

IMPACT OF CHEMISTRY STUDENTS' CONCEPTIONS AND MISCONCEPTIONS ON THEIR ACADEMIC ACHIEVEMENT IN STOICHIOMETRY

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Abstract

The study is on evaluating the impact of school location, school type and academic achievement on chemistry students' alternative conceptions and misconceptions in stoichiometry. Two research questions were raised to guide the study and one hypothesis formulated. The descriptive survey design was used for the study. The stratified random sampling technique was used to assign the strata into school types (public and private schools). 673 SS II Chemistry students were selected from 10 senior secondary schools in Warri South Local Government Area of Delta State. The instrument for the study was a two-tier Chemistry Achievement Test (CAT). The research instrument has two sections. Section A contains general information about the school and the students while section B was a 30 multiple choice test items with reasons for choosing the option. The research questions were analyzed using frequency, percentages and mean and standard deviation, and independent sample t-statistics was used to test the hypothesis at .05 level of significance. The results showed that a high percentage of the students holds correct conceptions about stoichiometry in Warri South Local Government Area. The result also showed that there is no significant difference between male female secondary school student correct conception and misconception of stoichiometry. From the findings, it was recommended that secondary school students should be taught stoichiometry using electronic centred teaching methods and that teachers should be trained through seminar and workshop for them to acquired skills needed for their usage.

Keywords: *Stoichiometry, Alternative Conceptions, Misconceptions and Chemistry Learning Difficulties*

Introduction

Science can be viewed as a continuing human effort to systematize knowledge for describing and understanding nature. Chemistry as a science subject deal with the composition, structure, properties and interaction of matter and is of use to human beings in daily life. These aspects can be best described and understood in terms of basic constituents of matter that are atoms and molecules. That is why chemistry is also called the science of atoms and molecules. Chemistry as a subject has many topics in its syllabus of which Stoichiometry and chemical equilibrium are one of them. Stoichiometry is an important part of many practicing chemists' work. This concept in

chemistry calculates the maximum amount of product that can be obtained from a reaction, with the assumption that it is the only reaction occurring and all products are collected. It is about determining the theoretical yield of a chemical reaction (Eya & Ugah, 2022).

Stoichiometry cuts across many sub disciplines of chemistry such as analytical chemistry, physical chemistry and organic chemistry. Hence, the instruction of stoichiometry problem solving is considered an essential part of the curriculum for senior secondary school chemistry students. Stoichiometry and chemical equilibrium are

chemistry topics studied by secondary school science students and these topics consist of abstract concepts. Abstract concepts can only be visualized at the atomic level, then to understand the chemical phenomenon requires the integration of three levels of representation, namely macroscopic, submicroscopic and symbolic (Blosser, 2018). Nakhleh (2019) asserted that in order to obtain a complete understanding of chemical concepts, integration of conceptual and algorithmic understanding is required. More students successfully balanced the equations. However, few of them could not explain the equation in the microscopic system. This makes the subject matter for the Stoichiometry and Chemical Equilibrium difficult to understand by senior secondary school student. These difficulties can lead to misconceptions if it happens continuously (Gabel & Sherwood, 2020). Misconceptions are also called alternative concepts or Spontaneous Knowledge (Dahsah & Coll, 2017). Studies such as: Opara (2014); Ajayi (2017); Mandina and Ochnogor (2018); Etokeren, et al, (2019); Mahafa, et al, (2022) all reported that two of the many reasons behind student's inability to understand stoichiometry: are that stoichiometry is an abstract topic and secondly, the chemical vocabulary associated with solving stoichiometric problems seems to prevent students from applying their mathematical skills to chemical phenomena in the learning process. Learning process is an active process and what students do with facts and ideas with which they have.

