DEVELOPMENT OF A DIAGNOSTIC TEST IN ELECTROCHEMISTRY CONCEPTS FOR SENIOR SECONDARY SCHOOLS

Victoria Chinyere Amadi and Callista Chioma Egwim

Abstract

This study focused on the development of a diagnostic test in electrochemistry concepts for senior secondary schools that could be used to identify the students' common misconception in electrochemistry. A sample of 1046 (540 males and 506 females) SS2 chemistry students from the 68 public secondary schools in Owerri Education Zone I of Imo State were selected using proportionate cluster random sampling. This study is an instrumentation research that employs an ex-post facto design. Three research questions formulated were answered by percentage and Kuder-Richardson 20 and a null hypothesis tested with chi-square. Data were collected using the diagnostic test developed by the researchers. The research showed that the diagnostic test is valid and reliable with a reliability coefficient of 0.86 and found that the students hold numerous misconceptions, significantly independent upon their gender. Recommendations were made including the use of diagnostic test to assess chemistry students to identify and correct their common misconceptions in electrochemistry.

Learning is said to have taken place when there is a change in behaviour in the learner. For such a change in behaviour to occur, the learner must be actively involved in the learning process, when learners are actively involved in the learning process, they construct meaning by looking at the new ideas with their existing knowledge. Every course/subject in the school curriculum is designed to impact some knowledge, skills and attitude in the students and the knowledge required is ultimately for the national development. The inculcation of the learning outcome is achieved through teaching and learning while the achievement of these outcomes is determined or measured through evaluation. Evaluation in simple term can be defined as the process of measuring the degree of success in any activity or venture in relation to the set goals or objectives.

According to Nwana (2007), evaluation judge outcome and its results indicate which way to go, whether to sustain a programme, modify it or abandon it. In some cases, the feedback may indicate why students are finding a certain learning area difficult. This process of determining the cause of persistent learning difficulty is diagnostic evaluation (Gronlund, 1976; Lehrman & Mehrens, 1985 and Nworgu, 2003). The diagnostic evaluation procedure demands that the cause or source of the difficulty be discovered, isolated and remediation applied, to permit the students affected to overcome their difficulty in the area detected and hence continue with their programme smoothly, whether in science and technology, arts or business. This is an aspect where modification is required. One important subject in the physical sciences studied in the senior secondary school is chemistry. A credit pass in the subject is required in many courses such as medicine, engineering and other science related courses in the university education. In fact chemistry is a core subject. Nigeria cannot develop

successfully without students performing well in the subject-chemistry. Unfortunately, students' poor performance in this subject particularly in electrochemistry, has been a source of worry to the educational system. This is buttressed by the chief examiners' Report (2000 - 2008) and 2012 that, there is persistent students' weaknesses in answering questions in some chemistry concepts; one of which is electrochemistry. This research therefore, is focused on identifying the secondary school students common misconceptions in electrochemistry.

Electrochemistry is a branch of chemistry that deals with motion of electron in molten or aqueous solution, comprising the most important topics in chemistry and plays a great role in the practical life, as it forms the basic ingredient in sustaining life. Practically, besides the generation of electricity it is also used in the isolation, purification and extraction of some metals. The goal of effective science instruction is to encourage the students to construct an understanding that is generally consistent with accepted scientific theory. It is known that students use pre-existing conceptions constructed from previous experiences to reason about newly presented science concepts (Heller & Finley, 1992). Such preconceptions are often incorrect from a scientific view point and interfere with the students' learning (Fredrickson & White, 1992). The students incorrect patterns of responses or idea which are inconsistent with established scientific theories are referred to as "misconceptions". Englehardt & Berchner (2003) in their study on students' understanding of direct current resistive electrical circuit (DIRECT), reveal that students especially females tend to hold multiple misconceptions even after instructions. The misconceptions have to be identified so that measures can be taken to help students improve themselves more on scientifically acceptable concepts (Gubar, 2008). This can be achieved with the use of diagnostic tests. However there has not been enough research in the field of diagnostic testing in Africa in general and Nigeria in particular (Nwana 2007) to determine the trend.

A diagnostic test is a specialized form of achievement test in which the questions center on the common errors made by learners within a specified field of study (Nwana, 2007). It helps to reveal problems which may be inhibiting a student from future learning. Chambers & Andre (1995) in their study found that each student comes into a class not as a blank state but brings into the classroom a system of common sense beliefs and intuitions about the natural world through their everyday life experiences, these common sense belief may be very stable and often incompatible with the chemistry being taught in the school. Traditional instruction does little to change these beliefs and they cause some students to misinterpret the subject material.

