RIVERS STATE UNIVERSITY, PORT HARCOURT

EXPLOITING MISCONCEPTIONS TOWARDS OPTIMUM TEACHING AND LEARNING

AN INAUGURAL LECTURE
By

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EXPLOITING MISCONCEPTIONS TOWARDS OPTIMUM TEACHING AND LEARNING

DEDICATION

This Lecture is dedicated to the
wonderful family the Lord has blessed me with
- My Husband, our six children their spouses
and our grandchildren.

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The Vice Chancellor,

Deputy Vice Chancellor,

The Registrar and other Principal officers of the University,

Provost, College of Health Sciences,

Deans of Faculties,

Professors, Directors of Institutes and Heads of Departments,

Distinguished Ladies and Gentlemen**.**

INTRODUCTION

It is a delight to have this opportunity to give an Inaugural Lecture. It is indeed an honour for which I am very grateful to God. I have always admired the prowess with which other colleagues deliver their Inaugural Lectures and I believed my day for this great academic exercise will come and by the grace of God today is the day. I must say that I find academic exercise very intriguing and fulfilling. At this juncture, I would like to say a big thank you to our amiable and fatherly Vice Chancellor, Professor Blessing Didia for the encouragement and awareness he continues to give to Professors about Inaugural Lectures and the need to "let the World know what they are professing about". It is indeed a worthy exercise that marks the erudition of an academic. I will also commend Professor I. K. E.

Ekweozor, the Chairman of the Senate Lectures Committee for his patience and serious commitment in coordinating the Inaugural Lectures.

Today's Lecture aims at giving us an understanding about how people learn and the products of teacher-learner interactions as it pertains to science teaching and learning. One major product of teacher-learner interaction is MISCONCEPTION. The main focus of this Lecture is how professional teachers can exploit or take advantage of students' misconceptions towards optimum teaching and learning. Students' misconceptions are seen here as their personal understandings which differ from universally accepted scientific knowledge.

Some contemporary philosophical stances, relativism for example, recognize the role of personal and social construction in the development of scientific knowledge. However, the teaching of science is yet to fully acknowledge these perspectives. Albert Einstein's (1905) theory of relativity, in Jenkin's (1979) view made a significant contribution towards a change in the conception of scientific knowledge and its relationship to “truth”, so also does Erwin Schrodinger's (1958) view which he expressed as follows:“…every man's world picture is and remains a construct of his mind and cannot be proved to have any other existence”(p. 41).

This Lecture will draw its essence from the Constructivist theory which is philosophically relativist and therefore sees knowledge as a construction rather than ontological reality.

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EXPLOITING MISCONCEPTIONS TOWARDS OPTIMUM TEACHING AND LEARNING

THE TEACHER AND LEARNING

The process of moving students from their initial state of knowledge and understanding to the desired optimum level of learning has been the focus of the teaching profession worldwide. Teaching has been described as the most immediate process for supporting learner-centered and context-based learning and for enabling learners acquire expected competencies UNESCO (2017), For a broader and more engaging description of expected competences, learning is assumed to have occurred when the learner has acquired certain stated knowledge, understanding, values and skills to cognitively and physically apply knowledge, analyze and synthesize ideas, evaluate, create or modify knowledge (Alamina, 2008). Individuals learn differently therefore the use of appropriate teaching methods, strategies, information communication technology in Education, is critical for optimum teaching and learning.

The United Nations Educational Social and Cultural Organization's global watch on achieving the 2030 Agenda for Sustainable Development for Education is focusing on teachers as 'the single most influential force to bring about equity, access and quality in education' (UNESCO, 2017). The teachers that are meant to bring about this, need to be professional teachers with adequate and proper background in content and pedagogy. Students' experiences differ, therefore, teaching contents should align with students' profile. In other words, teaching and learning need to be diagnostic (UNESCO, 2017). It is therefore very obvious that there is a serious disconnect in teaching without a background in pedagogy.

SCIENCE TEACHING AND PEDAGOGY

Science teaching is a department that trains science educators and science education is a field of study that focuses on applying pedagogical skills in preparing science teachers for school science teaching. The Science Educator is equipped with philosophical, psychological, sociological as well as historical knowledge about how learning takes place and application of these in formal teaching of science subjects for the development in the learner, various science process skills, cognitive, psychomotor and affective skills. A science educator is trained in a given area of science. This Inaugural Lecturer is a Science Educator trained in the field of Chemistry.

Chemistry is a science discipline that studies matter, its compositions, properties, structures, the interactions matter undergoes and the energy changes associated with the various types of bond making and breaking (- ionic, covalent, hydrogen and Van der Waals force bonds) involving fundamental particles of atoms and molecules. These interactions result in formation of new substances.

Pedagogy deals with the methods and activities of teaching, it has to do with the theory and practice of teaching. Pedagogy informs teacher actions, teaching strategies, teacher judgments and decisions as the teacher relates to students' profiles. Pedagogy takes into consideration theories of learning, understanding of students' backgrounds and individual needs. Pedagogy aims at the general development of human potential, creating avenues for acquisition of higher level cognitive skills as well as other general skills.

Teaching without pedagogy is yet another issue plaguing the teaching profession. Lecturing is the predominant method of teaching and it is not designed for development of higher level cognitive skills and other general skills in the learner especially for sustainable development purposes.

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The major theories of learning, behaviorism, cognitivism and constructivism have had what one could refer to as partial integrative build up, while maintaining their uniquely identifiable characteristics. Behaviorists ideas on learning involves a process of transmission of information from teacher to learner and is essentially the transmission of the appropriate certain stimulus along with positive reinforcement, to avoid learned responses from quickly becoming extinct.(Online Teaching Resource Centre)

Cognitivists view learning as involving the acquisition or reorganization of the cognitive structures through which humans process and store information. Cognitivist learning is concerned with the internal mental processes of the mind and how they could be utilized in promoting effective learning.

Constructivists views and, indeed, much of cognitive psychology, see the individual as responsible for acquiring his/her knowledge. They see knowledge construction as inherent in the individual, and support the idea that from infancy, the individual is physically and mentally active. Much as knowledge construction is inherent, what is constructed depends ultimately on the individual's cognitive structure. (Driver, 1988; Von Glaserfeld, E. 1991)

The practice of teaching relies heavily on these theories. This Lecture will rely heavily on the Constructivist Theory as it relates to science teaching and learning. Teaching is an interactive and holistic process. Good teaching may start off with a motivating and an exciting beginning, a versatile main body which involves various methods and strategies and finally a fruitful ending that can be evaluated.

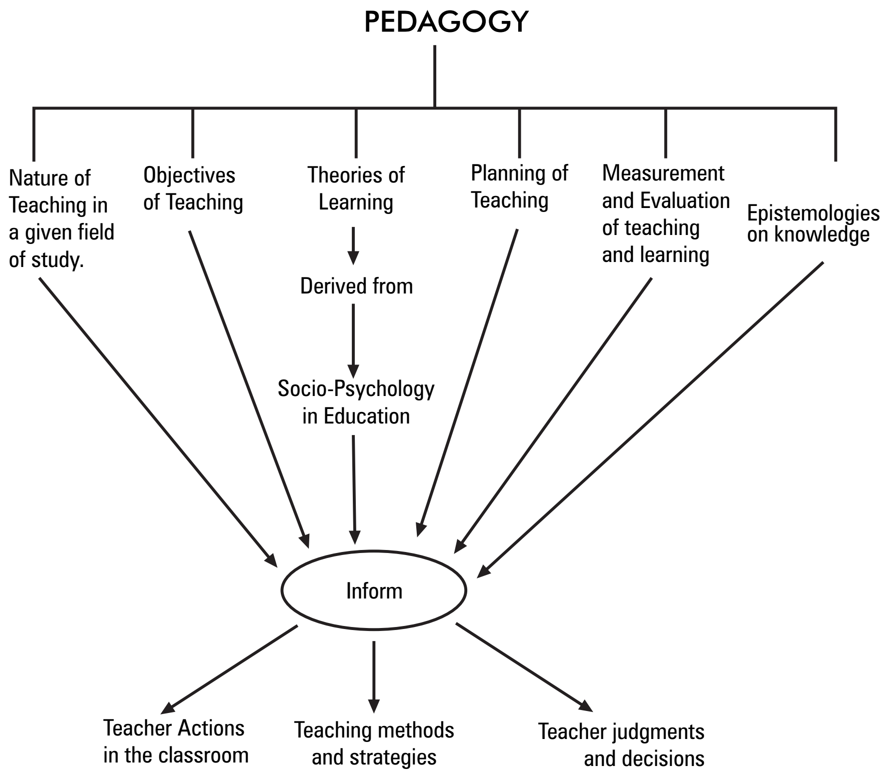

Figure 1: A Schematic representation of what Pedagogy involves.