Learning is an active process, and what students do with facts and ideas with which they have been presented depends to a very high degree on what they already think and believe. Teachers' recognition and working with these student-held ideas and conceptions is thus a key component of an effective educational strategy. Students who do not fully understand the mole experience difficulties in understanding the subsequent topics (Taha, et al., 2014). Especially, in stoichiometry

problems since the calculations revolve around the mole concept. Stoichiometry calculations have been considered difficult by secondary school students in general chemistry (Hanson & Wolfskill, 2018). This is due to the many different facets a student must master, such as the mole concept, balancing chemical equations, algebraic procedures, and interpretation of a word problem into mathematical equations that serve as procedural steps which would then lead to the correct answer. Tarha and Ishmail (2019) have shown that secondary students have difficulties in dealing with the abstract concepts required of them to perform stoichiometric calculations using the mole concept. They also found that for students to solve stoichiometric problems, they must also be able to apply a thorough understanding of the principle involved in mole ratio and proportion calculations.

Mulford and Robinson (2022) asserted that alternative conceptions play a larger role in learning chemistry than simply producing inadequate explanations to questions. Students at secondary school level either consciously or subconsciously construct their concepts as explanations for the behaviour, properties or theories they experience. They believe most of these explanations are correct because these explanations make sense in terms of their understanding of the behaviour of the world around them. Consequently, if students encounter new information that contradicts their alternative conceptions it may be difficult for them to accept the new information because it seems wrong.

Misconceptions are delineated as ideas or insights from students who provide incorrect meaning constructed based on an event or personal experience (Martin, 2011). Science misconceptions are individual knowledge gained from educational experience or informal events that are irrelevant or not having the meaning according to scientific concepts (Allen, 2014; Soeharto, et al., 2019). In summary, the misconception in science can be described as

secondary school students' ideas from life experience or informal education, which is not structured well and resulting in the incorrect meaning according to a scientific concept. It causes the students, mostly those with low academic achievement, to understand related concepts wrongly. In chemistry, this problem is very obvious since it involves scientific terms that are rarely heard by the students. Essentially, when students enter the classroom, they go through the learning process by having different thoughts or knowledge based on their past experiences. This sort of thinking influences their ways of learning which is often based on non-scientific belief or naive conception (Blosser, 2019).

Statement of the problem

One of the challenges that have been found in today's chemistry education is the effective instructional strategies (Agboro-Eravwoke, 2020), and adequate laboratory resources. The consequence is learning misconceptions, particularly in balancing basic stoichiometry. The content of basic stoichiometry in the senior. Errington and Bubna-Litic (2015) described learning objectives and questions in the current textbooks as inappropriate for promoting critical thinking secondary school textbook does not seem to engage the students in meaningful thinking. Particularly, if teachers' chemistry content knowledge and teaching strategies are inappropriate, conceptual understanding of basic stoichiometry will continue to be challenging. However, inadequate instructional hours could be very challenging too for a teacher to accomplish and eloquently address the demand of learning objectives and questions. This may pose difficulties to students' learning, and as they move from one class to another, content also changes from simpler to complex. Hence, it seems that instructors must first focus on developing students' knowledge base and skills base. Without these, students could not succeed in true problem solving. Thus, highlighting the relevance of the study on chemistry students'

conceptions about stoichiometry. An analysis of students' achievement from 2010-2022 the percentage number of students' made a credit pass in chemistry ranged from 44.16%-46.16%. From 2010-2012, the percentage of students who obtained a credit pass was below 50% except in 2010 with 50.7%. From 2013-2016, there was a persistent decline in the percentage of those who made a credit pass from 72.34% in 2013, to 62.49% in 2014, to 60.6% in 2015 and 57.74% in 2016.

From 2017-2022, reports on the worst academic achievement of students in chemistry were observed. This is because in 2018 through 2022, students' highest point of decline was observed. This has resorted to the upspring of so many researches into students' alternative conceptions and misconceptions about chemistry topics as it is perceived to be vital to their academic achievement in the subject.

