courses and the rapid advances in science. This singular event moved America to embark on educational revolution in the areas of Science, Technology and Mathematics education. It was believed that to get more and better scientists, then something had to be done regarding the nature of science education in schools. The launching of Sputnik ignited crash programmes for curriculum reform in science education and catalysed the paradigm shift from transmission view to discovery method. Today, America is the most industrialized nation in the world. The period that followed Sputnik has come to be known as the "Golden Age" of Science Education

(1955-1974). The curriculum that followed emphasised laboratory activities as an integral part of class routine. Emphasis was on doing what scientists do. This prompted US to produce surplus scientists and engineers and surpassed the then Soviet Union in various space projects including landing the first person on the moon. Post-Sputnik directed attention to science education practices-curriculum development and teacher training. For years, science educators advocated discovery instruction. In pursuance of this new teaching method in Nigeria, the Federal Ministry of Education, adopted the use of guided discovery strategy. The strategy is strongly recommended in the National Science Curriculum for Senior Secondary Schools. This strategy was adopted because it was believed that science should not be taught to a child but that he should be guided to discover it through such processes as observation, measuring, classification, etc. The strategy is activity oriented and involves discussion, practical demonstration, and experimentation. With this strategy, the teacher guides students in the use of data collected to illustrate concepts. There was a great burst of interest on the introduction of this strategy. A huge amount of money was spent in pre-service and in-service training programmes for science teachers to acquaint them with the new strategy. Within few years of introduction, lapses were observed.

1.2.1 Observations

i. Although students became more "active" in the sense that they were spending more time in the laboratory carrying out observations, they were not considered to be active in the sense of actively "constructing knowledge" (Pankratius, 1990).

ii. Over the years, students outcome in discovery instruction continued to be disappointing (STAN, 1992). It would be difficult to identify significant changes in learning that resulted from guided discovery strategy.

iii. Students were increasingly becoming incapable of understanding and handling fundamental science concepts.

iv. Employers of labour comment negatively on the quality of graduates produced from our institutions.

v. Failure rate in science examinations continued to increase, several studies reported decline in students performance in the sciences (Ajewole, 1991; Pankratius, 1990 & STAN, 1992).

vi. Data from West African Examinations Council (WAEC) showed a clear discernible low level of performance (Table 1.1a). In all the science subjects taken, less than 40% of the students passed at credit level.

Table 1.1a : Performance of Students in (1981-1991) GCE O' level

Year	% in Grades 1-6			
	Biology	Chemistry	Physics	Mathematics
1981	13.48	21.75	20.60	6.28
1982	60.08	17.48	20.38	13.30
1983	8.93	12.31	14.57	8.89
1984	10.60	25.53	23.44	10.48
1985	11.73	19.78	25.85	11.45
1986	16.17	39.78	24.82	10.20
1987	11.19	39.15	24.68	14.07
1988	9.41	27.06	31.15	21.69
1989	11.83	10.80	9.50	8.76
1990	15.73	4.10	20.17	10.56
1991	25.55	10.40	17.61	11.13

Source: STAN/WAEC (1992).

vii. The mean score of candidates who sat for the 1997 to 2003 Universities Matriculation Examination (UME) in the sciences and Mathematics (table 1.1b) gives cause for worrying. This is because these are subjects that are central to any technological development.

Table 1.1b : Performance of UME Candidates in STM (1997-2003)

Year	Subjects			
	Biology	Chemistry	Physics	Mathematics
1997	34.02	37.42	34.08	44.63
1998	44.45	45.77	47.12	53.50
1999	48.33	36.42	30.52	38.90
2000	37.95	36.47	26.19	25.65
2001	45.22	47.99	27.95	33.69
2002	43.77	41.56	33.84	40.27
2003	45.13	43.05	33.11	43.91

Source: JAMB .

viii. There appeared to have been an increase in the catalogue of science concepts perceived by students to be difficult (Ezenwa, 1993).

ix. WAEC Chief Examiners report (1988, 1989, 1990 & 1991) recommended that as a matter of necessity, science educators should think about what could be done to improve the situation of students' poor performance.

x. The result of the Second International Science Study (Rossier, 1990) showed that of the different countries that participated in the study, Nigerian pupils came last in primary science while Japanese primary school pupils came first. Also Nigeria came last but one in ranking in secondary science.

xi. Students seem to lack basic learning skills and study habits needed for success in science.

The question is why have students not learned?. Many reasons have been adduced for the poor performance of students and the decline in the understanding of many science concepts. Several of the factors outlined below, singly or in combination are implicated in the poor outcóme of our students.

1.2.2 What are the facts?

The facts are:

i. Some researchers found that the society is changing and discovery method is no more adequate (Hurd, 1990).

ii. Students lack committed attitude to science, they seem to be more inclined towards business and quick money making ventures.

iii. New family structures have emerged, less than 10% of mothers are currently full time housewives, therefore, the time parents and children spend with one another at home has decreased. (Hurd, 1990).

iv. Not only has science knowledge increased since 1960's but society faces (experiences) problems today such as acid rain, radioactive fallout, ozone depletion e.t.c, that were unimagined before.

v. Goals of science education have changed since 1960's.

vi. Sufficient attention was not given to the dimension of students view (prior knowledge) brought to the class that may influence their understanding of science concepts (Novak, 1990; Okebukola, 1990 & Onwu, 1985).

vii. Students brought a lot of misconceptions to the class and due to these misconceptions, concepts were rated as being difficult or abstract (Duit, 1990).

viii. Hudson (1993) observed that science activities were initially discovery in nature but degenerated to what he termed "pseudo" discovery because of class management.

ix. Lack of appropriate textbooks; most indigenous textbooks were directed towards external examinations (Abimbola & Baba, 1996).

x. Students' difficulties traced to quality of instruction and neglect of prior knowledge of students which led to misconceptions or alternative conceptions.

xi. Novak (1990) stated that the necessity for a prior conceptual framework before one could discover any thing at all was not accounted for.

xii. From studies, investigating instruction in science classes, research has shown that instruction played a major role and that lecture method was predominantly used in our schools though the method has been found to be deficient in meeting the goals of modern science.

With these facts that covered teachers, teaching, instruction, societal changes and students' attitude, it is now recognized that the major efforts of the '70s to improve science education have fallen short of expectation (STAN, 1992). What science educators expected to see was not what was happening in schools. There seemed to be a wide gap between expected and observed. There is therefore obvious disparity between what science educators would like to see happening in the classroom and what is actually happening (Jegede and Okebukola, 1988; Okebukola, 1990 and von Glaserfeld 1989).

The general picture is that science education lagged behind. Science education, the world over was faced with problem. If educational efforts are failing, the presupposition on which these efforts have been founded must be questioned. We need to look at what education deals in, that is, learning. This has led to a worldwide call for ways of reforming and repositioning science education by looking at ways students construct knowledge.

1.2.3 Scope of Effort

Investigations by researchers into various areas of learning with the aim of understanding student's learning difficulties, how they learn and how to help them learn science concepts in a meaningful way revealed the following:

1. Children had firm views about science topics prior to being taught science at school and that affected their learning. For example, some had the view that:
   - "light from a candle goes further or brighter at night".
   - "Friction only occurs between moving surfaces".
   - "Electric current is used up in a light bulb".
   - "A worm is not an animal".
   - "A spider is not an animal".
   - "Bubbles in boiling water are bubbles of air".

All these ideas are quite different from those of scientists and are termed "misconceptions". Misconception is a conceptual view that is not compatible with scientific view. Others are cultural beliefs and alternative conception.

2. Misconceptions in science areas which students have developed strong aversion include:
   - Force, light, energy, and electricity in physics.
   - Photosynthesis, ecology, genetics, evolution, and osmosis in biology.
   - Stoichiometry, mole concept, chemical kinetics, chemical equilibrium, particulate nature of matter and solubility in chemistry.

With such catalogue of concepts perceived to be difficult by students, if no intervention is forthcoming, time may be in sight when most of the topics in the secondary school syllabus will be considered difficult by most students.

3 Students sometimes invented a purpose for the lesson which was subtly but significantly different from the purpose intended by the teacher.

4 Students' understanding from the outcome of teaching or experimental work were frequently not those that the teacher assumed were developed. Of course, it does not take a good teacher very long to discover that saying things is not enough to "get them across".

5. When student's ideas were changed by science teaching, the changes sometimes are quite different from those intended. It is not so surprising that science teaching has not been as effective as it ought to be. For instance,
   - Students tended to consider each topic as an isolated event while the teacher assumed that they appreciated the connection between the topic and previous learning experiences.

6 Frequently, students passed tests and other formal assessment, but do not really change their ideas of how and why things behave as they do.

7. Some of these prior students' ideas that are not in line with scientific views (misconceptions) can be amazingly tenacious and resistant to change.