Contemporary Science teaching focuses on development of cognitive, affective and psychomotor skills as well as development of sustainable science process skills in the learners, to enable them become future science educators and future scientists. Below is a revised version of the Bloom's Taxonomy of the **cognitive domain skills,** hierarchically arranged from the lowest skill of remembering to the highest skill of creating. See also the Affective and Psychomotor Domain skills:

I equally appreciate Mrs Nkoli Awa, Mr. & Mrs. E. Nnebedum, Engr. & Mrs. Iyke Nwokoye & family, Mr Emma Orih & family, Pst.& Mrs Eddie Osakwe, Mr. & Mrs P Omuku, Pst. Kodjo Lekettey& family, Mr. Mensah Lekettey, Mr. & Mrs. Washington Ejims, My Uncles Mr. Augustus Omuku and his famiy, Rev. and Mrs T. Omuku, Mr. Ibie Soberekon & family. My big brother-in-law and wife, Sir. & Lady Ben Alamina and family, Mrs Matty Taribo and family, Mrs Violet Alali and family, Ven. A. Omubo, Mr. & Mrs S. Victor, Mr. T. Opuogulaya,, Mr. I. Emeya, Ms A. Omubo.Arch. Idua Jamabo, Rev.& Mrs Fred. Jamabo & family.Mrs. Paty Lekettey. I acknowledge and appreciate the following- Chief & Mrs. Iyerefaka Omubo-Ichi-Owu and Chief, Prof.& Mrs. Rollings S. Jamabo-Owu , Chief, & (Mrs.) Tamunoimama M. Okolobo, Chief, & Mrs. A Jamabo Ikulele, Mr. I. RobertsRev. and Justice (Mrs.) Iyke Oji, Miss Opekere Fubara, Mr. & Mrs Izu Okaka, Mrs U. E. Osigbo, Mr. & Mrs. Peterside, Mr. & Mrs Ik. Aguma, Mr. Solomon Fubara, Past. Amabere Jamabo, Mr. & Mrs E Wakama, Mrs F. Davies, Mrs. C.A. Chuku, I also acknowledge my Aunties Madam Gloria Dakoru and Mrs Eugenia E. Omubo. The members of the Ichi and Kalabulome families are very well appreciated.

My special gratitude goes to the wonderful family the Lord blessed me with, my Darling husband, Dr. P.T. Alamina who has been a great encourager all through my career and the periods I had to travel outside the country for one academic exercise or the other, our wonderful children with their great spouses and our glorious grandchildren. I cannot thank God enough for such a great and peaceful home. It is simply the Lords doing bringing me to this height of honour.

Above all, I greatly appreciate the Lord for the great and mighty things He does in the lives of His children. I return all the glory to Him who has done it all.

Park, Engr & Mrs W. Jaja, Mr. & Arch. Onugha, Engr. & Mrs T. Luke Sir, & Lady Iwuchukwu, Mr. & Mrs A. Timon, Dr. & Chf. Mag. T. Ibanibo, Mr.& Mrs. Dino MacHarry, Mr &.Mrs Atoju, Mr. & Prof. (Mrs) O Tawari, Barr M. Izzi, Mrs Akinwole, Mrs A. Anuku, Mrs. L Akparanta, Mrs. Membre, Dr. E. Sir & Lady I.. Masi, Dr (Mrs) A. Nwonuala, Dr (Mrs) N. Kalu-uche, Lady. Dr. J. C. Obunwo, Lady Dr, Gladys Ogan, Dr.(Mrs) M. Adaramola, Dr. (Mrs) C. Oladayo, Dr.S. E. Ojoko, Mr. D. Etokoren , Dr Jeremiah Samuel, Dr. D Ojimba, Dr. Justin Gabriel, Mr. Sunday Soberekon, Mr Believe Nwamae. Special thanks go to a host of other friends in my Church, Christ Church Port Harcourt. If I start mentioning all the names, the acknowledgement pages will be longer than the lecture pages. Permit me to use group names. I greatly appreciate the Elders in Christ Church represented by Sir, S. J. S Toby, the Men's League represented by Arch. Duboye Douglas, the Women's League represented by Dr.Lucrecia Baber, the group 5 (Green) women represented by Mrs. Rose Biambo, the prayer team represented by Elder, Barr. Cookey-Gam, the evangelism and missions group, represented by Dr.(Mrs) Chinyere Uwaga, The Sunday school teachers represented by Elder, Prof. C. M. Ekweozor, the youth fellowship represented by Mr. Precious Uzoma, the Choir, represented by Mr. J. Wilcox and all my children in the Lord.

I equally appreciate my students both Post Graduate and Under Graduate, especially those of them who I supervised their thesis and are today a pride to the Faculty as they continue to make useful contributions to knowledge and the society at large. It is difficult to list all the names. The Lord will continue to plant your feet on higher grounds as you look up to Him.

I also specially thank my siblings, The Lord Bishop of Southern Sudan, Rt. Rev. Precious S. Omuku and his wife Lady Jane Omuku, Deaconess, (Mrs) Victoria T Jamabo (the Registrar of the University) and her Husband Barr Sodieye Jamabo, Barr.Emmanuel Omuku and his wife Sarah, Pst, Mrs. Boma Alamina and her husband Mr. Mitchell Alamina with their lovely families.

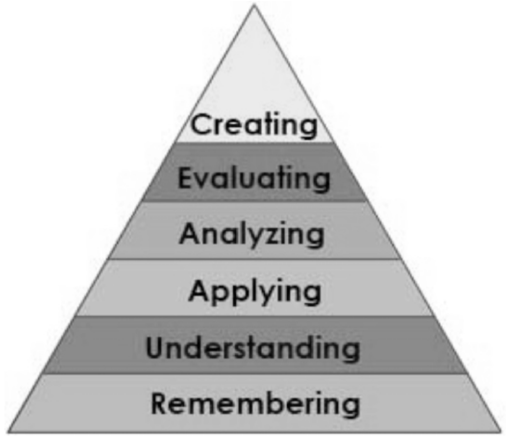

Figure 2. Bloom's Cognitive Domain Skills (Revised by Anderson, et al.(2001)

(1) Cognitive Skills **Action Verbs**

Remembering can the student recall, retrieve or remember learned materials?	define, memorize, recall, reproduce state, duplicate, list, repeat,
Understanding: can the student explain or summarize information, ideas or concepts?	Discuss, explain, identify, locate, recognize, describe, report, select, classify translate, paraphrase
Applying: can the student use what has been learned in a new way or a new situation or to extend knowledge?	Choose, interpret, operate, schedule, sketch, solve, use, write. demonstrate, dramatize, employ, illustrate,
Analyzing: can the students separate concepts into their component parts and distinguish between the different parts?	Appraise, contrast, criticize, differentiate, distinguish, examine, experiment, compare, discriminate, question, test.
Evaluating: can the student justify ideas and make value judgments' or decisions?	defend, judge, select, appraise, argue, support, value, evaluate
Creating: can the student design and construct original ideas or new products, new pattern or put parts together to form a whole?	Construct, assemble, develop, formulate, write create, design.

(2) Affective Domain skills

are the following and are concerned with the development of interests, values, attitudes and emotions. It also follows a hierarchy from simple to complex as shown below

(a) ***Receiving:*** becoming aware of a phenomenon sensorily

(b) ***Responding:*** possibly admiring and deciding to do something about the phenomenon.

(c) ***Valuing:*** placing worth on the phenomenon

(d) ***Organization:*** becoming very conscious about and getting involved with the organization of the phenomenon

(e) ***Characterization:*** Internalize the process of involvement such that it becomes part of ones life system.

AFFECTIVE SKILLS	ACTION VERBS
Receiving: becoming aware of a phenomenon sensorily. Becoming sensitive to the existence of a given condition, event, situation, problem	Asks, chooses, describes, follows, gives, holds, locates, points to, relies, uses
Responding: possibly admiring and deciding to do something about the phenomenon. Active participation.	Answers, assists, complies, conforms, greets, performs, practices, presents, recites, reports
Valuing: placing worth on the phenomenon	Completes, explains, initiates, invites, joins, justifies, proposes, shares, studies
Organization: becoming very conscious about and getting involved with the organization of the phenomenon	Adheres, alters, arranges, defends, generalizes, integrates, orders, prepares, relates
Characterization: Internalize the process of involvement such that it becomes part of one's life system	Acts, discriminates, displays, influences, modifies, proposes, qualifies, questions, revises, serves, solves, verifies

EXPLOITING MISCONCEPTIONS TOWARDS OPTIMUM TEACHING AND LEARNING

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(3) Psychomotor Domain Skill

are mental and motor skills with the three steps listed below.

(1) ***Observing:*** You observe a process e.g. table tennis playing.

(2) ***Imitate*** the observed behavior to develop basic skills

(3) ***Practice*** to perfect and to establish acquired skills.

PSYCHOMOTOR SKILLS	EXAMPLES
Reflex movements: Learning in response to some stimuli	Flexion, extension, stretch, postural adjustment
Basic fundamental movement: Movement patterns formed by combining of reflex	Pushing, pulling, manipulating. Follow instructions as demonstrated
Perceptual abilities: interpretation of various stimuli that enables one to make adjustment to the environment	Coordinated movement such as jumping rope, punting or catching. Select, isolate, detect, choose, describe
Physical abilities: embrace endurance, strength, flexibility and agility	Quick and precise movements: calibrate, grind, heat, fix, mix, construct, fasten
Skilled movements: acquisition of a degree of efficiency when performing a complex task	Writing and drawing, drumming, typing, playing the organ/piano. Build, assemble
Non-discursive communication: communicating through bodily movements, facial expressions	Choreography, creative facial expressions in acting a part. Create, combine, compose

Scientists through observations and experiments actively and confidently interact with their environments, constructing or creating new knowledge from ordered data, reviewing old knowledge in the light of emerging facts, formulating hypotheses and testing them, formulating theories, principles and laws which are useful in understanding the world around us. The knowledge obtained from doing science provide solutions to scientific problems, answer questions or raise new questions.