Method of the Study

The study adopted the descriptive survey design. The population of the study was made up of public and private senior secondary class two chemistry students, with total population of 2,446. There are 16 public and 22 private senior secondary schools in Warri South Local Government Area in Delta State. The sample for the study was 673 SS II Chemistry students was from 10 senior secondary schools in Warri South Local Government Area of Delta State. The simple random sampling technique was adopted. The schools were stratified based on type of school: public and private. Five schools from each stratum were selected. All the SS III Chemistry students in each selected school participated in the study.

The instrument for the study was a 30 multiple choice test item two tier Chemistry Achievement Test. Each item has two parts, an answer and a reason part. A correct answer with correct reason indicates a correct conception and a correct

answer with wrong reason or vice versa indicates an alternative conception while wrong answer with wrong reason or vice versa indicates misconception. The answer part of the items was constructed from previously standardized WAEC (West African Examination Council) examination questions also the reasons were constructed from the recommended and approved Chemistry texts. SPSS package was used for data analysis. Descriptive statistics such as mean and standard deviation was used to answer the research questions. One-Way ANOVA was used to test the hypotheses at 0.5 level of significance.

Results

Research Question 1: Examine the alternative conceptions and misconceptions of secondary school students about stoichiometry in Warri South Local Government Area.

Table 1: Frequency and Percentages showing Misconceptions of students about stoichiometry in Warri South Local Government Area

S/N	MISCONCEPTIONS	ANSWER	Correct Conception F(%)	Misconception/ Alternative Conception F(%)
1	Derived dimensions are those that can be developed in terms of fundamental dimensions.	Correct	370 (55%)	303 (45%)
2	lb mole = mass in lb/molecular weight.	correct	532 (79%)	141(21%)
3	lb mole = mass in lb/mass	Not correct	301 (44.7%)	372 (55.3%)
4	To covert, first convert 15 g mole of NaOH to grams of NaOH, and then use the conversion of 1 lb = 454g.	Correct	458 (68%)	215 (32%)
5	Number of moles = mass/mole	Not correct	298 (44.3%)	375 (55.7%)
6	Number of moles = mass / molecular weight.	Correct	431 (65%)	242 (36%)
7	Standard dimensions are those that can be developed in terms of fundamental dimension.	Not correct	372 (55.3%)	301 (44.7%)
8	Fundamental units are not those that can be measured independently.	Not correct	307 (45.6%)	366 (54.4%)
9	This chemical equation is balanced: Moles of Oxygen = Moles of NaOH + Moles of H ₂ O + 4(Moles of H ₂ SO ₄).	Not correct	341(50.7%)	332 (49.3%)
10	Fundamental unit does not require measurement	Not correct	401(59.6%)	272 (40.4%)
11	Weight percentage = Total mass / mass of the component	Not correct	395 (58.7%)	278 (41.3%)
12	It is called Molecular weight because it	Not correct	367 (54.5%)	306 (45.5%)

	contains 6.022×10^{23} amount of substance			
13	Mole percentage = Moles of the component / Total moles	Correct	431 (65%)	242 (36%)
14	It is called Mole because it contains 6.022×10^{23} amount of substance.	Not correct	369 (54.8%)	304 (45.2%)
15	A gm mole is composed of 6.022×10^{23} molecules and 1 lb mole is 453.6 times a gm mole.	Correct	486 (72.2%)	187 (27.8%)
16	Molecular weight is the ratio of mass and mole	Not correct	370(72.2%)	303(45%)
17	Number of moles = mass/ molecular weight can be used to calculate the number of moles of a substance when the mass of the substance and its molecular weight are known	Correct	395 (58.7%)	278 (41.3%)

