SENIOR SECONDARY STUDENTS' PERCEPTION OF THE NATURE OF THE ATOM IN OBIO AKPOR LOCAL GOVERNMENT AREA OF RIVERS STATE, NIGERIA

Joshua Macson Ahiakwo* and Uchenna Henry Johnwest
Department of Science Education, Rivers State University, Nigeria
*Corresponding author email: mcsahia@yahoo.com

ABSTRACT

The study investigated Senior Secondary (SS) Students' perception about the nature of the atom. Phenomenographic approach was adopted. Two thousand five hundred and twenty (2,520) SS3 Chemistry students from government owned schools in Obio/Akpor Local Government Area of Rivers State, Nigeria, volunteered to participate in the study. The instruments used in the study were a Perception Rating Scale Questionnaire (PRSQ) on the nature of atoms and an Atomic Theory Test (ATT). Overall findings of the study revealed that 60% of the items in PRSQ showed description of the atom by the students as a constituent of matter, 13.3% indicating constitution of the atom as a particle and 26.6% described the atom in terms of shape (model). It was further observed that 10.2% of the students agreed with the statements concerning the atom as a constituent of matter, the constitution of the atom and the model of an atom. With the students' knowledge about the atomic theory, they were able to associate the atom with such concepts as electrons, protons, neutrons, electronic configuration, nucleus, atomic number, shells and mass number. The implications of these findings were discussed in the study. *[African Journal of Chemical Education—AJCE 8(1), January 2018]*

INTRODUCTION

Atomic theory taken side by side with the nature of matter is central in chemistry and chemical education. The idea of atoms originated with the Greek philosophers Leucippus and Democritus during the 5th Century B.C., but the concept remained ignored and undeveloped until it was re-introduced in the early 19th century by John Daltonb1]. By measuring the masses of the elements taking part in chemical reactions Dalton was able to provide indirect evidence that "matter is made up of atoms".

Khan and Khan [2-3], have defined an atom as the smallest part of an element that has the same properties as the bulk. Dalton considered an atom as an indivisible and structureless particle. Later workers (Thomson, Rutherford, Mosley etc) showed experimentally that each atom consists of a dense positively charged nucleus made up of neutrons and protons. Negatively charged electrons orbit at different energy levels – called electron shells – surrounding nucleus.

The nature and structure of atom trace, the history from Thomson to Quantum mechanical model. According to 4] scientists do not have direct access to most natural phenomena and observations of nature are always filtered through our perceptions and interpreted from within theoretical framework. This seem to have complicated the difficulty students have in learning the concept and has led to subsequent construction of many alternative models [5] that will help them learn the concept.

Textbook representation of the concept is part of the difficulty students have in understanding the nature and structure of the atom. Netzell[6] reviewed that role of models and representations in teaching, learning and understanding of the atom and atomic concepts. The results of the study show that students often find concepts of atomic structure difficult and confusing. The abstract microscopic world of atoms cannot be seen with the naked eye, and models are therefore necessary and crucial educational tools for teaching atomic concepts in school. Netzell [6] further observed that when using a model, it is important for the teacher to explain the rules of the model and the advantages and limitations of the representation must be discussed.

Mishra [4] studied first year Indian students' perception of science vis-à-vis their understanding of nature of science. Part of the study was a review of a book chapter on the structure of atom looking for the representation of historical and philosophical treatment of the chapter. Mishra [4] observed that the textbook reviewed for the chapter; "structure of atom" was not written as per the historical and philosophical framework possibly because students did not appreciate the need to study older theories concerning the atom.

Unal and Zollman [7] investigated the students' ideas about an atom by asking them to describe an atom on a paper and pencil questionnaire. Students' understanding of the structure of an atom, its constituents and their approximate locations, the size of an atom and energy released by an atom were investigated. In describing the atom, most of the students fall into low hierarchical level of reasoning categories. Students do not seem to retain what they have learned from previous courses or years.

Bethge & Niedderer [8] asked German secondary students to draw an atom. They found that approximately 25% of the students' drawing included conceptions close to those of quantum and physics, another 25% used conceptions between quantum classical physics such as "smeared orbits", and 50% drew the atom in terms of classical physics. One class of students maintained these descriptions even after completing a teaching unit that used quantum mechanical approach in an advanced secondary school physics course.