'Young scientists to be' who are in secondary schools need to be equally involved in active learning processes. This is where science education comes in to make sure that these 'young scientists to be' acquire the content which are various logically related basic facts that are associated with a given subject matter, to enhance concept formation. The teacher's job should be mostly that of a facilitator and a guide to the learner's construction of knowledge. The learners require from the teachers, carefully selected knowledge examples, illustrations, analogies, demonstrations, good literature materials and conducive, safe, learning environment in the course of their doing science. Rote learning is not conducive for appropriate concept formation and development of sustainable skills. The young learners need to be regularly exposed to activities that will enable development of science process skills which are as follows:

(1) Observing
(2) Classifying
(3) Raising questions
(4) Predicting
(5) Formulating hypothesis
(6) Experimenting
(7) Measuring
(8) Interpreting data
(9) Inferring
(10) Manipulating objects
(11) Communicating
(12) Controlling variables
(13) Defining variables operationally
(14) Formulating models

EXPLOITING MISCONCEPTIONS TOWARDS OPTIMUM TEACHING AND LEARNING

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CONCLUSION

This lecture has focused mostly on the problem of misconceptions, what generates them, and how to exploit them for optimum teaching and learning. The Lecture has simply brought to the limelight the fact that as a professional teacher, you must focus on the products of learning as you interact with your students. You must be diagnostic in your approach to facilitate learning. Where there is misconception, it is your duty as the teacher to exploit it towards optimum teaching on your part and optimum learning on the part of the student. The strategies that take into consideration students' misconceptions have been provided. These strategies will enable the teacher develop in the learner higher level cognitive skills of understanding, applying, synthesizing, analyzing, evaluating and creating as well as other related educational skills These instructional strategies are designed to be activity oriented encouraging learner involvement, giving students the opportunity to find ways to deal with problems; thus developing their abilities and inclination to organize and coordinate information, make inferences and discover strategies for solving problems independently. This is where provision of resources for science activities becomes very crucial. Improvement of the state of science education in this Country should be a priority. The government needs to pay a close attention to the suggested solutions to the problems of Science Education in Nigeria pointed out earlier in the delivery of this Lecture. If the teacher does not play his or her part and the Government does not address squarely the quality of Education in this Country, the gap we are creating between our young children's education and that of the technologically civilized World who have adopted these constructivist strategies for 21st century teaching and learning will be very difficult to close up.

Doing Science involves cognitive or mental restructuring or reorganization of science substructures, consistent application of science process skills, cognitive skills, affective and psychomotor skills through well planned objectives-directed science lessons that have to be evaluated using items drawn up from a table of specification. Such activities lead to development and establishment of a variety of problem solving competences and skills in the young learner (Alamina, 1987).

A number of factors that affect cognitive development have contributed to the inability of most individuals to do science in the real sense of it. Even the few individuals that seem to have a good cognitive development through their developmental stages (from infancy through adulthood) and hence have good cognitive potentials, still need stimulating and challenging academic environment for continuous development and establishment of a variety of higher level cognitive and other related skills. There is therefore every need to adequately develop human resource in this direction.

THE STATE OF SCIENCE EDUCATION IN NIGERIA

The question now is, how can students effectively do science, acquire science substructures that will enable breeding of better cognitively developed and highly skilled professional teachers, scientist and technologists in this Country? In an attempt to answer this question, it is necessary to equally find out the state of Science Education in Nigeria.

A clearer picture of the state of Science Education in Nigeria has been revealed by the following authors (Soyinbo, 1986; Alamina, 1992; Eniayeju, P. A. &Eniayeju, A.A.2004; Adenike 2007; Omorogbe and Ewansiha 2013; Daworiye, Alagoa and Enaregha

2015; Achimugha 2016). They identified a number **of** factors militating against teaching and learning science in Nigeria. Some of the factors are listed below as non-availability of adequately equipped science laboratories for practicals.

- out dated and poor state of science equipment in science laboratories.
- Lack of laboratory assistants and lack of computer laboratories and information communication technology assistants.
- lack of familiarity by science teachers with the demands of contemporary developments in science education.
- insufficient time allocated to science teaching and learning.
- lack of suitable and current text books.
- Unavailability of suitable instructional and learning materials
- Inadequate utilization of available instructional materials
- Large class population.
- Unconducive learning/classroom environment
- lack of professionally qualified and experienced teachers
- poor teaching methods.
- lack of devotion to duty by teachers.
- Inadequate (in-service) professional development of science teachers
- lack of devotion to study by students.

EXPLOITING MISCONCEPTIONS TOWARDS OPTIMUM TEACHING AND LEARNING

Alamina, J.I & Adolphus, T. (2004).;Alamina J.I (2006);Alamina, J.(2006);

Alamina, J.I. (2006) ;Alamina, J.I & Ojoko, S. E (2006).;

Alamina, J.I. & Ukwa, N.(2007); Alamina, J.I. & Adaramola, M. O. (2007);

Alamina, J. I. & Oladayo, E. C. (2009); Kalu-Uche, N. & Alamina, J.I. (2014)

It is necessary that students understand with the aid of the teaching activities, the meaning of the words "react" in the context of a chemical reaction and "bonding"- ionic, covalent etc.(attractive forces between or among fundamental particles) in its various contexts for the secondary school chemistry level".

The Vice Chancellor Sir, this holistic approach is a constructivist strategy which enables the establishment of broad-based cognitive structures that enhances the generalization of inter-relationship of concepts by the learners. Such a holistic approach to the presentation of learning material does not disregard the conventional perception of concept development as a gradual occurrence. What is very relevant here is a regular presentation of conceptual relationships in a given learning area, that is i.e the explication of a concept map. Such a map would enhance the coordination of learned material by those students who might not otherwise be able to establish the conceptual relationship on their own. This concept mapping is aimed at preventing as well as correcting the misconception of the particulate matter, Chemical reaction and the substance phase - relationship.

Other related researches carried out on Constructivist theory, Instructional strategies and students conceptions by this Lecturer are as follows:

Adaramola, M. O. & Alamina, J. I. (2007); Adolphus, T, Alamina, J. &

Aderonmu, T. ; Alamina, J.I. (1993); Alamina, J.I. (1993) ; Alamina, J. I. (1994);

Alamina, J.I. (1994); Alamina, J.I. (1995); Alamina, J.I. (1998); Alamina, J. I (1998);

Alamina, J.I. (1998) ; Alamina, J.I. (2000) ;

- conceptions exhibited by students and teachers as well as those found in textbooks are not taken into consideration in the cause of teaching and learning.
- Inadequate supervision and poor management of schools.

Suggested Solutions to the Problems of Science Education in Nigeria.

In an attempt to solve the problem of Science Education in Nigeria, the following crucial questions need be seriously considered by stake holders in Education What is the purpose of education in Nigeria? Is that purpose being achieved with the current state of Science Education in Nigeria? Are teachers trained, recruited and regulated for quality delivery in our schools? What is governments' commitment to quality education? While we try to answer these questions the following are some suggested solutions to the listed problems of Science Education .

1. There is need for 'training the trainers'. A well planned and organized in-service training for teachers at scheduled times will be necessary for updating the teachers in 21st century methods and strategies for holistic science teaching and learning.
2. The appropriate Subject matter specialists and curriculum committee need to ascertain from research findings the suitability of the content of textbooks for the given age and level of learners. Also adequacy of the allotted time for teaching topics needs to be determined.
3. The teacher-student ratio of 1 to 30 should be maintained.

4. Appropriate teaching methods and strategies should be used.
5. The use of information communication technology in Education (ICT), are critical for optimum teaching and learning.
6. Teachers need to be trained in pedagogy and appropriate use of technology (ICT) in teaching.
7. Increase in teachers' welfare package will be necessary to motivate the teachers.
8. Students need to be motivated via proper counseling and good teacher presentation of materials.
9. Every Laboratory should have a trained laboratory technologist.
10. Proper attention should be given to misconceptions in students' and teachers' understandings as well as the text books. An adequately trained teacher in content and pedagogy should be able to identify students' misconceptions and build them into his or her teaching with the aim of correcting the misconceptions using appropriate teaching strategies.
11. Textbook writers should take into cognizance the findings of research and incorporate them appropriately into their textbooks.
12. Governments at both the Federal and State levels need to take the management of schools very seriously. For education to be what it is meant to be, half bread is as bad as nothing in today's highly scientific and technological World. We can have good plans and policies on paper but if they are not implemented appropriately and

This will give the students a clearer idea of how a single molecule relates to the phase as a whole. Students are capable of stretching their imaginations and would place the particles in their proper context in relation to the substance as a whole if they are taught appropriately.

HOLISTIC APPROACH TO SCIENCE TEACHING

Furthermore, when presenting materials to students, a holistic approach which involves a schematic representation of interrelated concepts students have been exposed to, is advocated. This may be done at intervals during the teaching sequence and at the end of the teaching sequence.

Below is an example depicting at a glance, the relationship between the particles, chemical reaction and substance phase.

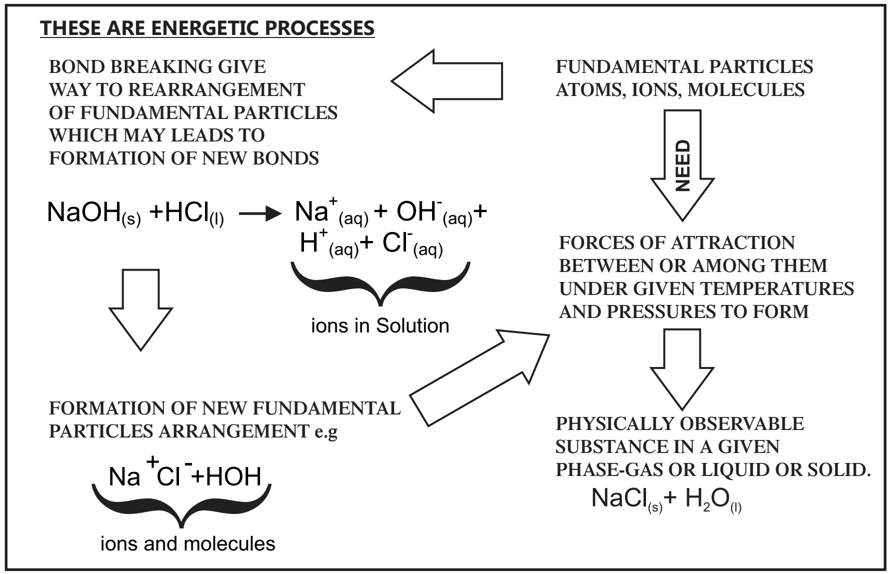

Figure 7: Schematic representation of the relationship between the particles, chemical reaction and substance phase

UTILIZING "THE IMAGINATION-STRETCH STRATEGY" TO CORRECT THE MISCONCEPTION OF THE PARTICULATE NATURE OF MATTER.