8. Sadly, these non-scientific ideas among students could still be found among science specialists. From these efforts, science educators saw the pressing need for reconsideration of the methodology in the teaching of science. The new consensus among science educators is that learners construct knowledge from already existing conceptions and this influenced their learning. The emerging construction of knowledge from prior experiences is the core of the constructivist framework. The constructivist view of learning has now become a leading idea in science and education. It is observed that some instructional strategies proposed to improve science instruction are those using the constructivist framework. There are evidences that the application of constructivist framework leads to meaningful learning.

2.0 CONSTRUCTIVISM

Constructivist epistemology sees production of new knowledge as a human construction. The premise behind " Constructivism" (current pedagogical practice in science education) is that knowledge is actively constructed by the learner on the ground of constructs already available to him/her and that learning is likely to occur, if the "facts" to be learned are construed by the learner as having personal relevance or meaning. The psychological theories of Piaget, Bruner and Ausubel have lent support to this epistemological movement. The constructivist view is similar to what Piaget (1953), described as the equilibrium of learning. Gagne (1970) realised the importance of relating the unfamiliar to the familiar in order to attain meaningful learning when he stated that "any piece of knowledge can be acquired by individuals who possessed certain prerequisite knowledge". Ausubel (1963) also stressed the importance of prior knowledge to learning. The philosophy behind individuals construction of meaning from prior experience is labelled as "constructivism". Of course, the usefulness of any philosophy of science includes a thorough knowledge of the nature of science, production of scientific knowledge and determination through concepts, laws, generalization, the epistemological interpretation of science in relation to "reality" and truth. All these help to inform what science is taught in schools.

All ideas about constructivism was combined to produce a model called "Generative learning Model" (GLM). This model shows how learners construct or generate meaning from old experiences by incorporating new construction into the old.

The model is summarised thus:

i The learner's memory store interacts with sensory input from the environment. It actively selects some inputs and ignores the others.

ii The selected input are attended to by the learner. The selected input in itself has no meaning until, the learner generates link between that input and those parts of his memory store relevant to the situation.

ii At times, the learner may make a link between the memory store not implied by the teacher (misconception by learner).

Iv The learner retrieves information from memory store which is used to construct meaning from the sensed experience.

v The learner tests the constructed meaning against memory and sensed experience.

Vi The learner may incorporate the construction alongside other ideas or sometimes a considerable restructuring of ideas and reinterpretation of experiences may be required to successfully incorporate the new construction.

vii. At times, the new construction and the previously existing ideas are held simultaneously. In learning, students reasoning often follow a linear sequence. Considering, a container being heated, they think of the process in directional terms with a source supplying heat to a receptor; whereas, from a scientific point of view, the situation is symmetrical with two systems interacting, one gaining energy and the other losing it. Also they might appreciate the effect of an increase in pressure on an enclosed body of gas, yet they have difficulty anticipating the effect of a reduction in pressure.

Viii. Finally, new status is placed on the new construction.

When students have two views of same idea, they use one in science lesson, the other for everyday living. The two view points may seem quite unrelated and the student may make no attempt to reduce the contradiction between the two stand points. Often these views may not be known to the teacher. Science, therefore, remains "unreal" to the student. These intuitive knowledge students possess adversely affect their ability to learn from science instruction meaningfully. Osborne & Cosgrove (1983) gave example of students attending science classes believing that the bubbles in boiling water are air. In science classes, they learn that water is made up of oxygen and hydrogen. They deduce that on boiling, water changes into hydrogen and oxygen. Thus showing that the direction of learning may be entirely different from that anticipated by the teacher. Hence, the emphasis of constructivist view on the role concept and prior ideas play in human construction of meaning.

Constructivist learning has gathered much support in the literature ranging from philosophical discussion, testimonial by researchers and educators who have seen constructivism work successfully with their students and experimental studies showing higher students' performance in constructivist learning environment (Ault, 1985; Duit, 1990; Novak 1990 and von Glaserfeld 1989). The tendency of many science educators to adopt the constructivist view expresses its efficacy. The new epistemology has attracted a great preponderance of adherents (Abimbola, 1997; Ezenwa, 1993; Jegede and Okebukola 1988; Lagoke 1998; Molame & Dekkers, 1984; Novak, 1992; Novak and Musanda 1991; Oyedokun, 1998; Pankratius, 1990; Regis, Albertazzi & Roleto, 1996; Sisovic & Bojovic, 2000 & Watts, 1988).

Many instructional strategies are embedded in this new epistemology. They include analogy, concept and vee mapping. Of all the new instructional strategies, within the constructivist framework, concept mapping is seen to have gained ground. Evidence abound in literature that it enhances students understanding of science concepts and brings about meaningful learning. It is the new philosophy of science education, constructivism, that formed the cornerstone of concept mapping with Novak and Gowin being the proponents of concept mapping. Concept mapping is a useful tool for instruction and meaning making. It has tremendous research base.

The role of the teacher is that of a diagnostician, prescriber of appropriate activity and facilitator of learning. He attaches much importance to ideas students bring to the classroom. The learner assumes the role of a meaning maker and has the final responsibility for his learning.

2.1 UNDERSTANDING AND CONTRUCTIVIST ACTIVITY

To explain what is meant by understanding, we must distinguish between memorization or rote learning and understanding. In case of memorization, information is stored away in the memory. One can learn by rote but such learning is highly limited to recall, for the mental structure has been functionally fixed. Higher mental activities beyond the level of just "know how" cannot be handled by such student. The process of understanding is characterized by seeing relations between stockpile experience and new phenomenon. When we talk of understanding a concept or a whole discipline we are referring to a state of knowledge, the pattern of information that is linked to, or that constitutes the target. Understanding is therefore a function of the number of elements of knowledge the person possesses about the target. More central to understanding is being able to explain the procedure used. Understanding is a lifelong process. We can therefore no longer maintain the preconceived notion that words convey ideas or knowledge as we want or that a listener who apparently "understands" what we say must necessarily have conceptual structures that are identical with ours. To understand what someone has said or written means no less but also no more than to have built up a conceptual structure that appears to be compatible with the structure the speaker had in mind. Concepts should be taught in such a way that it connects, relates and integrates with the memory stock. This would make meaning to the individual and lead to meaningful learning.

Mr. Vice Chancellor, Sir, ladies and gentlemen, you can now see what goes on in science and industrial and technology education during instruction and why majority of our students do well. The important thing is to show students the direction in which to go and teach them to find their own path.

2.2 CONCEPT

The term "concept" has been defined as:

* word used to mean some kind of object, event or idea.
* key to human learning and meaning making.
* a mental impression or mental constructs people have of words, objects, or events.

*	source of human understanding.
*	what we think with in science.

Thinking is a mental activity involving the use of symbols. The most important process in thinking is conceptualization, the forming of concepts. Perception is the first stage of conceptualization. In perceiving, for instance, an individual is aware of an object or event that is present in his senses. In recalling what he has perceived, he uses symbols or words to represent the object or event. In forming concepts, therefore, one goes through a long process of thinking and classification. Concepts are formed when characteristics common to certain objects are categorised. Hence, Novak, the pacesetter on concept mapping or learning how to learn, defines a concept as a perceived regularity in events or objects or records of events or objects, designated by some label. Most of the labels we use are words. Bonding for example is the label used for the process that involves chemical re-arrangement of atoms. Two or more concepts can be linked together with words to form propositions. Propositions are the unit of psychological meaning. Concepts are not learned in isolation but must be put on conceptual network.

To acquire any knowledge, the learner has to first acquire the necessary elements or attributes. Concepts are acquired early in life. By the age of 30 months, most normal children have acquired several hundred concepts. These early concept meanings are constructed by children before any formal school.

The instructional strategy employed by the teacher plays an important role in concept acquisition and meaningful learning (Hudson, 1993). All meaning making begins with objects or events observed. Concepts permeate the cognitive process and serve as organizers of all intellectual and cognitive activities, as well as of all kinds of communication (teacher-students, student-student, student-taught topic). Since they are main tools of thinking, their organization in cognitive structures is of great importance. The internalization of a concept into a system aids full understanding.

