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Chemical Analysis of Corrosion of Metals: A Resource for Teaching Difficult Concepts of Redox Reactions and Electrochemistry in Tertiary Institutions

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Abstract **- The research study was on the Chemistry of corrosion of metals – as a resource for teaching the concepts of redox reactions and electrochemistry through deployment of materials within the learner's immediate environment. This was undertaken to find a solution to persistent students' poor performance on the difficult concepts of redox reactions and electrochemistry in tertiary institutions. Three hypotheses were formulated to guide the study in investigating the effects of gender and computational ability on students achievement on the concepts, when exposed to experiments on the corrosion of metals and standard galvanic cell experiments, relevant literature were reviewed on various subheadings like improvisation in science teaching, students' academic performance in science (Chemistry), gender and academic performance, corrosion, types and mechanism, and demonstrating redox reactions in electrochemical systems. A non-randomized pre-test, post-test control group was used for the study and 100 students were drawn from four (4) intact classes in four (4) selected Colleges of Education in Cross River and Akwa Ibom States respectively from a population of (250) two hundred and fifty students. The instrument used in collecting data for the study was the test on redox reaction and electrochemistry (TORE) and test on computational ability (TOCA). Kurder Richardson formula 20 was used to establish the reliability of the test instruments and the validated instruments were administered to the subjects by the researchers. The following procedure was adopted in carrying out the research. Pre-test was administered to two groups and also computational ability test. After four weeks of teaching using corrosion of metals with galvanic cells to the experimental group, post-test was administered after treatment, and also after three weeks retention test was administered. Data collected were analysed using descriptive statistics, t – test and analysis of covariance (ANCOVA). All hypotheses were tested at 0.05 level of significance. The results indicated that teaching learning experiences/materials and students computational ability significantly influence students' performance on the concepts whereas gender does not. Result also indicates that experiments on corrosion of metals can be used to enhance students' performance on redox reaction and electrochemistry. The adoption and inclusion of experiments on corrosion of metals among learning experiments for teaching redox reaction and electrochemistry in tertiary institution were recommended.**

Keywords: Corrosion of Metals, Redox Reactions, Electrochemistry, galvanic cells, academic performance.

1. Introduction

The issue of poor performance of Chemistry students in Senior Secondary School Certificate Examinations (SSSCE)is established in each West African Examination Council (WAEC) Chief Examiners Reports of the years 2020 and 2021. This is taken over to their tertiary level of education as evidenced in College of Education and Universities. Literature also abounds on investigations to determine the factors responsible and strategies for remediation. [4], [3]and [7], as identified in WAEC Chiefs, Examiners Report (2020, 2021), poor performance of students in Chemistry at both secondary and tertiary levels is attributed to inadequate knowledge of basic principles, inadequate exposure of students to laboratory work, incompetence in basic Mathematics, inadequate understanding of the fundamental principles in Chemistry, unfamiliarity of students with many concepts, thus indicating non-coverage of the lectures and teachers work load and poor expression in English.

The documents also identify topics like collision theory, thermodynamics, redox reactions, chemical equilibrium, reaction rates, energetic, electrochemistry and extraction of metals as being abstract. On electrochemistry, WAEC (2020, 2021) stated and observed in colleges of Education many students avoid this topic, as most students may not know the reactions in the Daniel cell, or galvanic couple. The topic is

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very unpopular due to inclusion of electrochemical cell and experimental comparison of electric conductance of solution. Many students are handicapped because they could neither write half – cell equations nor calculate cell potential.

The above comments are clear evidence of inadequate exposure of the students to the concept and laboratory in electrochemistry.

Electrochemistry is an abstract concept which involve the study of the nature and behaviour of unobservable fundamental particles–actions, anions and electrons in electrochemical systems. Interestingly there are ways in which the behaviour of these particles can be effectively measured indirectly using appropriate institutions. