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Development of a Diagnostic Test in Iupac Nomenclature of Chemical Substances for Senior Secondary School Chemistry Students

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Abstract
The focus of this study was to develop a diagnostic test in the concept of IUPAC nomenclature for senior secondary schools which could be used to find out students misconceptions causing their inability to write the IUPAC names of chemical substances correctly. The study is an instrumentation research which had an ex-post facto dimension due to the fact that the researchers also investigated the percentage of students misconceptions based on gender. A sample of 1080 (576, males and 504, females) senior secondary two (SSII) chemistry students from the 72 public secondary schools in Owerri Education zone I of Imo state were selected using proportionate cluster random sampling technique. Three research questions that guided the study were answered using Kuder-Richardson formula 20 (K-R_{20}) and percentage while the hypothesis was tested using chi-square. The instrument used for data collection was the diagnostic test in IUPAC nomenclature of chemical substances which the researchers developed. Results from the study showed that the diagnostic test developed is valid and highly reliable with a coefficient reliability of 0.81. It was revealed that both the male and female students exhibited numerous misconceptions in the writing of the IUPAC nomenclature of chemical substances. Also it was discovered that the percentage score of wrong responses of students was significantly not dependent on gender. It was recommended amongst others that the diagnostic test should be used during classroom instructions (formative assessment) to identify common misconceptions in IUPAC naming system early enough to offer remediation before any summative examination.

Keywords: Diagnostic test, Chemistry IUPAC nomenclature.

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I. Introduction

One of the major functions of effective teaching and learning process of the school system is the evaluation of the students in what they have been taught in order to determine the extent to which instructional objectives are achieved by the students. Evaluation according to Onunkwo (2002) involves testing, assessing and measurement. By definition, test is regarded as the presentation of a standard set of questions to be answered which adequately qualify for the evaluation of the examinees in cognitive, affective and psychomotor domains of learning (Kpolovic, 2010). If the questions in the test instrument are targeted at eliciting information on the cognitive or intellectual abilities, such a test is referred to as achievement test, intelligent test or aptitude test. Achievement tests are used to measure the outcome of teaching and the quantity and quality of progress learners have made in a particular subject or group of subjects. In some cases the feedbacks from such test may indicate or determine why some students are finding a certain learning area difficult, when such is the case, it is known as diagnostic test/evaluation. According to Nwana (2007) therefore diagnostic/evaluation is a process of determining the cause of persistent learning difficulties, while carrying it out, it demands that the root cause of the difficulty be discovered, isolated and remedied so that the affected students may overcome their difficulty in the dictated areas and continue their normal education.

Chemistry is a core science subject and its importance in the study of most sciences are obvious. A credit pass in the study is required in many courses such as engineering and medicine in the university. The importance of chemistry for the development of any nation cannot be over emphasized, however, students poor performance in senior secondary school certificate examination have been observed (Ojukwu, 2016 and Asikhia, 2010). Poor performance in chemistry is an indication that students have difficulty in learning and mastering the content taught them and applying them when they are under examination conditions. This is buttressed by the chief examiners reports in Chemistry (2017) where they listed areas candidates exhibited weaknesses and amongst them was their inability to correctly write IUPAC name of compounds. According to them this was reflected evidently in their various responses to all questions answered which may not unlikely be that students had difficulty grappling with the concepts of valency and oxidation states of substances. According to Yarroch (1985), Andersson, (1980), Johnstone (1991) and Nakhleh and Krajeik (1994), one of the reasons for the difficulties that students experience in understanding the nature of matter (Chemistry is the study of matter) is related to the multiple levels of representations of valencies and oxidation states of elements that are used in chemistry instruction to describe and explain chemical phenomena and nomenclature of compounds.

