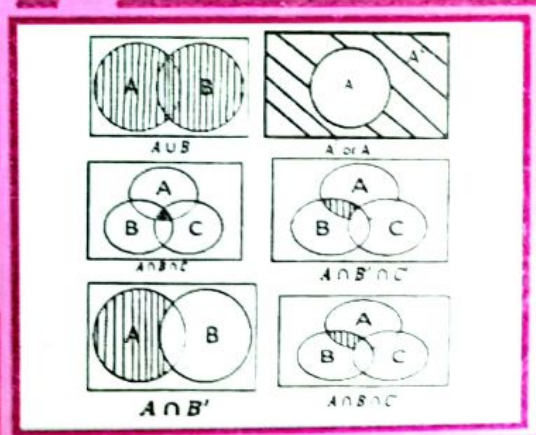


ENHANCING MATHEMATICS EDUCATION IN NIGERIA

A Festschrift in Honour of
Professor Michael
Olubusuyi Fajemidagba



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CHAPTER FIFTEEN

APPLICATION OF MATHEMATICS TO CHEMISTRY: IMPLICATIONS FOR MEANINGFUL LEARNING

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Introduction

The quest for Nigeria to meet up with developed nation requires the effective teaching and learning of sciences. The development in the field of science and technology has been used as a measure of the development of a nation (Agbaje & Alake, 2014). Since no nation is expected to rise above the standard of its education and science is perceived to be the bedrock of all technological development in all nations, there is need to prioritise the teaching and learning of science specifically chemistry because it is a central science that enhances the understanding of other branches of science.

Chemistry is a branch of science that deals with study of the nature, composition, structure, properties and uses of matter. Friedl (2016) defined chemistry as a branch of physical science that deals with the study of the properties and interactions between energy and matter. It also involves the study of the characteristics, properties and changes that occur in matter. Chemistry is an exact science that relies on quantitative models that can be described and applied by using mathematical language. Over the years, Chemistry has been identified as a difficult subject by students. This is because the topics are generally related or based on the structures of matter which tends to be abstract in nature (Sirhan, 2007). The subject incorporates several abstract concepts that are prerequisite to understanding of other branches of chemistry and other physical sciences. Another area of learning difficulty in chemistry apart from its abstract nature is the mathematical nature of chemistry (Taber, 2002). Generally, difficult perceived by teachers and students is as a result of their inability to transfer mathematical knowledge to bring about meaningful learning of the concepts in Chemistry. On this note, Childs and Sheehan (2009) reported that the main factor that contributes to the students' wrong perception of topics in chemistry (as being difficult) is their inability to grasp concepts in Mathematics ability. McLaughlin (2003) observed that the inability of chemistry student to understand and manipulate proportions hindered their understanding of mole and other chemical calculation. Therefore, to enhance meaningful learning of topics in Chemistry, the role of Mathematics cannot be overlooked.

Relevance of Mathematics to Chemistry and its Implication for Meaningful Learning

Constructivists approach to teaching and learning is based on the assumption that learning occurs as a result of individuals' construction of their own knowledge. That is

learners match new information or learning material to what they already know. Piaget's theory of constructivist learning has been known to have a wide array of application in teaching and learning. Meaningful learning occurs, when learners link prior experiences in their cognitive structure to new knowledge. The human brain processes two types of knowledge based on cognitive agreements. These are verbalisable knowledge of "knowing what" (declarative knowledge) and the knowledge of knowing how to manipulate or perform certain task (procedural knowledge) which requires the higher order thinking process of comprehension, application and analysis (Anderson, 1983). The understanding of how this knowledge interacts to mentally organise knowledge for meaningful learning is a significant tool in the teaching and learning processes.

Constructivist theorist like Ausubel (1963) in his theory of meaningful learning asserted that for learners to learn meaningfully, individuals must relate new learning materials to relevant knowledge they are familiar with. Therefore, new learning material must interact with prior knowledge in the learners' cognitive structure. The implication of this is that for meaningful learning in chemistry, learners must relate new chemistry concepts with related mathematical understanding in their cognitive structure. Hence, a deficiency in mathematical skills of students can hinder meaningful learning of some chemistry topics.