Albanese and Vicentini [9] point out that in teaching about atoms, the focus is not on the existence of atoms, but on convincing students of the validity of an atomic model in order to explain the macroscopic properties of matter. Therefore, a first issue in this transmission of knowledge may be identified as the epistemological problem of the role of models in scientific understanding. Albanese and Vicentini [9] concluded that “students seem to consider atoms not as the elements of a model which tries to explain macroscopic properties as emergent properties of collection of the elements (which by themselves do not possess them) but as the smallest part in which a microscopic object may be subdivided while retaining its characteristics.

It must be noted that the various studies of Netzell [6], Mishra [4] and Unal and Zollman [7] besides being conducted with foreign students were not conclusive about how students viewed the atom. Considering the central nature of the atom in the teaching and learning chemistry in our schools, it becomes necessary for an investigation to be made concerning how Nigerian students perceive the atom. May be the difficulty the students are likely to experience in learning the atom and related concept will be laid bare.

Accordingly, the focus of the study was to investigate the perception of students about the nature of the atom.

METHODOLOGY

Phenomenography is the method adopted in the research. Phenomenographers according to [10] is a research method for investigating qualitatively different ways in which people experience, conceptualize, perceive and understand various phenomena in their environment. Marton [11] further posited that phenomenography deal with individual’s specific description of aspects of the world as it appears to them.

Phenomenographers categorize their individuals’ descriptions, and these categorizations constitute the main outcome of the research [7]. Phenomenographers look for the most essential and distinctive structural aspects of the relation between the individual and the phenomenon [10]. Above all, each category is a potential part of a larger structure in which various categories of descriptions exists. A goal of phenomenography is to discover a structural framework that is useful in understanding students' knowledge.

Thus in the present study, attempt is made to clarify how the students perceive the atom. The study was not interested in hierarchy of categories of responses of the students. It was purely the categorization of the responses of the students according to the statements derived from the students' description of the atom.

Sample

Two thousand five hundred and twenty (2520) year three senior secondary students (SS3) from twenty (20) government owned schools in Obio/Akpor Local Government Area of Rivers State participated in the study. These students volunteered to take part in the study. The ages of the students ranged from 14 years to 18 years with mean age of 16.7 years and standard deviation of 2.62 years. The students had chemistry as one of the subjects they were preparing to be examined during their school certificate examination.

Instrumentation

The instruments of the study were a perception rating scale questionnaire (PRSQ) on the nature of an atom and Atomic Theory Test (ATT).

On the construction of the PRSQ, fifty (50) SS3 chemistry students from a school not involved in the study were allowed about ten minutes to write a composition on the nature of an atom. From the write up of the students, fifteen (15) items were written specifically describing what the students think about the nature of an atom. These constituted the PRSQ (see Table 1).

Each statement of the instrument carried four response labels of strongly agreed (SA), agree (A), disagree (D) and strongly disagree (SD). SA label was scored 4 points, 'A' scored 3 points, 'D' scored 2 point and SD scored 1 point.

The instrument (PRSQ) was given to a Professor of chemical education to check whether the items (statements) could be used to assess the students' perception of the nature of an atom. The professor indicated that the statements were simple and clearly written, unambiguous for senior secondary students in chemistry.

The Atomic Theory Test (ATT) was a ten item objective test, extracted from Past School Certificate Examination Question Papers. The test was used in the study to find out added information to the student's perception of the nature of the atom. Answers to the questions were not as important as the information concerning the students' thinking about the atom.

The instruments, PRSQ and ATT were administered separately to the students in their various schools during their lesson periods. In each of the administrations, it took the last student ten minutes to complete the questionnaire and the test. For the PRSQ, frequency distribution was obtained according to the response labels. Total score for each response label was multiplied by the frequency, thus, SA x f_{SA}, A x f_A, D x f_D and SD x f_{SD}. Total scores are obtained. These are divided by the total frequencies, namely $f_{SA} + f_A + f_D + f_{SD}$ to obtain the mean rating ($\bar{x}$r) for each item (statement) of the questionnaire.