Hestenes, Wells & Swackhamer (1992) developed an instrument called the Mechanics Diagnostic Test (MDT) which measured not the students' initial knowledge of Newtonian force but the discrepancy between the students' common sense beliefs and their belief in the Newtonian force concept. Many physical science instructors have reported students' difficulties with conceptual understanding after using the MDT, seeing exactly how poorly their own students performed. The value and the widespread use of this instrument (MDT) have led to the development of other multiple diagnostic tests in other areas of physical sciences. The researchers therefore developed a diagnostic

test in electrochemistry concepts for senior secondary schools to diagnose the students' understanding of electrochemistry with the following objectives in mind:

1. Ensure the validity and reliability of the test instrument.
2. Identify the percentages of wrong responses indicating students' misconception in electrochemistry from the test instrument.
3. Identify the percentage scores of wrong responses of male and female students.

Research Questions

1. What is the reliability coefficient of the diagnostic test instrument?

2. What percentage of wrong response indicates students' misconceptions in electrochemistry as identified from the test?

3. What are the percentage scores of wrong responses of the male and female students to the items of the test?

Hypothesis

1. The percentage score of wrong responses of the students is not significantly dependent on gender ($p<0.05$).

Method

This study is an instrumentation research as it involves the development of an instrument for educational practice. It also employs an ex-post facto design as the researcher also investigated the dependency of the students' common misconceptions on their gender.

The population for the study consists of all the 3383 senior secondary two (SS2) chemistry students in the 68 public secondary schools in Owerri Education Zone I of Imo State.

Multi-stage sampling procedure which involves cluster, proportionate and random sampling techniques was used to select 1046 SS2 chemistry students.

The instrument used for data collection was the diagnostic test in Electrochemistry concepts for senior secondary schools developed by the researchers. It comprises of 20 multiple choice test items. The test was developed following the rigorous step by step processes involved in test development which include: Identification of purpose, definition of the concept, development of a test-blue print, construction and review of an initial pool of items, trial testing, field-testing, determination of the statistical properties of the items, conducting reliability and validity studies for the final form of the test and preparing the administration guidelines for the test. The test items were constructed based on the test blue print developed from the electrochemistry concepts in the SS2 chemistry curriculum.

The test was subjected to validation giving the items to 5 experienced chemistry teachers and 4 experts in measurement and evaluation. The validation was also done by making sure that the test reflected the specifications on the test blue-print. The internal consistency reliability was established using Kuder-Richardson formula 20 and a coefficient of 0.86 was obtained.

The instrument was administered on all the 1046 SS2 chemistry students in the 21 secondary schools selected for the study with the help of their chemistry teachers. The researchers ensured that the students indicated their gender at the top of their test script. After the administration of the test, the student& scripts were marked and their wrong responses used in identifying their misconceptions. The data collected was analyzed with respect to the research questions and hypothesis. The decision rule for judging the level of misconceptions present among the students is presented as follows:

Percentage (%) - Level of Misconception

0-20	- very low
21-40	- low
41 60	- moderate
61-80	- high
81 - 100	- very high

The statistical tools used were; Kuder-Richardson formula 20 (K-R20) and chi-square test statistics. The hypothesis was tested at 0.05 level of significance.

Result

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

Through the use of Kuder-Richardson (K-R20) formula of determining the internal consistency reliability of an instrument, a reliability coefficient of 0.86 is determined, this shows that the instrument is highly reliable.

Research Question 2: What percentage of the wrong responses indicates students' misconceptions in the concept of electrochemistry as identified from the DTESSS?

Table 1: Percentages of the 1046 Students' Wrong Responses With Respect to the Identified Misconception From The Diagnostic Test.

Question Number	Students' misconception	No of Item	Responses		Percentage of wrong responses	Remark
			Item Range Total	Wrong responses observed		
1-3	Effect of electricity on matter, Arhenuis ionic theory	3	3138	1948	62	High
4-7	Electrolysis and its usefulness	4	4184	2092	50	Moderate
8-10	Faradays laws	3	3138	2325	74	High
11-12	Faraday and moles/molar mass of an element	2	2092	1359	65	High
13-15	Emf of a cell and operation of electrochemical cell/redox reaction	3	3138	2376	76	High
16-18	Conceptual undifferentiating	3	3138	2010	64	High
19-20	Phenominological unrelations	2	2092	1423	68	High

Table 1 above shows the percentage of wrong responses which indicates the various misconceptions identified from the DTESS. The levels of misconceptions identified which ranges from 62% to 76% were high, and only that of 50% was moderate.

Research Question 3: What are the percentage scores of wrong responses of the male and female students?