2.3 CONCEPT MAP

Mapping is making of routes that link objects / ideas / events in such a way that meaning is achieved. To map is to construct a bounded graphic representation that corresponds to a perceived reality. From early time, humans have ventured to explore and map their world of experience. Once mapped, it was no longer considered *terra in cognita* but a *terra cognita*, which means, a region known to human kind. To map, one needs to recognize patterns and make connections to visualize the unknown. Concept maps are designed to find out what the learner knows about a concept / subject and are in effect, maps of cognition, or graphic representation of scientific knowledge. Basic to making a concept map for a piece of scientific knowledge is the ability of the mapper to identify and relate its salient concepts to a general, superordinate concept. That requires an understanding of what constitutes (or the elements that constitute) the concept. Concept map is intended to represent meaningful relationship between concepts in the form of proposition. At first glance, a concept map looks like a flow chart without the arrows, however, it is not. Rather than representing a linear or branched sequence of steps in a process or procedure, concept maps are designed to parallel human cognitive structure, in that they show concepts organised hierarchically, whereas, flow charts do not. Instead of a representation that corresponds directly to a linear text or lecture and reflects the logical structure of knowledge as in outlines, concept maps reflect the psychological structure of knowledge. Concept mapping is a process of constructing concept maps. It involves mapping out logical relationships among concepts in a hierarchical order, such that the most general concepts are at the top of the map, with the most specific concepts at the bottom of the map as shown in the concept map on matter (fig. 1).

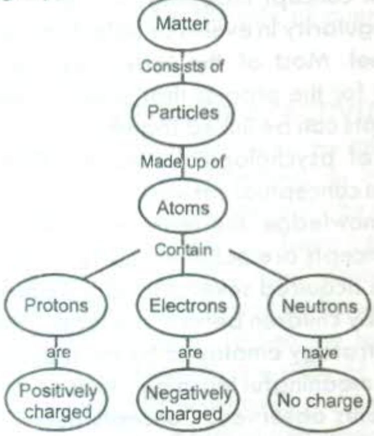

Fig. 1 : Concept Map of Matter

It is the construction of these relations between and within sub-concepts that produces meaningful learning. This type of learning is critical in science education. Concept map relies on three fundamental qualities; hierarchical structure, progressive differentiation and integrative reconciliation. It is both a meta learning (learning about meaningful learning) and meta- knowledge (learning about nature of knowledge) tool. It is based on the premise that concepts do not exist in isolation but depend upon others for meaning. Each concept is understood, ultimately through its relations with other concepts. To construct a map, students must decide how best to represent the concept.

The steps in concept mapping as in the concept of particulate nature of matter are:

- i Identify and list the key words/terms/concepts.
- ii Rank the listed concepts from the most abstract and inclusive to the most concrete and specific.
- iii Check for similarities and differences among the concepts of the same level of generality.
- iv Cluster the concepts as a two-dimensional array analogous to a road map. Each concept is in effect a potential destination for understanding. Its route is defined by other concepts. That is, the

concepts are clustered according to two-criteria, concepts that function at a similar level of abstraction and concepts that interact closely.

v Link related concepts with lines and label each line in propositional form. The clearer the link, the greater the understanding (see fig. 2).

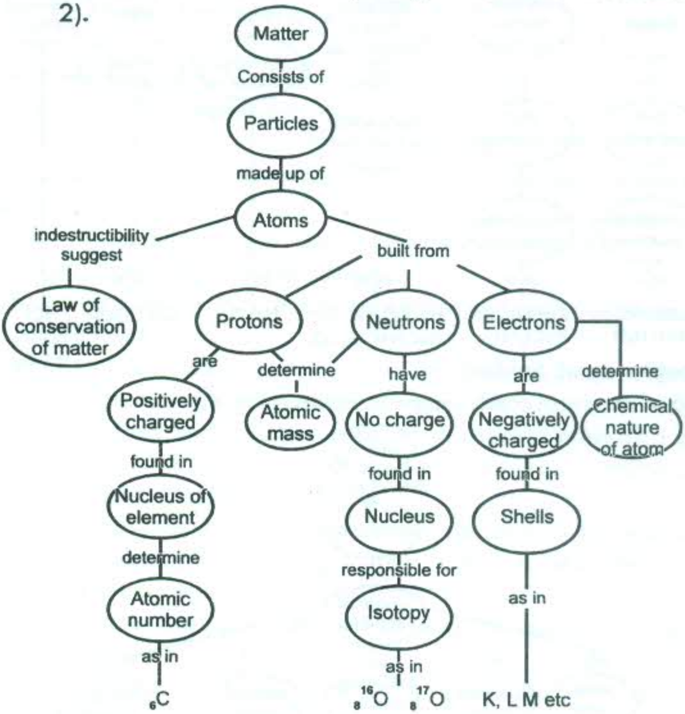

Fig. 2 : Concept map of particulate nature of Matter

The value of the connections and relations by maps lies not in memorization of connections and relations but in understanding and internalizing the system of concept. Since individuals have unique sequences of experiences leading to unique total sets of propositions, all concept meanings are to some extent idiosyncratic. The primary benefit of concept map accrues to the person who constructed the maps, no wonder, some students indicated that they were confused by concept maps prepared for them. It is worthy to note that a concept map does not have to contain all the concepts, in order to be effective. We cannot teach our students everything, about chemistry for example, in just one course nor should we try to. To construct the map, students must decide how best to represent the concepts hierarchically and the words to use to link concepts together.

Concepts in a map (as in the concept map of acids, fig. 3) relate to each other by connecting lines that define relationships between concepts, for instance, the acquisition of such relationship ("Acids have ionizable protons"; Acids turn blue litmus red, etc.) is the key element in meaningful learning.

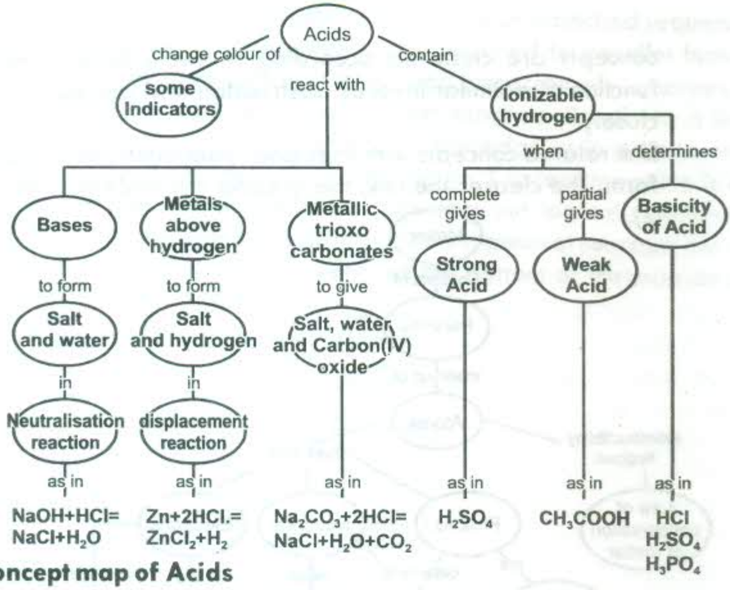

Fig. 3 : Concept map of Acids

Concept map of chemical combination is shown in fig. 4.

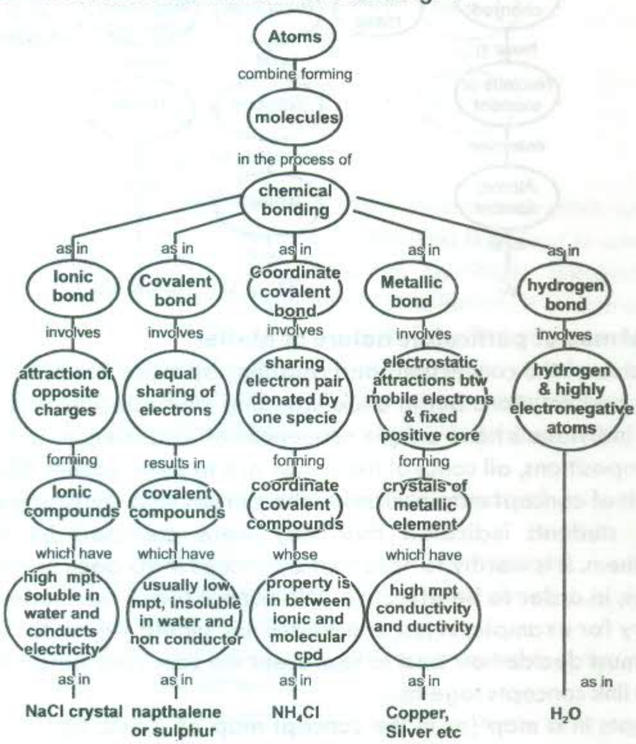

Fig. 4 : Concept map of chemical combination

2.4. GRAPHIC CONVENTION OF CONCEPT MAP

* Concepts are centered with circles or ellipses.
* Each level increases in specificity as it moves down.
* Lines connecting concepts are accompanied by linking words.
* Concept map is read from top down.
* Terminals of each branch is an example.