Mathematics is an integral component of all scientific discipline. Hence, its application within chemistry is numerous. Understanding of Mathematics allows the assimilation of a wide range of chemistry concepts, theories, models, experimentation and increases problem solving ability of students. It is essential that for meaningful understanding of chemistry it required that students understand mathematical ideas and concepts that chemistry contains so that the application of mathematical skills can be fully established. In the same vein, Faronbi (2014) noted that teachers will find it difficult to make headway in both science and technology without adequate knowledge of Mathematics. Ali (2013) described Mathematics as the queen of all sciences, while Childs and Sheehan (2009) described it as a gatekeeper for understanding of all chemistry concepts. Successful completion of chemistry and chemistry related courses at higher levels requires that learners are adequately equipped with the working knowledge of Mathematics and other problem solving skills. Therefore, the role of Mathematics in the effective teaching and learning of chemistry cannot be over emphasized. This is because to explain concepts in Chemistry, reference is made to related concepts in Mathematics for conceptual understanding of some chemistry concepts to take place.

Topics in Mathematics that are Prerequisite to the Understanding of Chemistry

Mathematics is a subject that is relevant to the teaching and learning of Chemistry. Prior understanding of some mathematical concepts paves way for meaningful understanding of concepts in Chemistry. The major area of chemistry that involves mathematical understanding includes experimentation and theories. The meaningful understanding of

chemistry can be achieved by applying knowledge of mathematical concepts like basic Mathematics, calculus, and 3- dimensional geometry (Flapan, et. al, n.d). Mathematical concepts that are related to chemistry are described as follows:

1. Basic Mathematics:

- ✓ unit conversions that are essential to understanding of measurements in chemistry e.g measurement of atomic weight, size of sub atomic particles among others;
- ✓ the use significant figures and decimal places e.g providing answers to measurement during titration in two decimal places and providing answers from calculations involving stoichiometry;
- ✓ adequate knowledge of proportions and concentrations is required in balancing of chemical equations and understanding calculations involving the mole concept;
- ✓ understanding of exponents and logarithms is required in understanding Arrhenius equation and calculations involving pH;
- ✓ knowledge of graphing is key to the understanding of structures of chemical compounds
- ✓ basic trigonometry and algebra;
- ✓ understanding of quadratic equations is essential to the understanding of calculations of rate constant, pH;
- ✓ summation notation;
- ✓ probability and statistics; and
- ✓ word problems.

2. **Calculus:** the knowledge of calculus will help students to understand the use of derivatives to find the maxima and minima of a function. Examples of such include: single variable calculus, multivariable calculus, differential equations and linear algebra. Hence, perquisite for basic understanding of general and physical chemistry.

3. **3-Dimensional Geometry:** the knowledge of visualising graph in 3-dimensional space, 3-dimensional vector arithmetic, 3- dimensional spherical and polar coordinates is prerequisite to understanding of shapes and structures of chemical compounds (complex and organic compounds).

Effective Chemistry Teaching through Understanding of Mathematical Concepts

There are different ways in which Mathematics is employed to explain concepts in Chemistry to solve the problem of its abstractness and making it concrete for students' understanding (Ali, 2013). Some of the instances are as follows:

- i. **Mathematics and Modelling in Chemistry:** A model is a simplified representation of a phenomenon e.g an object, system, events, processes or idea produced for a specific purpose which is abstract in nature (Chiu & Wu, 2009). The conceptual

understanding of model serves as mental model and background knowledge for students to produce their own model. The use of mathematical concepts in expressing what chemists have in mind about a particular concept is known as mental model. The use of this model is important in representing instructional contents to chemistry students in enhancing understanding of such concepts. An example of this model is the multiple representation model of chemical concepts (Johnstone, 1991) that is represented in a triangle which is a mathematical concept. It was established in the model that chemical concepts exist in three forms of representation which are macro, sub-micro and symbolic representations and none of these representations is superior to the other.

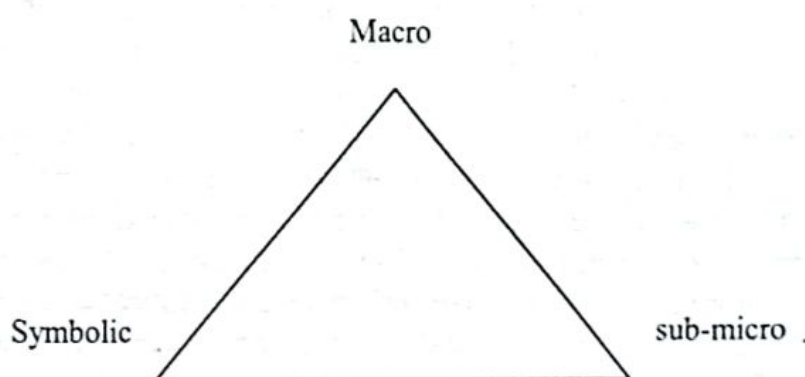
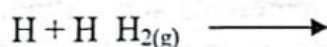


Figure 1

Source: Johnstone (1991)

For instance, hydrogen gas can be described using three forms of representation; first, macro representation that involves making use of laboratory where the characteristics of the gas can be demonstrated to students. Secondly, the sub-micro representation is the use of components that make up hydrogen gas to describe it, and lastly, the writing of the symbols in chemical equation, that is the symbolic representation.