The above strategy was designed in response to students' misconceptions about the particulate nature of matter. Before using this strategy, the students will have studied the states of matter and the kinetic theory of matter. Reference to the three phases of water would be an appropriate example of this strategy.

Imagination stretch instructional strategy is a conceptual change-based teaching approach proposed by Alamina (1995) and is rooted in the constructivist theory. The strategy involves

- ❖ a systematic presentation to the students, a known phenomenon – exhibition of change of solid ice to liquid water and to the gaseous state.
- ❖ Indicating the characteristics that identify each state of matter will be stated and known by the students.
- ❖ Stretching student's imagination from the concrete or macroscopic level which is within the learners' observable physical state and progressively moving from the concrete to the abstract level by using prompting questions such as 'If the gas molecules keep moving faster (in an open system) with increase in temperature and consequent increase in their kinetic energy and weakening of the intermolecular forces, can the molecules still maintain the characteristics of the gas phase as defined by the Kinetic theory of matter?
- ❖ The gaseous phase may be used to 'stretch' the pupils' imagination beyond the stage where they can actually imagine a single isolated molecule of water (which, in itself, does not represent or possess the characteristics of the gas phase as presented by the Kinetic theory of matter).

sustained then no good has been done to the education sector which is meant to sustain the Nation.

The Vice Chancellor Sir, the focus of this lecture is on misconceptions in Chemistry related concepts. Attention will be given to constructivist learning theory and the teaching strategies associated with it, which takes into consideration student' misconceptions. This has been the research focus of this Inaugural Lecturer (see for examples citations under the references). A number of the Nigerian Constructivist researchers have also been born from this stock. I believe some of them are present here.

A BRIEF LOOK AT THE CONSTRUCTIVIST THEORETICAL BACKGROUND ON MISCONCEPTION

Constructivism is an epistemology - a theory of knowledge which seeks to explain how we learn. Constructivism refers to an understanding about learning which proposes that learners build their own understanding of new ideas based on what they already know (Driver, 1988; Driver & Erickson, 1983; Lorsbach & Tobin, 1998; Piaget, 1967; Scott, 1987). Thus, constructivists see the individual as responsible for constructing and acquiring knowledge as the individual interacts with the environment. They support the idea that the individual is physically and mentally active from birth, therefore the construction of knowledge is inherent in the individual (Driver, 1988; Von Glasersfeld, 1991; Alamina, 1995). Constructivists believe that students learn best when they play an active role in the process of learning. The constructivist's view of learning therefore provides a premise on which students can achieve effective learning more independently. The subjectivity of knowledge is the reference point of constructivism which stresses that knowledge is influenced by subjective factors such as the individual's prior knowledge, expectations, feelings, beliefs and values. All these make up the individual's experiential World

Some Identified Factors That Give Rise To Misconceptions Of Some Concepts In Science

Alamina (1992), has recognized two factors, among others which can contribute to misconceptions in teaching and learning. One factor is the 'deficiency factor' and the other is the 'misrepresentation factor'. The following describe the ways these factors affect understanding. The 'deficiency factor' refers to lack of appropriate build-up of cognitive structures, which are related to problem-solving capabilities. These cognitive structures, influence the ways learners interact with the environment. A lack of the appropriate cognitive structures needed to relate to the topic presented by the teacher will result in misconception.

The 'misrepresentation factor' has to do with inappropriate presentation of materials to be learned which leads to inadequate understanding or misconception of the presented material. Learned knowledge is seen as a subjective construction built up from physical and mental (cognitive) interactions between the individual and his learning environment (Driver, 1988; Pope and Gilbert 1983; Osborne and Wittrock 1983; Von Glasersfeld 1984; Piaget 1967). This interaction process involves generation of meaning by the learner. It follows that misconceptions could arise as a result of wrong or inappropriate presentation of a learning experience which will in turn trigger a wrong internal co-ordination of cognitive structures that are involved in construction of knowledge or the generation of meaning. Inadequate understanding of scientific knowledge are often

Another approach to conceptual change, reported by Niedderer (1987) and also argued for by Solomon (1983), aims not at replacing pupils' theories, but making pupils aware of both their 'theory' and the accepted scientific theory. Having pupils aware of both theories is not of course sufficient. They also need to understand the differences between the two theories and establish the desired relationship, if any, between them, as shown in the following dialogue from an interview session with students on the particulate nature of matter.

Interviewer (1): Do we have atoms in wood?

Pupils Response (R1): They said an atom is the smallest unit or particle of a substance.

Interviewer (2): Where exactly can we find them?

Pupils Response (R2): We can find them in all parts

Interviewer(3): Describe exactly what you mean

Pupils Response(R3): If you break any part, I am sure there is an atom there but you cannot see it.

ANALYSIS

Responses RI and R2 give the impression that the pupil is aware of the particulate nature of matter. However, he does not understand how the particles are related to his concept of substance as revealed in responses R3. In this case, once there is an appropriate understanding between the particulate matter and the substance as a whole, i.e. between the micro and the macro, then, conceptual change would take place. See an example below.

BUILDING ON PUPILS' EXISTING IDEAS AND EXTENDING THESE TOWARDS THE ACCEPTED SCIENTIFIC POINT OF VIEW

Researchers such as Clement et al. (1987), Rowell and Dawson (1985) and Stavy (1991) have proposed this approach. Rowell and Dawson, however, have proposed the introduction of conflict after the scientific conceptions have been taught to pupils.

The Development of Pupils' Ideas Which Are Consistent With The Accepted Scientific Perspective.

This involves the use of analogies drawn between the accepted idea and the pupils' intuitive knowledge. Brown and Clement (1989) describe the steps involved. Their term 'anchoring intuition' represents the pupils' native idea which is compatible with the accepted scientific idea. If the teacher attempts to establish an analogy between the 'anchor' and the scientific idea and the pupil disagrees then the teacher will attempt to find a 'bridging analogy'.

Steps involved in the use of analogical relationships

- Students' misconceptions are established using a commonly misconceived physical idea. For example, when a book is placed on a table students do not conceive the idea of an upward pressure being exerted by the table on the book.
- An analogy -for example, a hand holding a book is introduced by the teacher. This is termed an anchoring example because it appeals to students' intuitions.
- A comparison is required of the student, between the target situation and the anchor in order to establish the elements of the analogical relation.

mixed with students' everyday common sense explanations. The following representation explains it further.

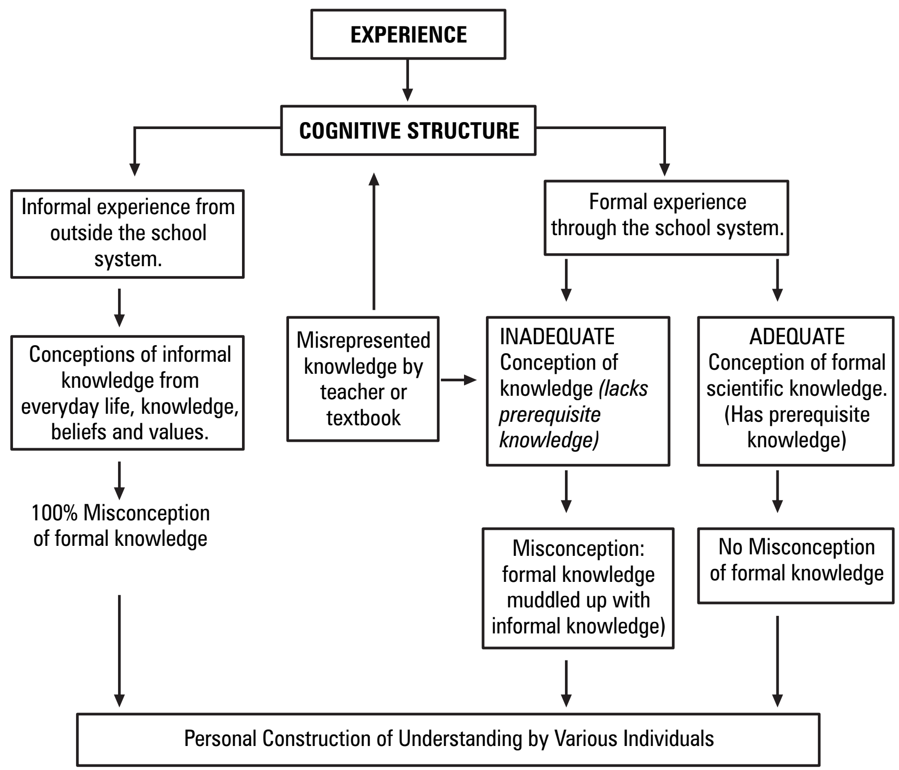

Figure 3: A Schematic Representation of Students' Experience and Understanding

In a nutshell the above schematic representation very briefly explains how we learn as it relates to the constructivist theory. The knowledge a learner acquires as his or her understanding is believed to be influenced by his formal and informal experiences to various degrees.