In order to take decision on each item of the questionnaire, sum of the scale weighting was divided by the number of scale thus $\frac{4+3+2+1}{4}$ = 10/4 = 5/2 = 2.5.

Any mean rating ($\bar{x}$r) equal to or above 2.5 was accepted to mean students' thinking of the nature of atom. Any mean rating ($\bar{x}$r) less than 2.5 was rejected. The results of the analyses are shown on Table 1.

For the ATT, each answer chosen by a student was scored 1 point. Frequency distributions were obtained for the options of the questions. These were converted to percentages. The results of the analyses are shown on figure 1.

Categorization of the students' responses

This was based on the three principles as adopted in the works of [10, 12, 13, 7] namely, that:

1) Categories should be extracted from the students' responses; thus we cannot have pre-assigned categories. In the case of this study, students' responses were derived from the composition (essay) written by them (students) on the nature of the atom;
2) Categories should not be mutually exclusive or inclusive, but distinguishable;
3) Responses must be explicit to be categorized.

Development of categories from the students' responses

Three postgraduate students at the Ph.D level who were interested in the study participated in the development of the categories from the students' essays. First, a mini conference was organized so as to discuss what to do with the essays. The method of categories used by [7] was very useful. The PG students looked out for descriptions near in meaning to

(i) The atom as a constituent of matter;

(ii) The constitution of an atom;

(iii) The model of an atom

These were considered as the categories on which the students' responses were classified.

ANALYSES OF DATA AND RESULTS

Data were analyzed according to the categories and the responses. Results of these are displayed in Table 1.

Table 1: Mean Rating ($\bar{x}r$) of how students perceived the atom according to categories (N=2520)

	Categories (c)/Statements	($\bar{x}$r)	% composition	Decision
C.1	**The atom as a constituent of matter**		60%	
	1.1 An atom is a cloud	2.51		Accepted
	1.2 An atom is a noun	2.90		Accepted
	1.3 An atom looks like the earth	2.59		Accepted
	1.4 Sunrays constitute the atom	2.65		Accepted
	1.5 An atom can be seen with the eyes	2.97		Accepted
	1.6 An atom can be seen with electron microscope	2.67		Accepted
	1.7 An atom is too tiny to be seen	2.63		Accepted
	1.8 An atom can be touched	2.73		Accepted
	1.9 An atom can be seen as dust	2.70		Accepted
C.2	**The constitution of atom**		13.3%	
	2.1 The atom contains a neutron	2.53		Accepted
	2.2 An atom consists of particles	2.55		Accepted
C.3	**The model of an atom**		26.6%	
	3.1 An atom looks like an orange	2.60		Accepted
	3.2 An atom is a circle	2.92		Accepted
	3.3 An atom is round	2.92		Accepted
	3.4 An atom is a wave	2.51		Accepted
	TOTAL		**99.9%**	

Analyses of the responses of the students revealed their mean rating above 2,50 indicating acceptance of the statements as representing their (students) description of the atom. It was further observed that 60% of the items showed description of the atom as a constituent of matter, 13.3% indicating constitution of atom as a particle and 26.6% revealing their shape of the atom.

The percentage constitution of the responses (statement) in the categories is 99.9% short of 100% indicating that there are categories not accounted for. Frequency distribution of the students' responses to each of the statements was carried out and percentages calculated. The result of the analyses is shown in Table 2.

Table 2: Percentage of students' responses to the statements according to response labels.

	Categories (C) statements	SA(%)	A (%)	D(%)	SD (%)
C1	**The atom as a constituent of matter**				
1.1	An atom is cloud.	17.3	25.7	47.8	9.2
1.2	An atom is a moon	40.4	24.7	19.5	15.4
1.3	An atom looks like the earth	25.2	29.7	24.0	21.1
1.4	Sunrays constitute the atom	8.8	10.5	14.4	66.3
1.5	An atom can be seen with the eye	9.6	11.3	12.0	67.1
1.6	An atom can be seen with electron microscope	6.9	10.2	19.0	63.9
1.7	An atom is too tiny to be seen	10.3	14.7	5.2	63.9
1.8	An atom can be touched	9.7	11.4	9.2	69.7
1.9	An atom can be seen as dust	10.1	11.3	7.6	71.0
C2 The constitution of atom					
2.1	The atom contains a neutron	28.3	21.1	25.4	25.2
2.2	An atom consists of particles	26.7	31.8	21.6	19.9
C3 The model of an atom					
3.1	An atom looks like an orange	24.2	28.5	38.4	8.9
3.2	An atom is a circle	30.2	43.0	15.2	11.6
3.3	An atom is round	30.2	42.8	15.2	11.8
3.4	An atom is a wave	25.2	24.5	25.9	29.4