2.5. APPLICATIONS OF CONCEPT MAP

Concept map has numerous applications:

i It enables students to appreciate the inter-relationship among concepts and sub-concepts.

ii It helps students recognise and modify faulty knowledge structure. It has been used to identify misconceptions.

iii Maps generated by learner can be source of feedback to students and for improving instruction.

iv It has been used as advance organizers. Teachers have effectively shown concept maps as visual reference during lesson.

v It has been used to develop curriculum. A concept map of a discipline is a large overview of general concepts and can lead to course concept map.

vi It has been used as a study strategy.

vii Concept maps are excellent activity for revision at the end of instruction. One major strength of concept map is that it provides a concise well organised overview of a topic / concept.

viii Concept maps are good starter-activity to explore or elicit students' understanding.

ix Concept map encourages brevity in notes and links lecture and text reading.

x Concept maps aid elaboration and memory. Elaborations are generated by readers as they apply their prior knowledge.

Now suppose that at some later time, readers are asked to recall the original statement, but for some reasons are unable to, first, elaboration could aid memory by providing additional routes of retrievals to the target idea. Second, the reader might remember the elaboration only and use it to infer what cannot be remembered. Hence concept map and elaboration have a facilitative effect on memory and retrieval. In considering the above cited applications of concept map, it can be described as a versatile educational medium.

2.6 CONCEPT MAPPING INSTRUCTIONAL STRATEGY

The instructional strategy employed by the teacher plays an important role in concept acquisition and meaningful learning. Science educators advocated for instructional practices that would help students construct knowledge. Some instructional strategies proposed to improve science instruction are those using the constructivist view. Such strategies include analogy, metaphor, concept mapping and vee mapping. Of all the new instructional strategies within the constructivist framework, there are evidences that concept mapping leads to meaningful learning and has been proven to be the most versatile. Concept mapping instructional strategy is an example of metacognitive strategy. Concept map used as instructional strategy aids organization of concepts.

It has tremendous psychological and philosophical base. The remarkable efficacy of concept mapping instructional strategy in enhancing meaningful learning in science has been widely reported in science education literature. According to Novak (1990), concept mapping instructional strategy (CMIS) helps students learn how to learn meaningfully and helps teachers become more effective in their teaching. CMIS is relatively new in Nigeria, most of the research in CMIS were done overseas on biology concepts; chemistry concepts, earth science concepts and physics concepts. The study samples covered primary schools children, high school students and fresh undergraduates (Ault, 1985; Novak, 1990; Pankratius, 1990 and Watts, 1988). In Nigeria, Ezenwa, 1993, 1994; 1995; 1996; Jegede and Okebukola 1990; Okebukola 1990, and others worked on concept mapping in the different science areas (biology, chemistry and physics) using mainly secondary school students.

These researchers are all in agreement that the utilization of CMIS brought meaningful learning. Concept mapping instructional strategy involves class discussion, practical demonstration and concept mapping activity. The strategy is such that during instruction students construct map of the topic as they identify and list key ideas, arrange them from general to specific and then link them in a meaningful way. It is the construction of these relations between and among concepts that produce meaningful learning. Therefore a seemingly fruitful way of bringing about understanding of science concept is through the use of CMIS.

Mapping exercise demands that a student should have a good knowledge of the attributes (different elements) of the concepts before locating (placing) them in the appropriate place on the map. It enables students to appreciate the inter-relationships among concepts and sub-concepts. This is particularly important in educational system such as in our country where study of science discipline within separate subjects start early, there is a problem of providing correlation of contents, and positive transfer of knowledge from one field to another. This is a necessary precondition for solid knowledge so that students can explain or perceive a phenomenon or a change from different angles and to be able to use such knowledge with other examples both in school and everyday life. If this is not so, the same concept taught within different subjects will have separate meanings. For instance, atoms in physics versus atoms in chemistry. Relating the various areas require the student to think in multiple directions and switch back and forth between different levels of abstraction. There is no doubt that an instructional strategy that lays emphasis on prior knowledge of students will reduce misconception and thereby raise the standard of students' performance. The world-wide use of CMIS is being reported in the literature. The proponent of CMIS posit that meaningful learning ensues when a learner is aware of and can control the cognitive processes associated with learning. Indeed some students commented that they never knew there was another way to learn other than to memorise definitions or "facts" and review answers to old examination questions.

I have worked on concept mapping instruction strategy within the constructivist framework to determine its capability in bringing about understanding of basic science concepts. The results have been promising. I was invited by WAEC, Yaba, Lagos in 1996 to present a paper on, concept mapping, which I titled "Concept Mapping; a metacognitive strategy for raising standard of performance of students in science" to science educators and teachers. In 2000, some of the misconceptions identified by my studies were used to develop chemistry questions for WAEC. Presently, I am preparing Concept Map text book for secondary school science students.

A significant number of studies have examined the use of CMIS in science learning. It has been shown to promote knowledge construction, encourage independent thinking and activity, foster deeper understanding of concepts or large thinking skills and lead to greater command and ownership of content.

So far, most research into CM have tended to compare the strategy with other teaching methods like expository and guided discovery. Its effect on some variables like gender, attitude, home factor and reasoning have also been investigated in many subjects.

3.0 RESEARCH SUPPORT FOR THE EFFICACY OF CONCEPT MAPPING AS A VERITABLE TOOL IN SCIENCE EDUCATION

I have carried out many researches which support the efficacy of using concept mapping for students' meaningful learning. The efficacy will be demonstrated from different perspectives.

First, the research results on concept mapping strategy and its effectiveness in improving achievements will be reviewed here.

Second, to determine if the use of concept mapping strategy by gender and different level of achievers (high, average and low achievers) have effect on learning and achievement.

Third, to determine if the use of concept mapping as an instructional strategy enhances reading comprehension.

Fourth, to determine if concept mapping strategy has influence on students attitude to science.

Fifth, to determine if concept mapping leads to higher reasoning ability of science concepts.

Sixth, to determine if any home factor variables could predict science achievement of students who used concept mapping.

Seventh, support for the use of concept map for assessment.

Finally, to highlight misconceptions revealed through the use of metacognitive strategies.

3.1 CAN THE USE OF CONCEPT MAPPING INSTRUCTIONAL STRATEGY OR ANY INSTRUCTIONAL STRATEGY IMPROVE STUDENTS UNDERSTANDING AND PERFORMANCE?

To determine effects of concept mapping on students learning is important because learning and teaching modes are changing into students-centered meaningful learning from teacher-centered rote learning as society changes and new technology is introduced. Findings on the use of concept mapping strategy within the past decade have converged in supporting the fact that the strategy is potent in bringing about meaningful learning and improved performance.

Ezenwa (1993) studied the effectiveness of two teaching strategies (Concept mapping and Guided discovery) using 246 chemistry students randomly selected from senior secondary one (SS1) in Niger State. The instrument for data collection was Chemistry Concept Achievement Test (CCAT). The test instrument was based on "Particulate nature of matter." This concept which is part of the SS1 chemistry syllabus is fundamental to the study of chemistry and it cuts across science disciplines. Moreover it has been identified through literature as topical difficult area. Seventy objective test items were originally selected from a collection of West African Examination Council (WAEC) assessment items available in the field of secondary school chemistry. The final 50 test items used as instrument for data collection were selected on the basis of:

(i) validation, (the KR 21 reliability for the test instrument was 0.86 and content validity of this test was also confirmed).
(ii) pilot study.
(iii) high discrimination index, $D > 0.3$.
(iv) high facility indices, $40 < F < 70$.

The 50 multiple choice test items were at all levels of Bloom's taxonomy (1956), except synthesis and evaluation. Pretest-Posttest control group design was adopted for the study. The students were randomly assigned into experimental and control groups and pre-tested to determine their equivalence with respect to their prior knowledge of the selected concept. The students were then taught the concept of particulate nature of matter for four weeks using the appropriate teaching strategy. The experimental group was taught using concept mapping strategy. This strategy involved the elicitation of students prior ideas of concepts, discussion, demonstration and concept mapping activities. This treatment was withheld from the control group which received same chemistry instruction but through the approach (guided discovery) recommended by the National Science Curriculum for Senior Secondary Schools. A posttest on the chemistry concept was administered at the end of the treatment period to both groups to evaluate the effectiveness of the instructional treatment. Four weeks later, a post-posttest was administered to determine the level of concept retention. The students score before and after exposure to the treatments were recorded and analysed using t-test statistics. Result of the analysis revealed that the 123 students in the experimental class taught using concept mapping strategy performed significantly better on the Chemistry Concept Achievement Test ($t = 4.88$, $P<0.05$) and retained more chemistry knowledge

($t = 10.18$, $P < 0.01$) than the control group taught with guided discovery strategy, (based on the same number of observations). This result is consistent with findings of Okebukola & Jegede (1990) who compared concept mapping and expository method on students performance. Findings revealed that concept mapping strategy had significant effect on students learning and achievement compared to expository method. Judging from the research evidences above, it is clear that concept mapping (CM) is superior to guided discovery (GD) which in turn is superior to expository method (EM) that is, CM > GD > EM.