- ❖ If the individual's cognitive structure is adequately built up with the pre-required knowledge to understand a new topic the teacher is presenting to the learner, then learning which is much less influenced by informal experience can readily take place. The learner will assimilate the knowledge as well as internalize it, and be able to possibly apply it elsewhere.
- ❖ The converse will happen where pre-requisite knowledge is lacking. The learner will not comprehend or assimilate the learning. Such a learner's response to any question on the topic will be a mix up with bits of formal and informal knowledge muddled up in some way outside the acceptable formal knowledge. This is the cognitive deficiency factor which has led to misconception. Misconception can arise from an external source through a wrong presentation of learning materials by the textbook writer or the teacher.
- ❖ Where the teacher or a textbook presents a concept inaccurately it is so misconceived by the learner, adds to the learner's cognitive structure and negatively affects subsequent learning if not corrected. Students are 'active' learners. There exists a continuous interaction between the individual and his/her environment or a new experience. Novak and Gowin (1984) have demonstrated that new knowledge is more readily acquired when new experiences can be related to already existing ideas. New ideas are thus more readily understood in terms of what the individual is already conversant with.

EXPLOITING MISCONCEPTIONS TOWARDS OPTIMUM TEACHING AND LEARNING

Rowell and Dawson's Teaching Strategy

- ❖ Students' initial ideas for solving a problem are established and retained in writing for consideration.
- ❖ A new theory (scientific) is presented to the students in a way that it is linked to a basic knowledge that is already available to the class.
- ❖ Students are required in their own construction to apply the new theory to solving the problem. This second idea (construction) is also written down for consideration.

  Students now compare their initial ideas with their second ideas after the theory was presented.

Cosgrove and Osborne's Teaching Strategy

There are four phases involved here as follows:

(i) **Preliminary *phase***: Teacher needs to understand the following views:

- ❖ His/her own views.
- ❖ The Learners' views
- ❖ The views of science

(ii) ***Focus phase***: Learners clarify their views

(iii) ***Challenge phase***: Learners debate with each other the pros and cons of their view in relation to the views of science.

(iv) ***Application phase***: New ideas are expected to be applied in other contexts.

B. Concept Development

- ❖ Use analogy to establish relationship between concept and real life.
- ❖ Learners' preconceptions can be deliberately manipulated and used as foundation for guiding students from what is known to what is to be known/scientific view <Scaffolding> (See the example using Imaginative teaching strategy to be discussed later in this lecture)
- ❖ Probing questions used to elicit students' immediate understandings <during-lesson knowledge constructions>
- ❖ Students given tasks to perform in class – practicals, drawings etc.<built-in assessment>
- ❖ Learning opportunities in which there is an increasing complexity of tasks, skills and knowledge acquisition <apprenticeship learning>
- ❖ Consideration of errors arising from misconceptions and use them as a mechanism to provide feedback on learners' understandings.

3. Champagne, Gunstone and Klopfer's Teaching Strategy

- ❖ Students' ideas about a given physical situation are obtained.
- ❖ Students provide an analysis to support their ideas.
- ❖ Discussion and argument follow as students attempt to convince each other of the validity of their ideas.
- ❖ Teacher presents a theoretical scientific explanation.
- ❖ Discussion follows as students compare their conceptions with the scientific one.

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- ❖ The social interaction amongst individuals allows for commonality in the use of meanings given to certain experiences. These common meanings are incorporated as elements in each individual's cognitive build-up, and are shared in several ways, notably by language.

MISCONCEPTIONS IN SCIENCE TEACHING AND LEARNING

The Vice Chancellor Sir, there is lack of acknowledgment of 'student misconception' in secondary science textbooks. Textbook writers need to point out these misconceptions as identified by research findings. Numerous research findings have identified these misconceptions being exhibited in all the sciences. See for example (Happs 1980; Eylon, Ben-zvi and Silberstein 1982; De Vos and Verdonk1987; Gable and Samuel 1987; Driver,1989; Harrison and Treagust 2002; Nakhleh et al. 2005; Chiu 2007; Johnson and Papageogiou 2010; Liang et al. 2011; Obunwo, J. C. & Alamina, J.I. 2012; Treagust et al. 2013).

Justi and Gilbert (2002) and Taba (2003) raised the concern about textbooks introducing 'hybrid models' which may constitute a hindrance to the understanding of particle model. Andersson (1990) pointed out that atoms and molecules are represented in a variety of ways (in textbooks), such as circles, balls, ball separated by springs, etc. He has argued that these different models, which are often given without explanation or justification, might be a source of misconception for pupils. He suggested emphasizing the distinction between models and observations, and providing a clear explanation of the <u>nature</u> of the model. He has also enumerated some 'category mistakes' found in textbooks and commonly made by teachers. One such mistake was the failure to make and sustain a clear distinction between substances and atoms/molecules. The problems identified by Anderson can only be solved by having teachers conceptualize atoms/molecules in their proper context in relation to the substance as a whole. Once this is achieved, the teachers will be able to facilitate student's appropriate conception of the particulate nature of matter especially as it relates to the substance as a whole.

Alamina's Research Findings About Students' Misconceptions of Particulate Matter and Chemical Change Involving Burning of a Piece of Paper and a Precipitation Reaction.

The following presents a brief conceptual backgrounds on the various Chemistry concepts treated

The Atomistic Models of Matter (The particulate Atom)

Early Greek ideas about matter included both continuous and atomistic notions. Despite the persuasiveness of Dalton's (1766-1844) atomic theory, which proposed that matter was composed of elementary particles, it was subjected to controversy and raised important questions about 'action at a distance' as presented by the undifferentiated 'billiard ball' picture of the atom.

Rutherford (1910), presented a picture of the atom which suggests that the electrons moved in orbits around the atom.

This picture of the atom with orbiting electrons portrayed the atom as unstable because from classical electro-dynamics such orbiting electrons would normally emit radiation continuously, lose energy and collapse into the nucleus. This would lead to a short-lived existence, yet the atom is known to be stable (Heilbron, 1981).

experiences to foster deeper and broader understanding of the concept. What is crucial at this stage is the student's ability to transfer learning by applying knowledge in different contexts.

Evaluate – This is the progress determining phase that encourages students to assess their understanding and abilities. It provides the teacher an opportunity to evaluate the students' progress through a formative and summative evaluation. Students can also pose questions to each other to evaluate themselves as well as learn from each other's understanding of the concept while the teacher moderate the section.

Extend – This is an addition to the elaboration phase. Students are challenged to extend their understanding in a context, compare and contrast ideas, theories and concepts in relationship with knowledge gained. Carry out further related studies.

2. Teaching model and strategies as derived from Murphy's (1997) checklist

(also see Kalu-Uche (2015) are highlighted below.

A. Concept Introduction

- ❖ Teacher gives students time to debate among temselves on what the new concept involves <Knowledge collaboration>
- ❖ Teacher elicits students' preconceptions by asking probing questions.<previous knowledge construction>
- ❖ Teacher presents concept cartoons to provide alternative viewpoints <multiple perspectives>

students by creating surprise or doubt through a demonstration that shows a piece of steel sinking and a steel toy boat floating. Similarly, a teacher may place an ice cube in a glass of water and have the class observe it float while the same ice cube placed in a second colourless liquid sinks. The corresponding conversation with the student may access their prior learning. The student should have the opportunity to ask and attempt to answer "why is it that the toy boat does not sink in the second colourless liquid"? These capture their attention, prompting curiosity and stimulate thinking. These short activities by the teacher excite the students; get them interested and ready to learn.

Explore – It is a phase in the learning cycle that provides an opportunity for students to explore their ideas raised at the engaging phase. That is, using prior knowledge to generate new ideas. It provides opportunity for students to observe, record data, isolate variable, etc. Teachers may frame prompting questions, suggest approaches and asses students' understan-ding.

Explain – This phase focuses students' attention on a particular aspect of engagement and exploration experiences thereby providing opportunities to explain and demonstrate their conceptual understanding, process skills and behaviours. The teacher guides the student toward coherent and consistent generalization, helps students with distinct scientific vocabulary and provides questions that help students use this vocabulary to explain the results of their exploration.

Elaborate – At this stage, the student has an opportunity to apply their knowledge in new domain hence challenge their conceptual understanding and skills through new

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Bohr (1913) suggested a way around the difficulty posed by Rutherford's model. He suggested the movement of electrons about the nucleus in orbits of fixed energy whereby changes in energy would be as a result of absorption of energy (jumping to an orbit of higher energy) or emission of energy (jumping to an orbit of lower energy). With this arrangement, energy will be emitted in discrete packets or quanta (Bohr's initial calculations were based on the hydrogen atom). However, applying spectral analysis, he suggested a model of how electrons were arranged in other atoms as well. This arrangement was confirmed experimentally by E. J. Evans in 1913 and J. Frank and G Hertz in 1914. Sommerfield and Pauli subsequently developed Bohr's work and were able to indicate the number of electrons in various orbits (Steele, 1970).

From the outset, Bohr's theory was known to be inadequate, a more sophisticated understanding found the development of wave mechanics and an acceptance of a dual nature of matter (particle and wave) Steele (1970), Heilbron (1981).

The wave nature of matter was confirmed by electron diffraction experiment done by Davisson and Germer in the United States in 1972 and in the same year by Thompson in Scotland.

A SCHOOL SCIENCE PERSPECTIVE ON CHEMICAL CHANGE AT THE SS1–SS 3 LEVEL

Secondary School science describes chemical change in terms of bond breaking, which is followed by the rearrangement of fundamental particles of the elements or compounds involved and the formation of new bonds (though not in all cases). As a result, new substances are constituted by the rearrangement of reactant particles. In schools, bonding is taught essentially in terms of the (discredited) Bohr's model of the atom and of ionic and covalent bonding in terms of electron donation and sharing respectively.

Since chemical reactions are assumed to take place at the atomic level, models are used to represent bonding processes. For ionic bonding, representational drawings of atoms showing the electron shells with their electrons usually drawn, indicating the loss of an electron/s by one atom and the gain by another atom. For covalent bonding, a similar representation is used, but in this case, the atoms are shown as sharing electrons. Other types of bonding such as hydrogen and metallic bonding can be similarly represented using the Bohr's model.