Students that understand the meaning of equilateral triangle should be able to apply such knowledge in understanding this model.

- ii. Mathematics and chemistry spatial skill ability: the ability of chemistry students to translate between two dimensional and three dimensional representations is known as spatial skill (Ferreira & Arroro, 2009). Development of chemistry spatial skills depends heavily on chemistry students understanding of mathematical concepts that deal with dimension of objects. Spatial skill is required for conceptual understanding of chemistry for students to be able to visualize 2- dimensional objects in textual material in 3- dimensional forms in real objects. Spatial skill also deals with recognition of shape of compounds in chemistry, e.g methane (CH₄) can be described using the shapes and angles in

between the atoms. Thus, indicating that it has a tetrahedral shape whose angles are not equal.

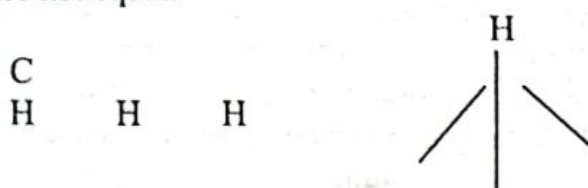


Figure 2: shape of methane molecule

Both tetrahedral shapes and angles are mathematical concepts employed to describe to the students about the description of methane molecule. Therefore, students' understanding of the structure of methane molecule is as a result of understanding of tetrahedral shapes and angles in Mathematics.

- iii. Mathematics and Measurement in Chemistry: The distinguishing feature of science is its quantitative character which is as a result of investigation which has to do with measurement as a branch of Mathematics (Farounbi, 2014). Chemistry as a branch of science deals with measurements due to its experimental nature. Hence, Otor (2013) described chemistry as a theoretical and experimental science. Considering the experimental aspect of chemistry, measurement as a mathematical concept is of utmost importance to teaching and learning of chemistry (Ali, 2013). During experimentation in chemistry such as volumetric analysis, there is need for measurement of samples in grams and other units and conversion of smaller quantities to larger ones or vice versa. Therefore, students who are deficient in conceptual knowledge of measurement in Mathematics will find it difficult to understand this aspect of chemistry.
- iv. Mathematics and use of signs and symbols in chemistry: Mathematics involves the use of signs and symbols (such as +, -, Δ denoting positive, negative and delta). Chemistry as a branch of science also shares the same attributes in describing ions (+ and - ions which represents cations and anions respectively) and delta for change or differences between the initial and end values of a quantity. Other symbols include: Σ which represents summation; π represents constant; α and β represents alpha and beta rays in an electrostatic field; Ω (ohm) as a unit in electricity, etc. These symbols enhance easy communication of research findings among chemistry students across the globe. Therefore, for chemistry students to be productive and communicate effectively in the language of chemistry. There is the need for them to be vast in the use of numbers and symbols that are products of Mathematics.

Conclusion

The application of Mathematics to science teaching and learning generally and that of chemistry in particular for meaningful learning to take place has been observed to be indispensable requirement. The perception of chemistry as an abstract science subject by majority of chemistry students can only be catered for when a better explanation

tools apart from chemistry concepts itself such as mathematical concepts are being employed to make chemistry concrete and understandable. Mathematics is seen as an international language that is suitable for expression of mental model possessed by chemistry teacher about a particular chemistry concept for students to have meaningful learning about those concepts.

Recommendation

It is therefore recommended that:

1. Chemistry students should be taught Mathematics concepts that are applicable in chemistry as a pre-requisite knowledge at any level of education for meaningful learning of chemistry to take place. Therefore, a vast Mathematics education should be paramount for every nation that craves for technological development.
2. The chemistry students understanding of mathematical concepts related to particular chemistry topics should be diagnosed before teaching, in order to determine the correct conceptions, misconceptions and alternative conceptions possessed by students' before teaching the chemistry topic so as to enhance meaningful learning as against rote memorisation.
3. Teachers should emphasise the relationship between Mathematics and chemistry to chemistry students, for them to put efforts in Mathematics lessons so that such knowledge could be utilised in chemistry lessons for meaningful learning to occur.

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