Analysis of the post-posttest revealed that concept mapping group retained more of the concept of "Particulate nature of matter" than the guided discovery group. Many other findings strongly confirm the effectiveness of concept mapping in promoting retention, (Novak and Musanda, 1991).

3.2 CAN THE USE OF CONCEPT MAPPING STRATEGY BRING ABOUT DIFFERENTIAL GENDER AND ACHIEVER LEVEL PERFORMANCE?

A recurring theme among educators, especially science educators, and the society at large is gender equity or gender friendliness. The concept "gender" has attracted the attention of many researchers. There is increasing research effort on affective and gender factors as they relate with cognitive factors in the empowerment or disempowerment of learners. Also in the Nigerian education system, classrooms are composed of boys and girls and students of different academic ability levels. Hence effect of concept mapping on boys and girls with different ability levels was aimed at finding out which gender and/or ability group(s) will benefit more than the other through concept mapping instructional strategy. My study was an attempt to determine whether gender and / or ability group(s) were important variables in students learning and performance.

Ezenwa (1999) determined the effect of concept mapping and guided discovery instructional strategies on two variables, gender and different level of achievers. The sample for the study consisted of 150 students from randomly selected co-educational schools in Minna metropolis. The instrument used for data collection was a 50 multiple choice item test on the concept "particulate nature of matter". Reliability coefficient of 0.86 was obtained for the instrument. The study recognised the difference in abilities among learners. The average and above achievers were distinguished from the lower achievers using the students junior secondary school results in integrated science. All the students were first pretested to determine their entry level. The students were randomly assigned to two groups (experimental and control). Thereafter, the students were personally taught the concept of 'Particulate nature of matter' for four weeks using appropriate teaching strategy for each group. A posttest was administered to both groups to assess the effect of instruction on gender and different achiever levels. The students' scores before and after exposure to treatment were analyzed using ANCOVA (General Linear Model Procedure) to determine post experimental effect of instruction on the performance of the different gender and ability levels. Pretest score on CCAT were inserted into the design as a covariate to remove extraneous variations from the posttest scores, thereby increasing measurement precision. The general linear models approach was used since differences in factors were sought. The result of the analysis is shown in Table 3.1.

Table 3.1 : Summary of ANCOVA showing the interaction of the variables of Gender, Achiever Levels and Methods on Teaching (Using General Linear Model Procedure)

Source of Variation	SS	DF	MS	F	P
Pretest	122.89	1	122 .89	2. 52	0 .1144ns
Achiever Level(ACL)	1093.85	2	546 .93	11 .21	0.0001**
Gender (G)	78.83	1	78. 83	1. 62	0.2053ns
Method (M)	13436.93	1	13436. 93	275 .52	0.0001**
2 – WAY INTERACTION					
Achiever x Gender	66.91	2	33 .46	0. 69	0.5047ns
Achiever x method	499.98	2	249.99	5. 13	0.0071**
Gender x method	38.38	1	38.38	0 .79	0.3761ns
3 – WAY INTERACTION					
ACLV X G X M.	27.19	2	13 .60	0 .28	0.7567ns

ns- Not Significant ** - Significant at 0.01 level.

The results of ANCOVA presented in Table 3.1 showed:

(i) a non significant difference in pretest. The concept mapping and guided discovery students did not differ significantly (F = 2.52, P>0.05) in their performance before treatment. Thus both groups were found to be equivalent before teaching treatment commenced.

(ii) that the P value of 0.2053 obtained on gender column indicated that there is no significant difference in the performance of boys and girls exposed to the guided discovery and concept mapping strategy. Both strategies seemed to favour boys and girls alike.

(iii) the interaction of gender and method was not significant (F = 0.79; P>0.05).

(iv) there was no significant interaction of different achievers, gender and method of instruction, (F = 0.28, df = 2; P > 0.05).

(v) that the P value of 0.0001 was significant for the teaching strategy variable. Thus, there is significant difference in the performance of students taught using concept mapping and guided discovery strategy. Achievement is therefore influenced by the teaching method.

(vi) that the students' ability level was a significant factor affecting achievement (F = 11.21, df = 2, P < 0.05). The performance of the high, average and low achievers exposed to concept mapping and guided discovery strategy was found to differ significantly.

(vii) that the P value of 0.0071 was significant for the interaction of different ability levels and methods of instruction (F = 5.13, df = 2, P < 0.05). This is an indication that there is significant difference in the performance of the different ability levels, with respect to teaching treatment.

(viii) there was no significant interaction of different achievers and gender ($F=0.69, P>0.05$).

An interesting observation here is the interaction effect of gender on the variables. Considering the single variable, the data revealed that:

(i) method (M) was significant ($F = 275.52$; $P<0.05$)

(ii) achiever level (ACLV) was significant ($F = 11.21$, $P<0.05$) but gender (G) was not significant ($F = 1.62$, $P>0.05$)

However, when two of the above variables at a time were considered, it was observed that the non-significant result of gender from above seemed to affect the combining variables result and reduced it to a level of no significance. For instance the interaction of (ACLV and (M) was significant ($F = 5.13$; $P<0.05$) but (ACLV) and (G) was not significant ($F=0.69$, $P>0.05$). Now a look at the three variables, (ACLV), (G) and (M) together revealed that the F value of 0.28 was not significant but (ACLV and M) combined were formally significant but when gender was brought into the 3-Way interaction, the presence of gender variable made the former significant result, non significant. It is therefore, clear that the moment gender variable is introduced, the result becomes non significant. Gender, therefore, seems to be a very strong determinant of non-significant result. One may therefore conclude that concept mapping as an instructional strategy is gender friendly. It affects both boys and girls equally.

The result of the ANCOVA in Table 3.1 revealed that the P-value of 0.0001 for achiever level and 0.0001 for method variables were significant. The P value of 0.0001 and 0.0071 were significant for the Achiever levels and Achiever levels / Method (2 way interaction) respectively. The mean pretest and posttest scores for teaching strategy and achiever levels are shown in Table 3.2.

Table 3.2 : Means of Treatment (Methods), Achiever levels, and the Interaction of Achiever Levels and Methods

Methods (Instructional Strategy)	Pretest LSM	Std Err LSM	Posttest LSM	Std Err LSM
Concept Mapping (CM)	11.20	0.64	38.32	1.02
Guided discovery (GD)	12.12	0.64	14.56	1.02
ACHIEVER LEVEL (ACLV)				
Average (A)	12.10	0.61	22.33	0.97
High (H)	13.07	0.71	28.72	1.14
Low(L)	9.80	0.98	28.47	1.59
(ACLV). VS METHOD)				
A 1 (CM)	12.74	0.86	31.84	1.37
A 2 (GD)	11.91	0.86	13.16	1.37
H 1 (CM)	12.91	1.01	41.36	1.60
H 2 (GD)	11.73	1.01	15.27	1.60
L 1(CM)	7.80	1.39	42.00	2.22
L 2 (GD)	11.80	1.39	14.00	2.22

The mean posttest scores for concept and guided discovery groups are 38.32 and 14.56 respectively. From a mean posttest score of 11. 20, the concept mapping group achieved a significant mean posttest of 38.32 whereas for the guided discovery group the achievement of 12.12 in pretest and 14.56 in the posttest was not significant. This showed that the significant difference observed between the instructional strategy in Table 3.1 ($F = 275.52$; $P<0.05$) could be attributed to concept mapping instruction strategy. Concept mapping is seen therefore to be a more significant and effective instruction strategy in helping students learn and improve their performance than the National recommended guided discovery strategy.

The mean posttest value for the different achiever levels in the concept mapping group are shown as 41.36, 31.84 and 42.00 for the high, average and low level achievers respectively. The high and low achievers appeared to have benefited more from the use of concept mapping than the average achiever. The low achievers were able to successfully utilize concept mapping for better performance comparing the pretest and posttest scores. The lower achiever benefited more from the use of the concept mapping than the higher achiever. From the mean pretest score of 7.80, the lower level achievers obtained 42.00 while the higher achievers from mean score of 12.91 obtained 41.36 in the posttest. The result with respect to achiever levels indicated that the lower achiever group was able to successfully utilize the concept mapping strategy for better performance than the average and higher achievers. Concept mapping strategy is seen to have positively influenced higher level of learning especially for the less capable students. The trend revealed that the low ability group caught up with and out performed both the higher and average ability. This result could be attributed to the nature of the strategy itself. The strategy required students to fully participate in instruction and reduced concept to very simple ideas that are linked in a meaningful way to aid understanding. Probably the problem of the lower ability before treatment might have been due to their inability to understand and see relationships in concepts taught. Concept mapping encourages a breakdown of concepts into smaller units or subconcepts to make meaning and enhance understanding. This could have accounted for the very high mean posttest scores of the low achievers compared to their very lower achievement mean score in the pretest. Also the mapping activities could have encouraged and forced students into generation of a coherent organizational structure, a process common to more capable students. It is worthy of note that despite the fact that this was the first time the students were exposed to this type of teaching and for a limited period, the concept mapping students still performed significantly better than the guided discovery students. In effect, these results suggest that CMIS is an effective tool in teaching and learning in schools especially for our students who are becoming increasingly unable to cope with the study of science. The study by Schmid and Telaro (1990) indicated that concept mapping facilitated low ability learners' performance, but only on higher level relational knowledge.