Table 2: Percentage of Students' Wrong Responses According to Gender

Gender	**No of Students**	**Wrong Response Score**	**% of Wrong Response**
Male	540	6842	51
Female	506	6691	49
Total	1046	13,533	100

From table 2, the percentage scores of wrong responses of male and female students are 51% and 49% respectively.

Hypothesis 1: The percentage scores of students' wrong responses is not significantly dependent on students' gender. ($P<0.05$)

Table 3: Chi-Square (X^2) Test of Students' Wrong Responses According to Gender.

	Gender	**Wrong responses**
Chi-square	1,008	489.998
Df	1	13
Asymp sig.	315	000

The P Value of 0.315 is greater than 0.05 level of significance which meets the criteria for accepting the null hypothesis. Thus, the percentage score of students' wrong responses to the items of the test is not significantly dependent upon gender.

Conclusion

The diagnostic test developed was found to be valid and highly reliable. The study established the existence of multiple common misconceptions among Secondary School Chemistry students in electrochemistry concepts. It reveals that this misconception were highly present among the students. This finding agree with the findings of Heller & Finley (1992) that students have common difficulties in understanding concepts related to electricity. E.m.f of a cell and operation of electrochemical cell had the highest percentage of misconceptions (76%). The study also reveals that the percentage of the students' wrong responses is not significantly dependent on their gender. This is in line with the findings of lhekwaba (2006) that the percentage of erroneous responses of students is not dependent on or related to gender, school type and school location but disagrees with the findings of Engelhardt & Beichner (2003) that the students wrong responses is significantly dependent on their gender. From the findings it can be concluded that the diagnostic test developed is valid and highly reliable and would go a long way to identifying students misconceptions and as well providing insight into students conceptual understanding of electrochemistry phenomena. Also that the students misconceptions were not significantly dependent on their gender, indicating that the students hold multiple misconceptions irrespective of their gender.

Recommendations

The researchers, based on the findings of this study, recommend that;

- The diagnostic test should be used to access the students and identify their common misconceptions in electrochemistry so that they can be corrected to prevent future learning hindrances and before going in for their senior school certificate Examinations.
- The ministry of education in collaboration with the secondary education management board should organize seminars and workshops to update the teachers on the best strategy for facilitating teaching and learning.
- Teachers should use the new chemistry teaching curriculum and strictly adhere to its guidelines and follow it accordingly to make teaching uniform. This will make the students to be able to compete with their counterparts in other schools.

Appendix I

Diagnostic Test in Electrochemistry Concepts for Senior Secondary School Students.

Time Allowed: 2 hours

Gender: Male Female

1. Which of the following substances decomposes when an electric current is passed through it?
A. Glucose Solution B. Hydrochloric acid
C. Zinc Rod D. Tetrachloromethane

2. The solution that will conduct the highest amount of electricity is; A. 2.0moldm^{-3} of ethanoic acid. B. 0.5 moldm^{-3} of ethanoic acid. C. 2.0 moIdm^{-3} of hydrochloric acid. D. 0.5 moldm^{-3} of hydrochloric acid.

3. In the Conductance of aqueous potassium tetraoxosulphate (vi) solution the current carriers are the; A. ions. B. Electrons C. Hydrated ions
D. Hydrated electrons.

4. When dilute copper (II) Chloride Solution is electrolysed, the reaction at the cathode is represented by the equation:
A. $Cu^{2+} + 2e$ -----> Cu
B. Cu-----> $Cu^{2+} + 2e$.
C. 4OH- 4e----> $0_2 + 2H_20$
D. 2CL------> CL2 + 2e.

5. A concentrated solution containing H^+, Cu^{2+}, OH and CL was electrolyzed using platinum electrodes. The ion that will be discharged at the cathode is;
A. H^+ B. Cu^{2+} C. OH^- D. CL^-

6. Which of the following substances on being electrolysed will produce mainly chlorine at the anode?
A. Dilute Sodium Chloride Solution
B. Dilute hydrochloric acid
C. Tetrachlorornethane
D. Concentrated potassium chloride solution.

7. Which of the following metals is purified commercially by electrolysis?
A. Zn B. Fe C. Sn D. Cu.

8. How many coulomb of electricity would be produced if a current of 0.4A flows for 1 hour?
A. 96500 coulombs B. 1440 coulombs
C. 9650 coulombs D. 144 coulombs.