Bond making and breaking are energetic processes. If at the end of the reaction the net energy absorbed is greater than energy released, the reaction is termed endothermic. If the converse is the case, the reaction is termed exothermic. Once started some exothermic reactions become self-sustaining.

The energy changes associated with chemical reaction derive from the enthalpies of bond making and breaking and from the accompanying changes in entropy. The latter receive little attention in most Secondary school syllabuses and, for the most part, energy changes are equated with the algebraic sum of the bond enthalpies involved.

SOME CONSTRUCTIVIST TEACHING STRATEGIES

Below are some of the constructivist teaching strategies. A number of our Post Graduate students have carried out research about the effectiveness of some of these strategies and recorded positive results.

The 7Es Instructional Model

1. 7E's instructional model is Eisenkarft's (2003) expanded version of the 5E model. The modification required the expansion of the "Engage stage" to "*Elicit and Engage*" and the two stages of "Elaborate and Evaluate" into three components "Elaborate, Evaluate and Extend". Teachers are expected to reflect these phases in their science teaching and learning interactions with students (See Naade 2018).

Below is the summary of 7E's instructional model.

Elicit – It has to do with determining the students' prior knowledge to ascertain what the student knows about the topic to be taught. Recognizing that students construct knowledge from existing knowledge, teachers need to find out what existing knowledge their students possess. The teacher may elicit prior knowledge by posing a "what do you think" question at the outset of the lesson. From the student's responses the teacher could elicit their prior knowledge and misconception would be addressed in course of the learning.

Engage – It is a phase in the learning cycle that the student is being engaged in a new concept through the use of short activities that prompt curiosity, enthusiasm and attention towards the new concept. It intends to capture students' mind and stimulate thinking. For example, a teacher may engage

In the case of the burning of paper, the students need to know that paper is a mixture made up mostly of cellulose (over 95% in many cases) and that it is this carbohydrate group of molecules that is involved in a chemical reaction with oxygen. The expected product from the complete combustion of such a carbohydrate group would be gaseous carbon (IV) oxide and water and not the observed ash (which is mostly burnable carbon, a product from the degradation of the carbohydrate molecule).

Knowing the essential composition of paper and the expected products of the burning of carbohydrates, the students are more likely to give a better explanation for the observed ash residue obtained from the burning of paper.

The Vice Chancellor Sir, research has shown that identifying misconceptions and taking them into consideration in teaching enables optimum learning. In recent times, based on this understanding, several teaching strategies, methods and models have been developed to take into consideration students' misconceptions. A number of these teaching strategies will be highlighted next in this Lecture.

Also at the Secondary school level, chemical changes are generally regarded as either reversible or not easily reversible. It is a necessary consequence of contemporary understanding of chemical change that all chemical reactions are, in principle, reversible. Reversibility requires a change in the conditions that determine the thermodynamics of the reaction. The relevant thermodynamic equation relates the Gibbs free energy, the enthalpy and the entropy to the absolute temperature.

$$\Delta G = \Delta H - T \Delta S$$

The sign and magnitude of the Gibbs free energy change ΔG is an indication of the thermodynamic feasibility of a given reaction. Given that, for a given reaction, ΔH is largely independent of temperature, T, a change in the latter may have a significant effect on the sign of ΔG and therefore, upon the thermodynamic feasibility of a reaction. Temperature, therefore, is an important factor in governing the position of a chemical equilibrium established by forward and reverse reactions continuing with no net change in the composition of a reaction mixture.

In practice, chemical reactions are often not reversible and the equilibrium position lies almost entirely in favour of products. The notion of reversibility, however, raises an additional difficulty for students learning chemistry and for those who teach them. This is that many school chemistry texts invoke reversibility as a criterion to differentiate chemical from the so-called physical changes. The latter are commonly stated to be easily reversed whereas chemical reactions are not. Gensler (1970) has argued that if reversibility were to be a criterion for classifying a change as physical then the following reaction and a number of the others would be classed as physical changes.

$$H_2 \underset{\text{COOL}}{\overset{\text{HEAT}}{<====>}} 2H$$

The boiling of water and the dissolution of copper(II) sulphate in water are usually presented as physical and not chemical changes. In reality both involve the breaking of chemical bonds and, in the case of aqueous copper sulphate it has some properties not shared by the solid e.g electrolytic conduction.

As Gensler (op.cit., p.155) has noted, the "recovery of the unchanged solute when a solvent is removed which is often used as an example of physical process is the macroscopic end result of a series of microscopic steps none of which can be defended as physical" thus, any distinction between chemical and physical processes which does not involve sub-microscopic particles, inter-atomic bonds, and inter-molecular bonds may be misleading.

A Perspective on the Chemistry of Combustion

Combustion is an exothermic reaction or a set of reactions. Its precise nature and characteristics are dependent on

1. The reaction involved.
2. The rates of the elementary steps involved.

Combustion involves both chemical and physical processes. The chemical processes are the chemical reactions involved and the physical processes are the transport of matter and energy which involve the conduction of heat, the diffusion of chemical species and the bulk flow of gas resulting from release of energy. When the rate of energy release is higher than the rate at which energy is conducted away, there is a rise in temperature of the system and a consequent increase in reaction rate. When this state of self-acceleration occurs, it is

terms 'mixtures' or 'substances' as used in more general conversation.

The students' responses in the studies were based on descriptions of what was simply observed to be happening. For instance, the interpretation of burning of paper in air commonly showed the flame on the paper to be from a source external to the paper, and having a destructive/transforming effect upon it. Scientific understanding about burning in air presents a different idea, namely that the flame is a consequence of the exothermicity of the combustion reaction (explained earlier). Since this study has shown that the students' ideas are dominated by observable and common-sense descriptions, the task of the teacher is to make the students aware of these misconceptions and using one of the constructivists strategies to have them conceptualize burning the scientific way appropriate to school science level.

PRESENTATION OF LEARNING MATERIALS

Consequent to the finding that many misconceive how compounds and elements relate to the notion of a substance as understood more generally, it is considered necessary in teaching the topic on chemical change that,

1. both pure substances (elements and compounds) and mixtures (commonly used substances, e.g. paper) be used to illustrate the idea of a chemical change.
2. the knowledge of the composition of such commonly used substances (since the findings from these studies also showed that most students considered the observed ash as the sole product of the burning of paper).

3. The role of an energy giver or a fuel.

It is not surprising to have such ascribed roles since definition of terms are not readily obvious, more so when such a term as burning has a variety of meanings derived from everyday experiences which are not scientifically acceptable.

The supportive role of oxygen as well as the role of a fuel as ascribed by students seems to have been derived from the knowledge that burning does not take place in an oxygen free environment (portrayed by such basic experiments as the burning of candle in a limited supply of oxygen environment). Such an experiment when introduced early in school science may be a source of misconception if the CHEMICAL involvement of oxygen is not made explicit to learners. In the ignorance of the chemical involvement of oxygen, the role of a catalyst may have been prompted by common-sense interpretation based on the observation that objects burn more rigorously when there is an air current.

The findings that most pupils thought burning was a chemical change yet offered mechanisms of change which indicated the transmutation of paper to ash and students identifying a gaseous oxide as the product of burning, which their mechanisms of change did not justify, both indicate that the students do not have a sound conception of chemical change. Furthermore, it was observed in this study that some pupils did not think that the burning of paper is a chemical change because paper was not considered a chemical. Students' responses often showed that they believed chemicals were materials found uniquely in the laboratories. These misconceptions stem from the lack of understanding about how elements and compounds (pure substances) relate to the

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termed the ignition point at the temperature. At this point, flame production is imminent. Flame is the term for a reaction zone which is luminous, and flame-producing reactions are rapid and involve chain reactions. Free radicals and atoms play an active part in the chemical reactions as they participate in the chain reaction. The chain reactions involved in combustion involve the following three steps:

1. The production of free radicals
2. The propagation reaction whereby the free radicals react with the reactant molecule resulting in the formation of a product and another free radical to continue the chain. In cases where more than one free radical or reactive specie is produced, the chain will no longer be linear but branched and the rate of reaction will further increase.
3. The chain termination processes involves the removal of chain carrying radicals. Combustion phenomena involve two components –a fuel and an oxidant, and the heat required to start the reaction.

   The nature of the reactive species involved in the reactions depends on the fuel-oxidant system. However, it is known that for most systems involving hydrogen and oxygen, the hydroxyl radical (OH) is the predominant and important radical though some reactions involve H_2O, H and O

A Secondary School Science Perspective on Combustion In Air

School science does not present combustion in terms of free radical mechanism. The importance of oxygen in burning is usually treated from the junior secondary school using, as a demonstration, the popular burning candle experiment in which oxygen is shown to be used up and as a result, the candle flame goes out.

At the senior secondary school level, pupils are taught that combustion in air involves a reaction between the fuel and oxygen which leads to the formation of oxides. Large amounts of energy are released in the process. They are also taught that living creatures 'burn' carbohydrates as fuel. The general reactions are presented below

1. Hydrocarbon (fuel) + Oxygen = Carbon (IV) Oxide + Water + Energy
2. Carbohydrates + Oxygen = Carbon (IV) Oxide + water + Energy.