3.3. CAN CONCEPT MAPPING INSTRUCTIONAL STRATEGY IMPROVE READING COMPREHENSION?

Many educators have commented on the importance of comprehending language of instruction. Language is without doubt the most important factor in the learning process, for the transfer of knowledge and skills is mediated through spoken or written word. It is observed that the failure or the success of the educational enterprise is heavily dependent upon how well students are able to read and comprehend language in instruction and instructional materials. The ability of students to read with understanding and participate fully during instruction may likely affect their understanding of the subject. Reading comprehension and activity oriented science emphasize the same intellectual skills and are both concerned with thinking process, the art of discovery, keenness of observation and imagination. When a teacher helps students to develop science processes, reading and comprehension are simultaneously being developed. Reading involves the ability to decode and decipher intelligently the graphic symbols of a given language. However, it is not enough to be able to read, but to read well with maximum understanding. Understanding fully what one reads leads to meaningful learning. Quinto (1979) stated that the problem of language use and comprehension militate against the effort of science educators in Nigeria. Quinto reported that over 90% of Nigerian secondary school chemistry students could not distinguish between the verbs heat and warm, words routinely used in chemistry laboratory classes. Students' understanding of science classroom vocabulary was studied, it was found that when they simplified the key words in questions substantially, greater number of students were able to comprehend and answer the questions correctly. For example, more students would answer the question "which of the following is a choking gas" than could answer "which of the following is a pungent gas". Ajewole (1991) attributed high failure rate of science students in SSCE to poor comprehension of science concepts.

Ezenwa (1993) investigated the linkage between student's reading comprehension and teaching strategies in the learning of some selected chemistry concepts. The objective was to determine if students reading comprehension would improve significantly when teaching was done using concept mapping and guided discovery strategy. The same 246 students in Niger State made up the sample for the study. The students were randomly assigned to two groups one taught with concept mapping strategy and the other with guided discovery strategy. The two groups were taught the concepts, "Acids, Bases and Salts". 50 item Reading Comprehension Test based on practical application of Acid, Bases and Salts was given to the students. Data analysed revealed that there was significant difference in the reading comprehension score ($t = 8.62$, $df = 121$, $P<0.05$). The concept mapping group with mean score of 54.39 demonstrated superior performance over the guided discovery group (mean = 34.72). This indicated that concept mapping strategy enabled the students to read and comprehend chemistry concepts more than the guided discovery strategy. Text cannot be comprehended unless the great majority of its sentences can be converted to propositions that are familiar or that can be related immediately to elements that are present in the memory. One important process that affects reading comprehension is the process of elaboration. Elaboration aids memory by providing additional routes of information retrieval and construction. Perhaps, the significant effect of concept mapping on reading comprehension was due to the concept mapping exercise which created relationships between important sets of concepts and linked the related concepts in a readable meaningful manner. The strategy, therefore, has a tremendous capacity for helping students comprehend what they read and learn.

The reading comprehension passage given to the students was based on acid victim in the school laboratory and the teachers' explanation of the concept "Acid, Bases and Salts" citing examples with ulcer patients, liming of soil and soil acidity. Three sample test items are given below.

Question 1: From the passage read, the best immediate aid to be given when acid pours on an individual is:

(a) to take him to the health center
(b) to clean the acid with laboratory coat
(c) to look for a teacher
(d) to pour a large amount of water on the affected part
(e) to pour some base on the affected area so as to neutralize the effect of the acid

Question 2: Doctors usually prescribe antacid for patients with stomach ulcer, the antacid is likely to contain mainly

(a) a form of acid
(b) a base
(c) an antibiotic
(d) analgesic
(e) sugar

Question 3: The acid soil is limed so as to:

(a) make most nutrients in the soil available to the crop
(b) neutralize the acid in the soil.
(c) increase the organic content of the soil
(d) decrease the base content of the soil
(e) reduce soil erosion

The popular wrong answers given by students were:

For question 1: e and a
For question 2: a and c
For question 3: d and e

Other examples from SSCE chemistry will give a clear indication of how a lack of reading comprehension affects students comprehension.

Question 1: State what would be observed if conc. HCl is added to an equilibrium system represented by the following equation.

$$CaCl_2(aq) + H_2C_2O_4(aq) \qquad CaC_2O_4(s) + 2HCl(aq)$$

Correct answer: The precipitate of CaC_2O_4 will dissolve

Popular wrong answer: The equilibrium position will shift to the right.

The question was on observable effect but the wrong answer was based on equilibrium shift which cannot be observed.

Question 2: Arrange the following compounds in their correct order of increasing boiling point.

(i) $CH_3CH_2CH_2CH_3$

(ii) CH_3COOH

(iii) $CH_3C(CH_3)H\,CH_3$

Correct Answer: $CH_3C(CH_3)HCH_3 < CH_3CH_2CH_2CH_3 < CH_3COOH$

Most Popular wrong answer: $CH_3COOH > CH_3CH_2CH_2CH_3 > CH_3C(CH_3)HCH_3$

The students understood that the compounds should be arranged but some failed to comprehend the difference between increasing and decreasing order.

Ezenwa (1993) established a strong linkage between concept mapping strategy and improved reading comprehension. Concept mapping strategy could be said to be a tool needed to improve students' reading comprehension. Therefore a seemingly fruitful way of bringing about comprehension of science concepts is through the use of concept mapping instructional strategy. By engaging in concept mapping, students would see that concepts do not exist in isolation, but depend on each other for meaning. When students struggle with unconnected ideas about complex events, the result is poor understanding of the event. Students in that case are incapable of seeing relations and hence incapable of comprehending what they read or learn. Perhaps this was the case with science concept learning in schools resulting in poor performance in test.

3.4. CAN CONCEPT MAPPING STRATEGY INFLUENCE STUDENTS ATTITUDE?

Attitude, interest, appreciation are terms used to describe what educators call the "affective domain". Actually, the development of attitude is a basic goal for science teaching and is no less important than cognitive goals. Attitude influences cognitive learning. The attitude an individual has influences his/her learning of science, and use of science information to a considerable degree (Ajewole, 1991). Students' reaction to a subject and teaching is influenced by their attitude to it. Attitude in this exposition refers to one's feeling, thought and predisposition to behave or respond in some particular manner to science, scientist and science activities. Attitudes are best expressed when individuals make statements about their feelings and opinions. Attitude research is important because important decisions which students make are strongly bound with their attitude. Literature has shown that students' attitude toward science seems to improve through the use of some instructional models or procedure. Study by Ezenwa (1995) has shown that learners evince a more positive attitude towards science learning through effective instruction.

Ezenwa (1995) studied the effect of exposure to concept mapping strategy and guided discovery on the attitude of students to chemistry learning. A 40 item Attitude Questionnaire was used for data collection. The instrument is a Likert-type questionnaire using four scales strongly agree (SA); agree (A); disagree (D); and strongly disagree (SD). The four options bore simple weights, 4, 3, 2, 1 respectively for positive items and the reverse for negative items. High scores represented favorable attitudes and low scores represented negative attitudes. The reliability coefficient of the test instrument was determined as 0.76 using split half technique. Data collected were analyzed using standard deviation and t-test. Findings revealed that exposure to concept mapping instruction positively and significantly enhanced students' attitude towards chemistry learning ($t = 5.61$, $P < 0.01$). Also, a correlation of attitude to chemistry and academic performance (through concept mapping instruction) revealed a significant correlation of 0.62.

3.5. CAN CONCEPT MAPPING STRATEGY ENHANCE STUDENTS REASONING ABILITY?

Reasoning is the conscious direction of thought process in orderly sequence to a logical conclusion. When a child has reached a stage where he is capable of reasoning by hypothesis, then his thinking makes use of concepts. Reasoning is often involved when concepts are formed. Reasoning ability is an important pre-requisite for concept learning.