IUPAC (International Union of Pure and Applied Chemists) was founded in 1919 by Chemists from industry and academia who recognized the need for international standardization in chemistry. The standardization of weights, measures, names and symbols is essential to the well being and continuous success of the scientific enterprise and the smooth development and growth of international trade and commerce. These move of body of chemists led to the nomenclature (i.e naming) of inorganic and organic compounds, standardization of organic weights, standardization of physical constants, editing tables of properties of matter to mention but a few. Believe it or not it is easier to have IUPAC rules and names than to name compounds after someone/something or give them nick-names. It would amount to confusing learners because there are so many compounds and we want to know everything about some compounds just by reading the name. For example formic acid (HCOOH) as was called before but now by IUPAC, known as methanoic acid shows that it is a carboxylic acid with functional group COOH, from the simplest alkane group called methane. Next in line is acetic acid (CH_3COOH) as was formally called, but now by IUPAC known as ethanoic acid, shows that it is a carboxylic acid with functional group COOH and from the next alkane after methane known as ethane. An inorganic substance with formula H_2SO_4 formally called sulphuric acid but now known by IUPAC as tetraoxosulphate (vi) acid, tetra oxo because there are four (tetra) oxygen (oxo) atoms present, sulphate (vi) because six is the oxidation number of sulphur in the compound and the word acid is included in the name because of the presence of hydrogen. Carbon dioxide (CO_2) now called carbon (iv) oxide is because the oxidation number of carbon in the oxidized form is 4. Buttressing the above fact, IUPAC nomenclature is a set of logical rules devised and used to teach learners so as to circumvent problems caused by arbitrary nomenclature. Considering an organic compound for example, given the IUPAC name, one should be able to write a structural formula because students are meant to know generally that the IUPAC name will have three essential features:

- A root or base indicating a major or chain or ring of carbon atoms found in the molecular structure.
- A suffix or other element(s) designating functional groups that may be present in the compound.
- Names of substituent groups, other than hydrogen that complete the molecular structure.

Therefore, saying 2-propanone means, giving a descriptive name to describe a ketone with three carbon atoms on it (hence "prop"), as well as the middle carbon being part of the carbonyl group (hence "one") giving the structural formula as CH_3COCH_3. At the secondary school level IUPAC nomenclature of substances are taught by grounding the learners on the concept of valencies and oxidation numbers of substances. Valency is defined as the combining capacity of an atom while oxidation number is the charge an atom can carry (Greenwood and Earnshaw, 1997). For instance nitrogen has the valency of 3 and 5 and its oxidation number can range from – 3 to – 5.

The theoretical basis of this study is the constructivist approach that is grounded in the belief that what a learner already knows is a major factor determining the outcome of learning. (Ausubel, 1968). The complex and abstract nature of chemistry makes the study of the subject difficult for students (Johnstone, 1993, Nakhleh, 1992, Gabel, 1999 and Treagust and Chittleborough, 2001). As a result students tend to hold particular idiosyncratic views or understanding about scientific phenomena and concepts that they bring with to science lessons. These different forms of understanding according to Clement, Brown and Zutsman (1989), Driver and Easley (1978) and Helm (1990) are known as misconceptions. These misconceptions are the result of several factors such as their sensory experiences and influence of their cultural background, peers, mass media as well as classroom instruction (Duit and Treagust, 1995). The term misconception stresses or showcases differences between the ideas the student bring to instruction and the concepts by the current scientific theories or for short, conceptions that contradict scientifically accepted theories. Studies carried out by Ahmed, Tariq and Tahseen (2012) and Uzezi, Ezekiel and Auwal (2017) highlighted the existence of these misconceptions amongst chemistry students while that of Ahmed et al observed no significant difference between girls and boys and that of Uzezi et al found out that there was significant influence of gender, school nature and school location on students misconceptions. Methods to diagnose misconception in a valid and reliable way have great importance in science education. This is the motive behind every effective scientific instruction because it is all about understanding of wrong and flawed conceptions that impede learning or the identification of productive components of these flawed conceptions for other contexts. Therefore the identification of these misconceptions in a valid and reliable way which help the students improve themselves more on scientifically acceptable concepts cannot be over emphasized. This is achieved with the use of diagnostic tests.

Diagnostic tests are assessment tools which are concerned with the persistence or re-occurring learning difficulties that are left unresolved and are the causes of learning difficulties (Gronlund 1991). In other words, they are instruments that bring to light the disparity between what we want our students to know or learn and what they really know or learn. A number of them have been developed as recorded in literature such as:

- Acid-Bases Diagnostic Test (ABDT) by Andej, Ratanarontai, Coll and Thorngpenchange 2010.
- States of Matter Diagnostic Instrument (SMDT) by Kirbulut and Geban 2014.
- Thermodynamics Diagnostic Instrument (THEDI) by Sneenivasnlu and Subramaniam 2013.
- Heat and Temperature Concepts Test (HTCT) by Baser and Geban 2007.