The result in Table 1 showed that 370 of the secondary school students representing 55% hold correct conception while 303 of them representing 45% of students hold misconception/alternative conception about derived dimensions are those that can be developed in terms of fundamental dimensions. Also, the result in the table showed that 532 of the secondary school students representing 79% of them hold correct conception while 141 of them representing 21% of secondary school students hold misconception about lb mole = mass in lb/molecular weight, of the students do not. More so, 372 of the secondary school students representing 55.3% of them hold correct conception while 301 of the students representing 44.7% of the them hold misconception about lb mole = mass in lb/mass, Also, the student's response to; to covert, first convert 15g mole of NaOH to grams of NaOH, and then use the conversion of 1 lb = 454g, showed that 458 of them representing 68% of the secondary school students hold correct conception while 215 of them representing 32% of secondary school students have misconception about. The result in the table above also showed that 375 of the secondary school students representing 55.7% have correct conception about the statement that Number of moles = mass/mole while 298 of them representing 44.3% of the secondary school students hold misconception. Also, the result in the table showed that 431 of the secondary school

students representing 65% of the them hold correct conception while 242 of them 36% of the secondary students hold misconception about the statement that Number of moles = mass/molecular weight. Furthermore, the result in the table also showed that while 301 of the secondary school students representing 44.7% of them have correct conception while 372 of them representing 55.3% of the secondary school students hold misconception about the statement that Standard dimensions are those that can be developed in terms of fundamental dimension. More so, 272 of the students representing 40.4% of the students have correct conception while 401 of them representing 59.6% of the secondary school students hold misconception about the statement that Fundamental unit does not require measurement. The result in the table also showed that 306 of the secondary school students representing 45.5% of them hold correct conception while 367 of them representing 54.5% of secondary student hold misconception about the statement that it is called Molecular weight because it contains 6.022×10^{23} amount of substance. More so, the result in the Table also showed that 242 of the secondary school students representing 36% of the them holds correct conception while 431 of them representing 65% of them hold misconception about the statement that Mole percentage = Moles of the component/Total moles. Furthermore, the result

in the table also showed that 486 of the secondary school students representing 72.2% of them have correct conception while 187 of the secondary school students representing 27.8% of them hold misconception about the statement that A gm mole is composed of 6.022×10^{23} molecules and 1 lb mole is 453.6 times a gm mole. The result in the table also showed that 303 of the secondary school students representing 45% of them hold correct conception while 370 of them representing 55% of secondary school students hold misconception about the statement that Molecular weight is the ratio of Mass and Mole Lastly, the result in the table also showed that 395 of the secondary school students representing 58.7% of them have correct conception while 278 of the secondary school students representing 41.3% of students hold misconception about the statement that Number of moles = mass/molecular weight can be used to calculate the number of moles of a substance when the

mass of the substance and its molecular weight are known. This implies that student's misconception about stoichiometry are that: lb mole = mass in lb/mass, Number of moles = mass/mole, Standard dimensions are those that can be developed in terms of fundamental dimension, Fundamental units are not those that can be measured independently, this chemical equation is balanced: Moles of Oxygen = Moles of NaOH + Moles of H₂O + 4(Moles of H₂SO₄), Fundamental unit does not require measurement, Weight percentage = Total mass/mass of the component, it is called Molecular weight because it contains 6.022×10^{23} amount of substance, and Molecular weight is the ratio of Mass and Mole.

Research Question 2: What is the difference between the male and female conceptions and misconceptions of School secondary about stoichiometry in Warri South Local Government Area.

Table 2: Mean and Stand deviation showing Male and Female Secondary School Students correct Conceptions and Misconceptions about Stoichiometry in Warri South Local Government Area

Sex	Correct conception				Misconception			
	N	Mean	Mean Diff	SD	Mean	Mean Diff	SD	
Male	310	26.38		6.06	20.98	3.81		
		.31			.41			
Female	363	26.69		6.18	21.41	6.06		

Table 2 showed that the male students have a correct conception mean score of 26.38 and a standard deviation of 6.06 while their female counterpart had a correct conception mean score of 26.69 with a standard deviation of 6.18. There exists a correct conception mean difference of .31 in favour of the females. Also, the table shows that the male students had a misconception mean score of 20.98 and a standard deviation of 3.81 while their female counterpart had a misconception mean score of 21.41 with a

standard deviation of 6.04. There exists a misconception mean difference of .31 in favour of the females. To determine if these differences are significant, independent sample t-test statistics was used to test H₀₁ Government Area. **H₀₁:** There is no significance difference between the mean scores of male and female secondary students' correct conceptions and misconceptions about stoichiometry in Warri South Local Government Area