It is observed in Table 2 that over 10.2% of the students agreed with the statements concerning the atom as a constituent of matter, the constitution of the atom and the model of an atom. Students were further assessed using a test to find out their thinking about an atom. The results of the analyses are displayed in fig. 1.

1	The atomic theory was put forward by A. Avogado (18.0%) *B. Dalton (37.1%) C. Gay Lussac (14.9%) D. Rutherford (30.0%)
2	The number of atoms in one mole of a substance is equal to the ……... A. Atomic number (41,2%) *B. Arogado's number (36.3%) C. Mass number (7.4%) D. Oxidation number (15.1%)
3	If an atom of an element is represented as $^{40}_{20}Y$, this shows that it has …… A. 40 neutrons (11.2%) B. Mass number 20 (27.95) *C. 20 protons (35.6%) D. Atomic number 40 (25.3%)
4.	The atom and ion of chloride have the same ……………… *A. Number of protons (49.7%) B. Electronic configuration (16.4%) C. Chemical properties (6.2%) D. Electrical charge (27.7%)
5	Almost the entire mass of an atom is concentrated in the ………………. A. Proton (35.32) B. electron (26.1%) *C. nucleus D. neutrons (9.1%)
6	Electron was discovered by ………………………. A. Chadwick (17.8%) *B. Thomson (42.0%) C. Goldstein (30.3%) D. Bohr (9.98)
7	An atom has a mass number of 23 and atomic number of 11. The number of protons is …… *A. 11 (29.4%) B. 12(30.18) C. 23 (39.6%) D. 44 (0.9%)
8	The mass of the atom is determined by ……….. A. Neutrons (6.1%) *B. Neutron and proton (28.1%) C. electron (20.4%) D. electron and neutron (44.2%)
9	The K,L,M, shells of an atom are full. Its atomic number is ……………. *A. 18 (31.6%) B. 20 (25.9%) C. 10 (20.0%) D. 12 (22.5%)
10	Carbon 12 atom has ……… *A. 6 electrons, 6 protons, 6 neutrons (36.8%) B. 6 electrons, 12 protons, 6 neutrons (14.1%) C. 12 electrons, 6 protons, 6 neutrons (15.9%) D. 18 electrons, 6 protons, 6 neutrons (33.2%)

Fig. 1: Students' performance in atomic theory test (N=2520)

The analyses in Fig. 1. Showed that the students responded to all the options of the test items. With the students' knowledge about the atomic theory, they were able to associate the atom with such concepts as electrons, protons, neutrons, electronic configuration, nucleus, atomic number, shells, mass number.

DISCUSSION OF FINDINGS

Discussion of findings is done according to the categories of the students' responses, as related to the nature of an atom.

The atom as a constituent of matter

A cursory look into the regulations and syllabuses for the senior school certificate chemistry in Nigeria reveals what the students are expected to learn about the atom, namely, Atomic structure: (a) the fundamental particles of the atom – protons, neutrons and electrons; (b) atomic number (c) arrangement of electrons in the main and sub-energy levels (d) orbitals and their shapes [14]. There is no indication that the students should know the nature and definition of an atom. It is assumed that the students would have known about the atom in their basic science, Integrated Science, Senior Secondary 1 and 2 Chemistry. This seems not to have helped the year three senior secondary students. This appears to be supported by the perception of the students concerning the atom as a constituent of matter – the cloud, moon, earth, sunrays and dust as representing an atom (Table 1). The students' responses presented some controversy when they indicated on one hand that an atom can be touched and on the other hand that the atom is too tiny to be seen. In all, the students' misconceptions about the nature of the atom as a constituent of matter represented 60% of all their responses. This points to the fact that the foundation preparing the students to understand the nature of the atom was not well prepared. Because the students started learning about the atom from its structure, the students were left to imagine, what the atom is by looking at it from different perspectives.