In Secondary schools, burning is commonly illustrated using the burning of methane in air for the SS2 and SS3 students. The process is represented by the following equation:

$$CH_{4(g)} + 2O_{2(g)} \text{----------}> CO_{2(g)} + 2H_2O + \text{Energy}$$

Even though the processes involved in the combustion of methane in air are not treated in detail, students are taught that for a fuel to burn in air energy is needed to start the reaction (Activation energy) and that a large amount of heat is given off when the reaction does occur. The pupils are also taught that energy is required to break the covalent bonds in the molecules of methane and that thereafter new

In the above figure, the pupil represented the combination by electrostatic bonds between the combining radicals while the 'spectator' ions continued their random motion in solution. One could say that this pupil has a good understanding of a precipitation reaction and its associated particles at a level appropriate to school science. She has a clear conception of the reacting species which most of the pupils who involved particles in their explanation did not. The other pupils, if they invoked particles at all, talked rather in terms of neutral atoms and molecules combining.

The need for the teachers to conceptualize adequately the particulate nature of matter before they teach the concept of chemical change is strongly suggested without which it is difficult to see how they can understand and teach the notion and universality of chemical change, or even teach the important fundamental differences between compounds, elements and mixtures.

Demonstration 2

The burning of the paper in demonstration 2, provided insight into students' ideas about the role of the oxygen, the paper, the flame and the ash.

Only 10 percent of the pupils understood burning as involving a CHEMICAL combination with oxygen, even though 71 percent of the pupils were aware that oxygen is necessary for burning.

The misconceptions ascribed to oxygen in the reaction are the following.

1. The role of a catalyst
2. The role of a provider of supportive environment for burning.

mixed together, these ions combine. They exchange their radicals, one formed an insoluble salt and one formed a soluble salt.

I5. Make a drawing of what you think you would see if you could see through the new substance.

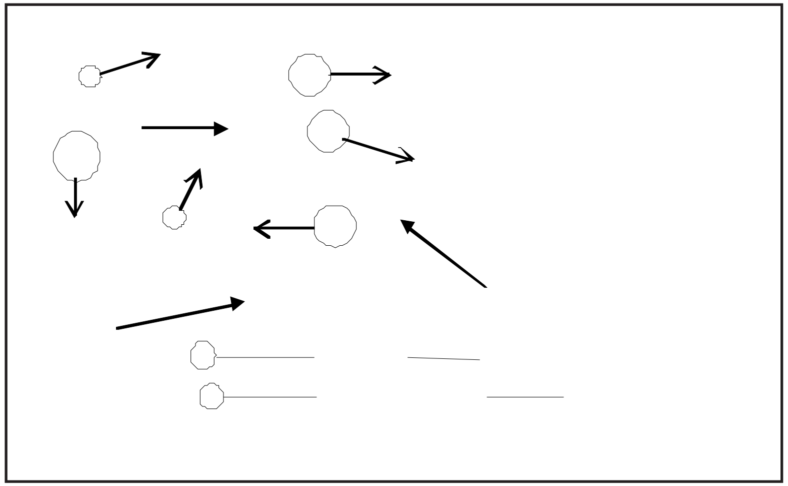

Figure 6: Pupil's representation illustrating fundamental particles as reacting species.

The above representation is consistent with the scientific ideas presented at the secondary school level about particulate nature of matter and about exchange of ions in solution leading to the formation of a soluble and an insoluble salt.

Here, the ions were depicted to be in random motion before the anions of compound A combined with the cations of compound B. The pupil recognized that substance A and substance B are chemical compounds which most of the other pupils did not seem to appreciate.

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bonds are formed, giving new molecules arrangement of carbon dioxide and water, with a net release of energy.

Precipitation As A Chemical Reaction

Precipitation as a chemical reaction is governed by the principles of chemical equilibrium. For a saturated aqueous solution in contact with the solid solute, there exists a state of equilibrium between the ions in solution and the solid phase. In order to precipitate a solid phase from an aqueous solution, the ionic product of the salt must exceed the solubility product (K_{sp}) at the temperature of the precipitation.

At the SS1, SS2 and SS3 levels in the Nigerian secondary schools, precipitation reactions are considered mostly under 'types of chemical reactions' as a 'double decomposition reaction'. These are reactions in which two normally soluble compounds take part, both are 'decomposed' their ions are exchanged and two new substances formed – one soluble and the other insoluble. Such reactions are normally represented as

$$AB_{(aq)} + CD_{(aq)} \longrightarrow AD_{(s)} + CB_{(aq)}$$

The idea of 'decomposition' in respect to many of these compounds which are mostly salts is not strictly acceptable from a modern point of view since these compounds are fully ionized in solution.

Contemporary understanding of chemical change however, depends essentially upon the particulate nature of matter and the electronic theory of chemical bonding. The fundamental hypothesis is that matter consists of particles, atoms, each of which is unique to one of the hundred and five or so elements known to exist. In a chemical reaction, these atoms are neither created nor destroyed so that there is an overall conservation of mass. In addition the atoms (micro particles) do not retain the macro substance properties and a single micro particle cannot be said to exist in any known state of matter as described by the kinetic theory of matter.

A study of senior secondary students understanding of the particulate nature of matter by Alamina (1992) revealed a number of facts about students' ideas about atoms. The study identified five categories of conceptions students have about the particulate nature of matter as it relates to the substance as a whole. These five categories of conceptions differ from the scientific understanding where the macro substance does not present the same features or characteristics as the micro particles.

THE DEMONSTRATIONS PRESENTED TO THE STUDENTS

DEMONSTRATION 1

The precipitation reaction demonstrated to the students was used for the specific purpose of finding out students' understanding of Chemical change, the nature of the reacting species which led to the formation of the product, as well as their more general understanding of the particulate nature of matter.

At the end of a demonstration of a precipitation reaction involving Lead Nitrate and Copper Sulphate, students were asked what type of change occurred and whether atoms were involved in the change they observed. 88% of SS1, 91% of SS2 and 100% of SS3 students indicated that the change was chemical and that atoms were involved..

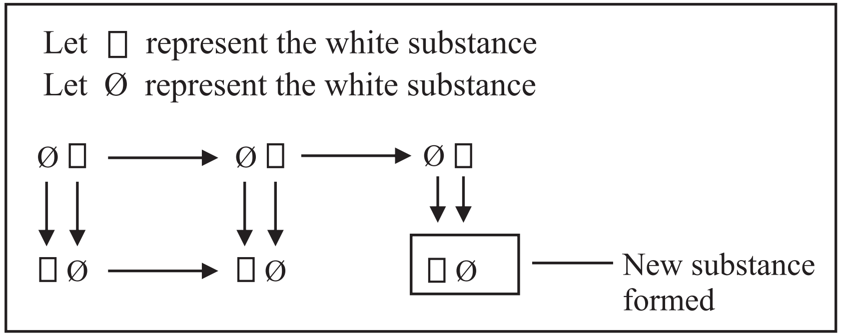

Figure 5: Pupil's representation of his idea

Below is an example of responses where fundamental chemical particles are reacting entities.

Example 2

I1 What do you mean by a reaction?

RI. New substances have been formed?

I2. Do you think it is possible to get back the substances we started with?

R2. I didn't think so

I3. Why not?

R3. Maybe some kind of substance or chemical has combined. It is some kind of precipitation. I assume a double decomposition has taken place. Two soluble salts have mixed and formed one insoluble. I don't know if another soluble salt has been formed at the same time or not.

I4. How does this come about?

R4. These substances were dissolved in water and they were supposed to have formed ions but when they were

I2: Why do you think so?

R2: Because the former bonds have been broken to produce new ones

I3: How?

R3: That is when we say chemical reaction has taken place we mean bonds have been broken to form new bonds and when the two solution were not added the colour of the solution was not the way it is now, and (since) I am seeing some particles in the water which are moving and trying to settle at the bottom but have not yet settled.

I4: Is it possible for us to get back the original substance

R4: I don't think we can get them the way it was before we started

I5: Why not?

R5: Because the way I see it this is a kind of chemical change. Since it is a chemical change it is irreversible. This may be as a result of the two substances reacting together. I don't think they can be separated.

I6: Assuming you had X-ray eyes to see through this product, what do you think you would see?

R6: I will see the reaction-taking place. The combination or interchanging of the solutes (see drawing below)

When asked how atoms were involved in the chemical change demonstrated, the answer most frequently given was that the 'atom' is the smallest particle of an element'. This response could give the impression of an appropriate conception of the particulate nature of matter by students. However, further interviews and probing confirmed this impression to be wrong.

Analysis of students' responses as well as students' drawings (as they were requested to put down their ideas as a drawing) revealed that students have various conceptions about atoms in relation to the substance as a whole. The following are the identified conceptions:

CONCEPTION 1 - The atoms are interspersed throughout the substance.

CONCEPTION 2 - The atoms are centralized and surrounded by the substance.

CONCEPTION 3 - The atoms are a collection enclosed by the 'wall' of the element.

CONCEPTION 4 - The atoms are 'the same' as cells in human body.

CONCEPTION 5 - The atoms are chopped bits of the substance.

CONCEPTION 6 - The atoms are fundamental particles of the substance.

Of the 102 students interviewed only ten students' ideas portrayed the conception that atoms are fundamental particles of the substance. There is therefore every indication that an appropriate conception of the atom has not been developed by most students and therefore they cannot understand what chemical reaction involves in any scientific way. The need for the development of certain basic conceptions about atoms which will give a proper base for understanding of chemical reactions at the secondary school science level becomes very crucial.

Using Students' Conceptions To Cross Check The Teachers'

Much of the research on 'misconceptions' of science concepts or 'alternative concepts' as regarded by some scholars have focused mainly on students and not the teachers. This next study is a follow up aimed at determining if the teachers have similar misconceptions as the students about the particulate nature of matter as it relates to the substance as a whole. The sample for the study was made up of 34 selected government secondary school chemistry teachers from the six Niger Delta states in Nigeria who attended a capacity building program organized by SPDC. The instrument administered to these teachers was the five identified conceptions of students about the particulate nature of matter as it relates to the substance as a whole (see the list above). The instrument was administered to the teachers and they were to indicate whether or not they agreed with each conception as well as give their reason for agreeing or disagreeing.