A possible reason why students see some science topics as difficult could be that the method of instruction does not enhance reasoning. Novak (1990) showed that it is possible to advance the use of proportional reasoning of many secondary school students by means of a well designed teaching programme. The effect of concept mapping instructional strategy on the reasoning ability of students was investigated by Ezenwa and Otuka (1994). Chemistry concept (Chemical combination) was chosen for the study. This same 246 SS1 students from Niger State secondary schools formed the sample for the study. The instrument for data collection was a non-verbal reasoning ability test (with little or no cultural trait) consisting of 50 items. Each item had 5 options of which only one was correct. The result of the study showed that concept mapping group out-performed the group without concept mapping in the reasoning test ($t_{(121)} = 13.85$, $P < 0.05$). The higher reasoning ability exhibited by the concept mapping group seemed to be a direct carry-over experience from mapping exercises. Concept mapping requires students to think in multiple directions and to switch back and forth between different levels of abstraction. Students in the concept mapping group were seen to move a particular subconcept from one section of the map to another until appropriate location reflecting its correct position on the map was obtained. The whole exercise requires a great amount of reasoning before a meaningful map portraying correct linkages could be obtained. One can confidently say that reasoning by concept mapping instruction is one way by which students develop knowledge structure of unfamiliar concept. The finding of Ezenwa (1994) is an indicator that concept mapping strategy is a powerful tool that assists students learn how to think critically and creatively.

3.6 CAN HOME FACTORS PREDICT PERFORMANCE WHEN CONCEPT MAPPING STRATEGY IS USED?

A reasonable number of studies have been conducted over the years to evaluate the impact made by various factors including age, school, and home on school learning. This is because learning does not occur in a vacuum. Students' performance is affected by factors in the school as well as conditions in the home. The home and school are links through which school/child understands the world around him/her. Examination of the status of family factors in explaining variation in school achievement revealed that consumption occurring within a household and the size of the family influenced educational achievement. Accordingly a household within a given income is likely to spend more on food, the more mouths it has to feed and that family must, therefore, spend less on some other areas.

Ezenwa (1997) determined the independent and combined contribution of measure of home factor variables to prediction of students' performance in chemistry. The factors measured were parental status; parental involvement in the students' study and students' study routine. The instrument for data collection was 30 item Home factor questionnaire designed to obtain information about the home variables. The questionnaire was administered to only concept mapping group. The study provided evidence that performance could be predicted from only one home *factor variable parental involvement in students' study*. Also the three factors when taken together as gross indicators of home factor accounted for only 6.9% of the total variance in students performance ($R^2 = 0.069$ and $F = 2.95$). Correlation of variables revealed significant correlation at 0.01 level between parental involvement in students study and students' study routine. The observed correlation of parental involvement and study routine seems to stress the importance of parental involvement in the learning process of their children / wards. The result of the study provided evidence that performance of students is positively affected when parents show interest in students study. It is just not enough to pay school fees and be satisfied. Parents should see themselves as contributors to children's school success or failure and therefore should set their priorities right. Parental involvement is in the area of making available relevant books, opportunity for extra study and checking of schoolwork.

3.7 HOW CAN CONCEPT MAP BE USED FOR ASSESSMENT AND HOW EFFECTIVE IS THE ASSESSMENT?

Concept maps are used for assessment by scoring the propositions, hierarchy, cross-link and examples. Scoring criteria for concept maps are given below.

i) Propositions: Each meaningful, valid proposition shown, scores (one) 1 point.

ii) Hierarchy: Score of 5 points for each valid level of hierarchy.

iii) Cross Links: 10 points for each link that is both valid and significant and 3 points for each cross link that is valid but does not illustrate a synthesis between sets of related concepts or propositions.

iv) Examples: Valid specific events or objects score 1 point to a maximum of 10points. These examples are not circled because they are not concepts.

The use of this criteria revealed:

i) changes in students cognitive structure.

ii) that students who showed valid relationships between concepts learn meaningfully and performed well.

Iii) that students who constructed valid hierarchically organized concept maps scored highly.

iv) that many students did not have cross-link in their maps but mainly direct link. Cross-link is more related to higher cognitive tasks than direct link.

3.8 IDENTIFIED MISCONCEPTIONS IN SOME BIOLOGY, CHEMISTRY AND PHYSICS CONCEPTS

Students' misconceptions in many important and fundamental concepts in the sciences especially in biology, chemistry and physics were identified. A look at these misconceptions (as written by students) will give one the idea about the status of our students/ children's/wards' education and performance so that when they come from NECO and WAEC halls and tell you that the examination was good but eventually the result turns out bad, you will not be surprised. Samples of these misconceptions held by students are shown in tables 3.3; 3.4 and 3.5.

Table 3.3 : Types of Conceptions held by Students in Genetics.

S/N	CONCEPTS	SAMPLE OF MISCONCEPTIONS	
1.	MUTATION:	1	Mutation is the natural changes that occur in organism from one stage of development to another e.g. Egg -pupa - adult as in the life cycle of cockroach.
		2	The sudden change in sun
		3	The mutual association of two organisms.
		4	The organisms of different species.

S/N	CONCEPTS	SAMPLE OF MISCONCEPTIONS
2.	GENOTYPE:	1. A branch in biology that study genes in living organism. 2. The physical appearance in color eg. Mother is yellow, while some will be black. 3. The blood test you take to know your blood group. 4. Genetic transfer of characteristics form parent of a living organism to his offspring.
3.	HEREDITY:	5. They are infra rays from the sun 6. The act of giving birth to our younger ones. 7. This is a process whereby an organism gives challenge to a young or offspring. 8. The collection of property left behind from the late parent.

Table 3.4 : Types of Conceptions held by Students of Evolution

S/N	CONCEPTS	MISCONCEPTIONS
1.	COMPETITION	1 The Interaction of organism which both benefit from one another as no one is harmed. 2 The act of winning a right of opposite sex 3 The activities that had been carried out just to entertain people. 4 A process by which organisms find essential needs in a place.
2.	VARIATION	1. This is standard deviation. 2. This is the study of human structure and organs. 3. The same species that live in a particular place.
3	ISOLATION:	1. Elimination of organism e.g. birds, mosquitoes, wild animals. 2. This is the exposure of an organism in the sun ray or radiation. 3. The selection of genes to be dominant in character. 4. It is the spraying of insects with chemicals.

Table 3.5 : Identified Chemistry Misconceptions

S/N	CONCEPT	MISCONCEPTIONS
1	METALS	1. Man has been depending on metal since dawn civilization. 2. Metals are compounds which loss their electrons to become positively charge. 3. These are substance that has iron in them.

S/N	CONCEPT	MISCONCEPTIONS
2	**ATOMIC NUMBER**	1. The number of proton and neutron in the nucleus of an atom. 2. Element that has the same number of proton but different number of electron. 3. Is the amount of that element which is present in one gram of carbon 12.

Table: 3.6 Samples of Students' Misconceptions of Some Physics Concepts

S/N	CONCEPTS	MISCONCEPTIONS
1.	Force	1. Agent required to either move up or down an object 2. Rate of energy to change the position of an object 3. Rate of energy to change the state of uniform motion in a straight line 4. Agent inform of energy to vibrate.
2.	Energy	1. Rate of ability to do work. 2. Rate by which work is done in conjunction with time. 3. Power needed to perform specific work.

The above misconceptions speak for themselves. Parents should be interested in what their children know (the cognitive development of their children). It is not enough to pay school fees or JAMB fee for years because one can afford it while the child wastes away and comes back each time with poor result. We should develop the habit of helping our children by coaching them at least once a week for at least one hour. We are crying about armed robbery, examination malpractice, drug addiction, cultism etc, yet fail to realize that frustration can move children (youth) into such anti-social vices. These identified misconceptions are useful for teachers and curriculum developers to bear in mind particularly when it comes to planning and teaching specific topics.

Giving the benefits of concept mapping instructional strategy and its overwhelming evidence from research work, it would appear that the most effective way of raising the standard of performance is through the use of concept mapping strategy. This strategy progressively integrates, reconciles and connects concepts while at the same time, it provides students with a background skill and understanding critical to success in science. It could be asserted that if meaningful learning is made to prevail in science classes, improved performance would be assured. Perhaps, the problem students had, were that they struggled with unconnected ideas about complex events. It could well also be that students were presented with concepts in isolation and were expected to learn them in a given sequence unconnected to students' own imagery, especially when the ideas were not linked and conflicting ideas not resolved. This puts on the students the burden of memorization which comes from acquiring information without structure. Under this atmosphere, the student will be incapable of flexible and critical thinking and this is reflected in poor performance especially when in-depth rather than rote knowledge is tested. This might well be the case with our students and our method of instruction. However, concept mapping strategy has the desired effect of getting students to think creatively.