All these examples are foreign ones, confirming the statement of Nwana (2007), that there has not been enough researches in the field of diagnostic testing in Africa and Nigeria in particular to determine the trend of these misconceptions. The great need to tackle these misconceptions leading to poor performance in chemistry as recorded by WAEC chief examiner exhibited in students inability to correctly write IUPAC name of compounds is what has lead to the development of a diagnostic instrument or test in IUPAC nomenclature or naming system for senior secondary schools.

There are several ways to diagnose students misconceptions in science ranging from Interview, Open-ended tests, ordinary multiple choice test, two-tier multiple choice test, three-tier multiple choice test and four-tier multiple choice test. For the purposes of this study, the ordinary, multiple choice test (MCT), is preferred to the others as serving the purpose.

In the mind of the researchers the following were aimed at:

1 Establish the validity and reliability of the test instrument developed
2 Identify student's misconceptions from the percentage of wrong responses in the test items.
3 Determine the percentage score of wrong responses in the test items based on students gender.

In other to achieve the above objectives, three research questions and one hypothesis were raised making a total of four.

1 What is the reliability coefficient of the instrument developed
2 What are the identified students misconceptions from the percentage of wrong responses in the diagnostic test
3 What are the percentage scores of wrong responses of test items based on student's gender.
4 There is no significant difference between the percentage score of wrong responses of male and female chemistry students on the items of the test ($P < 0.05$).

II. Method

The study is basically an instrumentation research with ex-post facto design. This is because a new instrument of educational practice is developed and the involvement of the gender variable makes it to have an ex-post facto design dimension. The population of the study is all the senior secondary (SS2) chemistry students in all the 72 public secondary schools in Owerri zone I of Imo State. The study employed a multi-stage sampling procedure involving cluster, proportionate and random sampling techniques. This was used to select 1080 SS2 chemistry students (M = 8, F = 7) making a total of 15 students from each of the 72 schools.

Diagnostic test in IUPAC nomenclature of chemical substances for senior secondary schools developed by the researchers served as the instrument used for data collection. It has a total of 20 – items patterned after the ordinary multiple choice test (selected from the initial pool of 50 - items) which was constructed based on the test blue print developed from IUPAC nomenclature of chemical substances in SSS chemistry curriculum. Each of the multiple choice items was configured to consist of a question stem followed by five options of one correct answer or key and four incorrect options that were used to minimize probability of guessing by students as only good distracters were used. The items were validated by 5 experts, 2 in chemistry and 3 in measurement and evaluation. They were asked to do a careful editing and critical review of the wordings of the items in order to avoid the inclusion of irrelevant defective items and to establish the face and content validity of the instrument. The validated items of the instrument were trial tested on 200 students, who were not part of the sample. With the use of Kuder-Richardson formula 20, the internal consistency reliability was established with a coefficient value of 0.81. The instrument was then administered to the sampled students in their respective schools with the help of their teachers. While the students were writing the test, the researchers went round to make sure that the students indicated their gender on their test scripts.

After administering the test, the students scripts were collected and scored to indicate their wrong responses which was used to identify their inability to correctly write IUPAC names of compounds (misconceptions). The data generated were subjected to analysis based on the research questions and hypothesis. The level of misconceptions exhibited by the students were judged as follows; 0-29 (very low),30-39 (low), 40-49 (moderate) 50-59 (very moderate), 60-69 (high), 70 and above (very high). Research question one, which is on the reliability index of the instrument was answered using Kuder- Richardson formula (KR-20). Research question two and three were answered using simple percentage while null hypothesis was tested using chi-square test statistics.

III. Result

Research Question 1: What is the reliability coefficient of the diagnostic test?

To answer the research question on the reliability coefficient of the diagnostic test instrument, 200 Chemistry SS II students were selected who were not part of the sample for testing. These 200 students took the validated diagnostic test items, through the use of Kuder-Richardson (KR-20) formular for determining internal consistency of an instrument, a reliability coefficient of 0.81 was determined. A value of 0.81 shows that the instrument developed has a high reliability index.

Research Question 2: What are the identified student's misconceptions in IUPAC nomenclature of chemical substances from the percentages of wrong responses in the diagnostic test?