The following bar chart shows the proportion of teachers agreeing or disagreeing with each conception.

STUDENT'S MISCONCEPTIONS ABOUT PRECIPITATION AS A CHEMICAL REACTION

The reasons offered for the classification of precipitation as a chemical change were as follows:

- Irreversibility of the change
- Reversibility of the change
- Difficulty of reversing the change, and
- The involvement of chemicals

The nature of the reacting entities

In the second instance where small units of the substance were thought to react, pupils used the term 'particles' and an analysis of their ideas indicated that the particles meant tiny bits of the original substances which also persisted in the final product.

Finally, in the instance in which atoms were thought to be involved, the solid product of the reaction did not contain small parts of the original substance. Rather, it consisted of particles **chemically bonded** together in a manner different from that of the starting materials (see example, E2). The following examples illustrate the type of the reacting entities referred to above.

Below is an example of responses where **whole substances** are thought to react.

Example 1 **('I' stands for the interviewer and 'R' student's response)**

I: What do you think has happened?

R1: I think a chemical reaction has taken place

4 **Elements are conceived as walled and atoms found inside them (conception III).**

5 **Atoms are conceived as compartmentalized in the substance (Conception II).**

6 **Some of the teachers did not show consistency in their conceptualization of the particulate nature of matter. In other words atoms may be conceived as particulate in one response yet in another response atoms are conceived as embedded in a continuous substance.**

The Vice Chancellor Sir, the study did reveal quite a number of facts that have serious pedagogical implications. The findings showed that many of the teachers and students alike have scientifically inadequate conceptions of the particulate nature of matter as it relates to the substance and still retain the ancient Greek ideas of matter being continuous with particles embedded in the continuous matter. The micro properties of the atom of which matter consist does not have the same macro properties of the substance. This has not adequately been conceptualized by most teachers and students alike. The misconceptions the students have may to a great extent be traced to the teacher's inadequate conception and probably to the inadequacy of textbook explanations. These findings call for a re-visitation of science teaching, the curriculum at the teacher education level and the school science level.

If the teachers have adequate conception then they should be able to facilitate students' conceptions of the particulate nature of matter, which from different studies have shown not to be the scientific understanding, see for example, (De Vos and Verdonk 1996; Driver et al. 1994; Gable and Samuel 1987; Johnson and Papageogiou, 2010; Justi and Gilbert 2002; Liu and Lesniak 2006; Renstrom et al. 1990; Taba 2003; and Treagust, 2013).

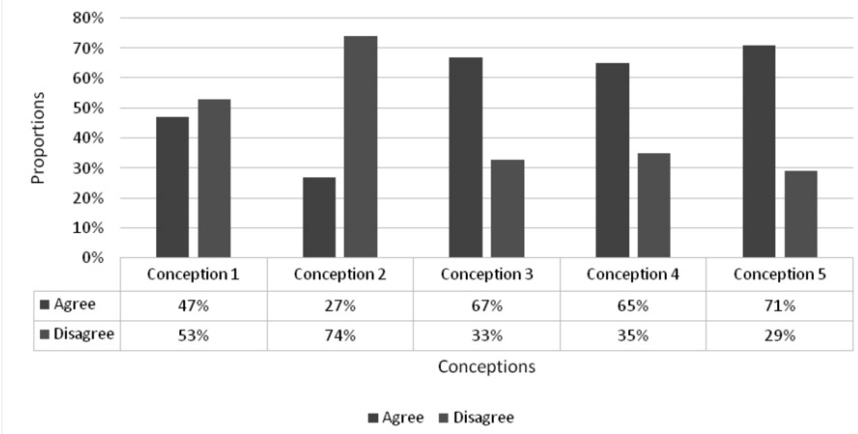

Figure 4: Proportion of teachers agreeing or disagreeing with each conception

Surprisingly, quite a good proportion (65%) of the teachers see the cells in plants as atoms (conception 4). These findings have revealed some fundamental problems in the teaching and learning of chemistry.

Below are presented some of the reasons given by the teachers for agreeing with a given students' conception.

Conception I - The atoms are interspersed throughout the crystal substance.

Agree because,

- The crystals inside contains the atoms, the crystals are made up of molecules in which the atoms reside
- The atoms are the smallest particles found inside the crystals.
- The definition of an Atom says that Atom is the smallest indivisible part of an element. Atoms are smaller than the Crystals therefore they are contained in Crystals.

- The atom is everywhere in that crystal being very tiny, therefore there is no part of the crystal you cannot find the atom.

The crystal covers the atom and so the atom is inside the crystal

Conception II - The atoms are centralized and surrounded by the substance.

Agree because,

- The nucleus – P + N of the atom gives the mass of the atom, and the nucleus is found in the heart while the electrons move round in shells or energy levels.
- The Atoms are tiny particles found in the heart of the wood. They make up the wood. The heart of the wood does not contain the atom per se but contain particles of the atom.
- The atoms are not usually found in the hearts of woods. Hearts of woods are made of Hemicelluloses and Polysaccharides.
- Atoms are not contained in the middle of wood rather it is called the pit.

Conception III - The atoms are a collection enclosed by the 'wall' of the element.

Agree because,

- The Atoms come together to form elements. Atoms are contained in elements.
- They also possess nucleus. They are found all over the body of the elements.

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Conception V - The atoms are chopped bits of the substance.

Disagree because,

- The atom is never the same thing as chopped bits of substance. Particular noting that one cannot physically divide bits of substance to atomic size.
- The chopped off bits of wood or other substances cannot be analogous to atoms, as the bits of wood would not react when undergoing a chemical change as atoms of any element but as wood, exhibiting the properties of the different elements substances in it.
- A chopped wood, even though tiny cannot be regarded as an atom because it still has the properties of a wood.
- There are several atoms in those chopped pieces of wood and again atoms cannot be separated by physical means.

FINDINGS

The findings reveal the following:

1 **A number of the teachers of chemistry involved do not have scientifically acceptable conception of the particle atoms in relation to the substance as a whole.**

2 **A number of the teachers do not seem to have a broad based conception of matter. For some, plants or living things are not seen as being made up of atoms (conception IV).**

3 **Atoms are conceived as embedded in a continuous substance (conception I).**

- The element is made up of atoms and in the atom, you find the nucleus, the nucleus is not separate from the atom.
- Atoms of the same element are alike in all respect (size, weight e.t.c) and an element does not have a wall or membrane as such.

Conception IV - Atoms are the same as cells.

Disagree because,

- Cells with their nuclei and other organelles are themselves built up form atoms the smallest units of elements which combine to form substances (compounds) that make up the cells.
- The atom is never synonymous with the cell. This is a clear misconception.
- Atoms are not the same as cell. The cell is made up of atoms.
- Cells are living tissues found only in plants or animals while atoms are not found in living membrane or tissues.
- It is the cell that is made up of atoms. Therefore the atom cannot be the cell – cell is a combination of atoms.
- This is because the cell is a single unit of a living organism and the atom is not a single unit but it is a made up of three fundamental elements.

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- This is because the atom is found inside the element and not outside or periphery of the element.

Conception IV -. Atoms are the same as cells

Agree because,

- Atoms are the same as cells because the cell is the smallest unit of a living thing just as atom is the smallest unit of elements or compound.
- Plant cells are linked together to form tissue, atoms are equally .
- Cells are the building block, which form the entire organism, so also atoms to element or matter.
- The cells are the basic units of plants just as atoms are basic units of the element.

Conception V - The atoms are chopped bits of the substance.

Agree because,

- The atoms are chopped bits of the substance, compared to the wood log because they are regarded as the smallest neutral particle of a substance as regard the size of the wood.
- A log of wood chopped to get tiny particles. This is because the atoms are tiny particles which are bits of the wood.
- Atoms are chopped bits of the elements because elements can be divided further into atoms. Therefore atoms come together to form elements.
- This is because when a wood is broken down into chopped bits a point will emerge when it cannot be

broken down into bits, that stage is known to contain an atom.

- Although, it depends on the size of the chopped bit of woods, but atoms are very minute bits or particles of a substance just as the tiny bits of wood, which are indivisible.

Below are presented some of the reasons given by the teachers for disagreeing with a given conception.

Conception I - The atoms are interspersed throughout the crystal substance.

Disagree because

- The crystal if it is made of one element i.e. diamond must be made up (build up) from its atoms carbon, but the conceptual diagram with its underlying statement seems to portray that the atom found at the centre is different from the crystal itself.
- Atoms are never found in isolated positions as shown in the conception considered. They must be linked together chemically.
- Crystals are made up of atoms and many atoms come together to form the crystal so an atom cannot be inside a crystal.
- An atom is the small particles of the entire crystal.
- Atom is the smallest particles of an element. It can't be inside the crystal.
- Atom is smaller than crystal. Atom is not just inside the crystal but the crystal is made up of atoms –atoms make up the entire crystal.

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Conception II – The atoms are centralized and surrounded by the substance.

Disagree because,

- An atom is the make-up particle of any substance.
- It is not only at the centre of the wood that an atom can be found.
- Atoms form the mass or bulk of the wood. It is scattered all over the woods.
- It is not only in the centre of wood that atoms can be found.
- Even though atom is present in a wood the exact position cannot be determined i.e they are on every part since they are tiny particles that made up the wood.
- This concept is not holistic in the wood (whole) is made of several atoms and not usually in the heart of the wood.

Conception III - The atoms are a collection enclosed by the 'wall' of the element.

Disagree because,

- Elements do not have walls.
- Atoms are everywhere and the nucleus is always at the centre of the atom.
- The conceptual diagram here shows a given element, which must be made of the same material all through. Thus the smaller balls inside with the nuclei must be the building blocks of the whole and I think this makes sense.