9. Calculate the time it will take 96500C of electricity to be produced, when a current of 1.60A is used;
A. 0.5 minutes B.1.0 minutes
C. 10.0 minutes D. 100 minutes

10. Determine the amount of electrons needed to deposit 6.4g of copper during the electrolysis of copper (II) tetraoxosulphate (VI) solution (Cu=64).
A. 0.20mol B. 0.1mol C. 1.0mol D. 2.0mol

11. Consider the reaction represented by the following equation. $Fe^{2+}_{(aq)} + 2e$ ——--> $Fe_{(S)}$ How many moles of electrons are required to liberate) 112g of iron? (Fe=56) A. 2 B. 3
C. 4 D. 5

12. When a current L was passed through an electrolyte solution for 40 minutes, a mass Xg of a univalent metal was deposited at the cathodes What mass of the metal will be deposited when a current of 21 is passed through the solution for 10 minutes?
A. $(^{x}/_{4})_g$ B. $(^{x}/_{2})_g$ C. $2X_g$ D. $4X_g$

13. Consider the cell represented below;
$Mg_{(s)}/Mg^{2+}_{(aq)}//Pb^{2+}_{(aq)}/Pb_{(s)}$ Which of the following is correct about the cell?
A. It is an electrolytic cell
B. Pb is oxidized to Pb^{2+}
C. Mg is oxidized to Mg^{2+}
D. Each single line represents a salt bridge

14. In a leclanche cell, the anode is normally
A. Zinc container B. Ammonlum chloride paste C. copper vessel D. Carbon rod

15. The following are reactions that occur in motor car batteries EXCEPT
A. $Pb_{(s)} + H_2SO_{4(aq0} \text{-----> } PbSO_{4(s)} + 2H^+$
B. $Pb^{2+}_{(aq)} + SO_4^{2-}{}_{(aq)} \text{----> } PbSO_{4(s)}$
C. $Pb^{2+}_{(aq)} + 2H_2O_{(L)} \text{-----> } PbO_{2\,(g)} + 4H_{(aq)} + 2e^-$
D. $PbO_{2(g)} + 4H^+_{(aq)} + 2e \text{-----> } Pb^{2+}_{(aq)} + 2H_2O_{(L)}$

16. Energy conversion in an electrolytic cell is;
A. Chemical to electrical B. Electrical to Light
C. Electrical to mechanical D. Electrical to chemical

17. Electrolysis cannot be used to
A. Electroplate metals B. Extract electricity

C. Generate electricity D. Manufacture compound

18. One faraday is equal to
A. One mole of electron B. half a mole of electron
C. Two moles of electron D. 96500 coulombs

19. The mass of an element liberated at an electrode during electrolysis depends on which of the following? I. Nature of the electrode II. Quality of electricity passed III. Magnitude of electrical charge on its ion.
A. II only B. I, II and III C. II and III only D. I and II only.

20. Metals and graphite are good conductors of electricity because their atoms possess electron that is;
A. Stationary B. Static C. Mobile D.Flexible.

References

Chambers, S.K. & Andre, T. (1995). Are conceptual change approaches to learning science effective for every one? Gender, prior subject matter Interest and learning about electricity" *Contemporary educational psychology*. 20(4): 377-391.

Engelhardt, P.V. & Beichner, RJ. (2003). Students' understanding of direct current resistive electrical circuits. *American journal of physics* 72(1) p. 93- 115.

Frederickson, J. & White, B. (1992). Mental models and understanding: A problem for science education. In Scalon, E. and Oshea, T. (eds) *New directions in educational technology*. *NATO ASI seri*es F(196), 211-215.

Gronlund, N.E. (1976). M*easurement and Evaluation in teaching*. New York: Macmillan Publishing Co. Inc.

Gubar, W.R. (2008) Misconceptions on scientifically acceptable concepts. *American journal of science education*. 684) 181-183.

Heller, M.P. & Finley, N.F. (1992). Variable uses of alternative conceptions. A case study in rent electricity. *Journal of Research in Science Education*, 29(3),259-276.

Hestenes, D. Wells, M., & Swackhamer, G. (1992) *Force concept inventory*, *Physics Teacher*, 30(3), 141-158.

Ihekwaba, C.N. (2006). *Development and Validation of A Diagnostic Physics Test for Senior Secondary Schools in Imo State*. Unpublished Ph.D dissertation, Imo State University.

Merhrens, W.A. & Lehmann, I.I. (198S). *Measurement and Evaluation in Education and Psychology*. New York: Holt: Rinehart and Winston.

Nwana, O.C. (2007). *Educational measurement and evaluation.* Owerri: BomaWay Publishers.

Nworgu, B.G. (2003). *Measurement and evaluation: Theories and Practice*. Nsukka: University trust Publishers.

West African Examination Council (2012). *Chief examiners' Reports in Chemistry.*