4.0 FUTURE DIRECTIVES IN EDUCATION

There is currently a transformation of curriculum from a traditional discipline- based approach to an integrated body system teaching program incorporating elements of problem based learning, multimedia, information technology and education unit. The overarching goal is to produce graduates who are independent, life long learners. Some of the problems that fueled the new curriculum transformation were: insufficient integration between basic and other services; insufficient attention to communication skills, and problem solving skills, overhead of details and unnecessary duplication of content. The pedagogical model for the new approach incorporates elements of problem based learning. The use of Information Technology (IT) will be an important feature of the new curriculum. Computers are very necessary for every individual, especially lecturers and departments in the university to access internet and soft wares. Students could access assignments, some educational details, notes, references and announcements via the computer . As such computer based learning will complement but not replace traditional mode of learning. Multimedia as learning resources will be used extensively in areas that students traditionally had difficulty understanding, or in areas where the use of media, such as video, audio or animation is particularly appropriate to demonstrate a concept. It is likely that audio-visual laboratories will be expanded in many institutions to include many modern media educational gadgets. In that case, concepts that have traditionally caused student's difficulty are areas that are likely to benefit from the change. Such resource such as website and multimedia can be accessed by students from departmental computer laboratory or multimedia center. In addition, a number of different teaching strategies will be utilized for the new approach including concept mapping.

The Faculty of Education unit of Melbourne University, Australia worked directly with clinicians and academics to try the new approach. The methods used for meaningful and purposeful learning included concept mapping, scaffolding, practicals, demonstration and problem solving. This innovation according to Keppel, Elliot and Harris (1998) enhanced learning of medical concepts. Developed countries attach a great deal of importance to curriculum issues especially the areas of teaching and learning. We are quite familiar with the situation in Japan and US, when the then Soviet Union launched the first satellite before US. America felt something was wrong with their education system and came out with a strategy which Japan copied and allowed to crystallize within their cultural setting. Today, Japan is leading in many areas of technology. **Of course curriculum development**

is better left in the hands of educationists who can use their expertise in curriculum development and processes to advise or guide the various stages of the development programme or indeed in any educational planning system.

5.0 SUMMARY

Educators share the goal of generating knowledge in their students. Knowledge is not a transferable commodity but a generative organization of concepts. Educators have become increasingly familiar with lack of basic learning skills and study habits needed for success by students. This situation moved educators to seek better ways of organizing learning to promote students' meaningful learning. The emergent epistemology, (constructivism), in science education with psychological foundation on meaningful learning was found to be effective for developing students cognitive strategy for meaningful learning. The premise behind the constructivist view is that knowledge is actively constructed by the learner on the ground of constructs already available to him. The metacognitive strategy, concept mapping, within the constructivist framework has become widely accepted as a potent and veritable tool in science education for meaningful learning. Concept is defined as a regularity in events or objects designated by some label. People think with concepts. Concepts are not learned in isolation, they must be put on conceptual network. Concept maps represent what students know and how they organize their knowledge. Changes in students' cognitive structures are reflected in the concept maps they draw. Concept mapping is structured by including main concepts at the top of the map and specified into several specific concepts hierarchically. The degree of differentiation among concepts is indicated by the branching of the concept map. Lines connecting the concepts indicate relationship between concepts and cross-links. This strategy when used in the classroom for instruction is referred to as concept mapping instructional strategy.

Concept mapping is student centered for meaningful learning. The quest for the efficacy of concept mapping strategy in bringing about meaningful learning and enhanced achievement in science was discussed in different perspectives. Students who showed evidence of meaningful learning tend to construct best hierarchically organized concept maps. This was found to be true with biology, chemistry and physics students. Concept map reveals quality and quantity of concept propositional networks held by students before and after instruction. It helps students take charge of their own meaning making. Concept mapping as an instruction strategy has also been shown as a useful tool for making students of different abilities especially the lower achievers learn meaningfully. Concept mapping strategy has also proven to be useful and effective for both cognitive and affective gains. Research results support the efficiency of using concept mapping strategy as a veritable tool in the science classroom for enhancing meaningful learning, reasoning ability, long term retention of knowledge, enhanced attitude and reading comprehension, identification of misconception and for any gender. All research results presented positive effects on students' learning using concept mapping. Findings on the use of concept mapping in the past decade or two in

Nigeria and overseas, in different science subjects with various difficult science concepts (topics) in public schools and university environment using secondary and university students have converged in supporting that the strategy is potent in bringing about meaningful learning and improved performance. It is clear that concept mapping plays central role in students achievement for meaningful learning. An interesting thing about concept mapping is that studies were carried out in public schools in Nigeria where facilities were minimal and students-teacher ratio high and the study was for a limited period, yet the results continue to be promising. Concept mapping strategy can therefore be said to be a very powerful tool for promoting students' meaningful learning.

6.0 CONCLUSION

Mr. Vice Chancellor, distinguished ladies and gentlemen, in the course of my lecture, I have taken you through landmark events of my involvement in concept mapping strategy through research work. The message of this lecture is that concept mapping instructional strategy is a veritable tool in science education. I considered the topic most relevant and appropriate at this period when students are becoming increasingly unable to cope with fundamental science concepts. A concept map is an educational tool that shows connections and relations between concepts, helps students form a correct system of concepts, a necessary basis for understanding and usage of knowledge. It helps students to analyze a problem from different angles, to develop a divergent way of thinking, to develop and enlarge their network of knowledge as well as their ability to make use of it. It attends to both what students know and how they organize their knowledge. It is seen to have contributed so far to the solution of the problems facing meaningful learning of scientific concepts and ineffective teaching. During the 15years, that I researched in this area, I used concept mapping with secondary school students and few undergraduate students to teach chemistry and science education courses., I continue to be impressed by the potential of this metacognitive tool in improving learning and teaching. Indeed, research results on concept mapping strategy demonstrate that meaningful learning results from its use. The remarkable efficiency of the strategy in enhancing learning, improving retention, reasoning, attitude and reading comprehension amongst others in the basic areas of science has been widely reported. Concept mapping in this lecture has also been shown to aid planning of lesson and improve quality education. Quality education is a pre-requisite for development and a crucial part of this is the presence of well-trained teachers.

Vice Chancellor, Sir, quality improvement in teaching must be deemed our priority to move this nation forward. If this nation is to adopt educational curriculum practices that encourage meaningful learning, then concept mapping instructional strategy is the tool. I am well aware that ideas that challenge current practices and call for re-orientation from what has been, often met with resistance of all sort. The good news is that concept mapping instructional strategy has the ability to raise the quality of learning with little extra effort or resources cost to the instructional system. Curriculum change is slow except a revolution speeds it up. The utilization of concept mapping instructional strategy is gradual but it is likely that it will become widely used metacognitive tool for learning in the near future.

Having had these experiences, I have come to the conclusion that concept mapping instructional strategy is a potent and veritable tool in science education. Mr. Vice Chancellor, Sir, I submit that, to produce students who are qualitatively better learners and who can acquire and retain significantly more concepts and be ready for the challenges of the new century and modern age, concept mapping instructional strategy is the key and an important determinant of students' achievement. Then we can look forward with confidence to a new era of education, understanding and performance as our future leaders map their way to success.

7.0 RECOMMENDATIONS

The following recommendations are made:

1. Concept mapping strategy be adopted in the national curriculum.
2. Practicing teachers should explore the use of this strategy in teaching.
3. Students can only find satisfaction in learning by becoming aware of the neatness of fit they have achieved in their own conceptual construction.
4. Using concept mapping requires cognitive skill, university students can apply this to their learning and even utilize it as a study strategy.
5. Concept maps presented by teachers using projectors give powerful effect on learning and also remove misconceptions. Educators and teachers should have interest in developing appropriate concept map which can aid students' learning. Schools are encouraged to tryout this strategy in their various subject areas.
6. Teachers need to direct students to talk about their ideas and what they currently know about a topic before instruction. These ideas form good starting point for the teacher.
7. Publishers, authors and educators must develop textbooks which can help students to organize new concepts.
8. Parents, teachers and librarians should select books with much elaboration and without misconceptions.
9. Parents should be involved in their children's learning by assisting them and buying the relevant materials.
10. There is the need to promote and raise the level of teaching even at the university level. Pedagogical training is important for newly employed lecturers and pedagogical training course for experienced lecturers.
11. Merit awards at all school levels be instituted in recognition of exemplary teachers to motivate teachers to strive towards excellence.

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our Lord and saviour Jesus Christ for sparing my life and giving me good health to witness this wonderful, historic day.
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I most heartily acknowledge the presence of everyone here present. I acknowledge my fellow professors present here to felicitate with me and my family.

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Now to the King eternal, immortal, invisible, to God who alone is wise, be honour and glory forever and ever. Amen. (1 Timothy 1:17).

Mr. Vice-Chancellor, Sir, Distinguished audience, I thank you all for your attention and God bless us all.

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