Table 1: Showing Percentage Wrong Responses of the 1080 students from the Identified Misconceptions in the Diagnostic Test.

Items No.	Topics Students Exhibited Misconceptions	Topics No. of Items	Item Range Total	Responses		Remarks
				Wrong Response	Percentage Wrong Responses	
1 - 2	Electrons and Valency	2	2160	1231	57	Very Moderate
3 – 4	Valency versus oxidation number	2	2160	1512	70	Very High
5 – 8	Variation of valency versus oxidation state for bonds between elements in compounds	4	4320	3499	81	Very High
9 – 10	Maximum number of bonds	2	2160	1382	64	High
11 – 12	Maximum valency of elements (periodic table)	2	2160	1469	68	High
13 – 16	Rules of IUPAC naming and formular of inorganic compounds	4	4320	3110	72	Very High
17 – 20	Rules of IUPAC naming and formular of organic compounds	4	4320	3240	75	Very High

Table 1 above shows that the identified students level of misconceptions in the diagnostic test instrument is quite high (very high = 4, while high = 2). Only one was very moderate = 57% while others ranged from high to very high 64% - 81%.

Research Question 3: What are the percentage scores of wrong responses of test items based on students gender.

Table 2: Showing Students Percentage Scores of Wrong responses based on their gender.

Students Gender	No. of Students	Wrong Response Scores	Percentage Score of Wrong Responses
Male	576	8185	53
Female	504	7258	47
Total	1080	15443	100

From table 2 above the percentage scores of wrong responses of the male and female chemistry students are respectively 53% and 47%.

Hypothesis I: There is no significant difference between the percentage scores of wrong responses of male and female chemistry students to the items of the test ($P<0.05$).

Table 3: Chi-square (X^2) test of male and female students wrong Responses to the test items.

Test Statistics	Gender	Wrong Responses
Chi-square	1.008	489.989
Degree of Freedom	1	13
A symp. Sig	0.316	.000

Analysis of Table 3 above shows that the P value of 0.316 is greater than the 0.05 alpha level of significance. This indicates that there is no significant difference between the percentage scores of wrong responses of male and female chemistry students to the diagnostic test. Otherwise meaning that the null hypothesis is accepted.

IV. Discussion

The reliability coefficient value of 0.81 obtained, shows that the diagnostic test instrument developed is highly reliable. The study reveals the existence of numerous common misconceptions among secondary schools chemistry students in their inability to correctly write the IUPAC name of chemical substances, confirming the WAEC chief examiners report of (2017). Variation of valency versus oxidation state for bonds between elements in compounds had the highest percentage of 81. This also was confirmed by Yarroch 1985, Anderson (1980), Johnstone (1991) and Nakhleh and Krascik (1994) who stated that the reasons for the difficulties that students experience in understanding the nature of matter is related to the multiple levels of representations of valencies and oxidation states of elements that are used in chemistry instruction to describe and explain chemical phenomena and nomenclature of compounds. The students usually are not able to resolve the idea of variable nature of valencies and oxidation states of substances. Also revealed is that the percentage of students wrong misconception is not significantly based on gender of the students. This was contrary to the findings of Uzezi, Ezekiel and Auwal (2017) who found out that there were significant influence of gender, school nature and school location on students misconceptions but in agreement with that of Ahmed, Tariq and Tahseen (2012) who recorded an overall high proportion of gender misconceptions in boys as well as in girls which according to them points to a big problem for science educationists.

V. Conclusion

It can be concluded from the findings of the study, that the diagnostic test developed is valid and highly reliable. Therefore one of the ways to encourage more students to study science is by presenting science to them in such a way that through the teachers planned formative assessment using multiple-choice diagnostic test items, students can begin to question and understand the underlying science concepts. Through this type of teaching, students will be encouraged to think about the concepts and consider alternative explanations rather than memorise basic facts for a test or examination which are then forgotten.

VI. Recommendations

Based on the findings of this study, the researchers therefore recommend the use of these diagnostic instruments in classroom instructions as a means of planned formative assessment. This will also enable teachers diagnose students' misconceptions in particular areas as well as serve as a means of remediation prior to any summative assessment like WASSCE.

The ministry of education should organize cooperative group work as well as a variety of individual learning opportunities on diagnostic test development. When used effectively, these tests can contribute to student's deeper understanding of science concepts in the curriculum.

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