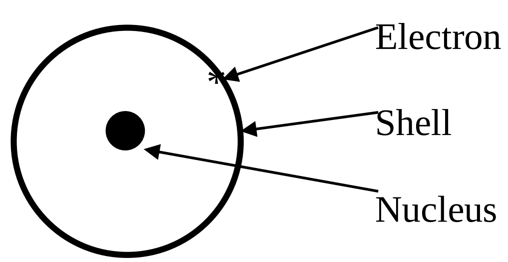
If we personalize an atom, we can ask a question on behalf of an atom, namely who do you think I am? Another way of saying, what is an atom? What do the students think an atom is? The students' perspective as revealed in Table 1, show that they think an atom is. Will these responses help them (students) learn about the atom? This study is conducted to expose the lapses in the content of what the students are expected to learn in chemistry. Once students' background is shaky in chemical principles, they (students) are bound to experience difficulty. The basis of chemical reactions is the knowledge of the atom.

The constitution of atom

Two items were captured as representing the perception of the students about the constitution of an atom. These represented 13.3% of the entire responses (Table 1). Even when the teacher started his/her lessons with atomic structure as shown in the WAEC content, the students could only remember neutrons and that atoms consist of particles. It is surprising to note that the initial fifty students from equivalent schools as those used for the study could not remember to indicate in their compositions other fundamental particles of the atom. However, in the 10-items test on atomic theory presented to the students, they responded to all options of the multiple choice objective questions. This in a way showed that the students needed external memory aids to remember the constitutions of the atom (fig. 1).

The model of an atom

There are two models of interest according to the perception of the students (Table 1); these are the circular look of the atom (e.g. an orange) and the wave-like nature of the atom. Most textbooks used by students in Nigeria e.g. [15,16,17,18,19] illustrate the atom and atomic structure as a circle. For example, hydrogen atom with one electron and a nucleus is shown as



This simple model's repeated in other atoms of elements depending on the number of shells. No wonder the students perceived any round object as a model of an atom.

Teachers also use this circular model to explain the nature and structure of the atom to the students. The problem is that the students carry this idea of the atom to higher level of learning.

It was surprising that some students (more than 24%, Table 2) thought of an atom as a wave. These are just year 3 senior secondary chemistry students. They may have heard about Bohr's model and other models including Schrodinger's. This means that limiting what the students are expected to learn to the content of their syllabus is not to the advantage of their memory capacity. Though the test of the students' knowledge about atomic theory (fig. 1) was not really designed to test that but the students' responses showed that they (students) know about the fundamental particles of the atom. They no doubt would have, also known that with the various modifications of Dalton's Atomic theory, atom is no longer the indivisible particle of an element.

IMPLICATION OF FINDINGS FOR CHEMICAL EDUCATION

The study revealed the misconceptions senior secondary students have about the nature of the atom. Although the study did not investigate the conception of the chemistry teachers concerning the atom, it is to be understood that what the students have in their memory is due to the teaching influence of their chemistry teacher. Textbooks in common use as recommended by the teachers and Ministry of Education are also part of this learning influence of the students. Chemistry textbooks present atomic models to the students with real picture whereas such models are not real. Science textbooks read by the students from basic science through integrated science to senior secondary level paint the same picture of the atom which the students believe in.

Knowledge of atoms in chemistry form the basis of understanding chemical reactions. If the students do not understand the nature and structure of atoms, their knowledge of chemical reaction will be shallow thereby leading to difficulty in learning.

There is the need to find out the content of chemistry education in our colleges of education and faculties of education in the universities. It appears that chemistry teachers have difficulty in explaining the nature and structure of the atom to the students. The teachers explain to the students what they obtain from the textbooks. Do the chemistry textbooks at the senior secondary school level present the true picture of the atom? We see that at the tertiary level, chemistry students begin with the historical development of the particulate nature of matter and progress to some complicated state of understanding the true nature of the atom. Chemistry textbook writers should consider the simplification of the true nature of the atom to the understanding of the students. After all, any subject can be taught effectively in some intellectually honest form to any child at any stage of development" [20].

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