Table 3: Independent Sample Statistics Comparing Male and Female Secondary School Students Correct Conceptions and Misconceptions about Stoichiometry in Warri South Local Government Area

Sex	Correct conception					Misconception					
	N	Mean	Mean	SD	df	tcal	Sig (2tailed)	Mean	Mean	SD	
Male	310	26.38	6.06			20.98	3.81				
		.31	671	.664	.520		.41		671	1.505	.133
Female	363	26.69	6.18			21.41	6.06				

Table 3 showed that the difference between the male and female chemistry students correct conception and misconception of stoichiometry is not significant since the calculates significant value of .520 and .133 are greater than .05 alpha level of significant with this, H_{01} which states that

there is no significance difference between the mean scores of male and female secondary students' correct conceptions and misconceptions about stoichiometry in Warri South Local Government Area is retained.

Discussion of Findings

The first finding of the study shows that a high percentage of the secondary school students holds correct conception of stoichiometry compared to the misconception. The study revealed that students' misconception about stoichiometry are that: lb mole = mass in lb/mass, Number of moles = mass/mole, Standard dimensions are those that can be developed in terms of fundamental dimension, Fundamental units are not those that can be measured independently, this chemical equation is balanced: Moles of Oxygen = Moles of NaOH + Moles of H₂O + 4(Moles of H₂SO₄), Fundamental unit does not require measurement, Weight percentage = Total mass/mass of the component. It is called Molecular weight because it contains 6.022×10^{23} amount of substance, and Molecular weight is the ratio of Mass and Mole. This finding is in line with Gabel and Sherwood (2020) who asserted that some senior secondary school students could not explain the equation in the microscopic system. This makes the subject matter for the Stoichiometry and Chemical Equilibrium difficult to understand by students and also in consonance with Hanson and

Wolfskill (2018) who asserted that stoichiometry calculations have been considered difficult by students in general. This is due to the many different facets a student must master, such as the mole concept, balancing chemical equations, algebraic procedures, and interpretation of a word problem into mathematical equations that serve as procedural steps which would then lead to the correct answer.

The second finding of the study shows that there is no significant difference between male and female secondary students' correct conception and misconceptions mean scores about stoichiometry in Warri South Local Government Area. This shows that male and female students have same level of understanding and lack of understanding of the concept of stoichiometry. This may be due to the method that is used to present the concept to them by their teachers. This finding is in line with that of Samuel, et al (2024) whose findings shows no significant gender-based difference on students' conception.

Conclusion and Recommendations

This study examined the impact of students' correct conceptions and misconceptions on their

academic achievement in stoichiometry. Based on the findings of the study, the researcher concludes that a high percentage of secondary school students have correct conception about stoichiometry and that the misconception held about stoichiometry includes: lb mole = mass in lb/mass, Number of moles = mass/mole, Standard dimensions are those that can be developed in terms of fundamental dimension, Fundamental units are not those that can be measured independently, this chemical equation is balanced: Moles of Oxygen = Moles of NaOH + Moles of H₂O + 4(Moles of H₂SO₄), Fundamental unit does not require measurement, Weight percentage = Total mass/mass of the component, It is called Molecular weight because it contains 6.022×10^{23} amount of substance, and Molecular weight is the ratio of Mass and Mole. And that there is no significant difference in the male and female secondary school students mean conception scores of stoichiometry.

Based on the finding of the study, the researcher recommends that electronic centred teaching methods should be used in teaching the concept of stoichiometry so that students will be able to observe the concept visually and participate effectively in the teaching and learning process and teachers should be trained through seminars and workshops on how to use these methodologies in order to enable them acquire the skills needed for their usage

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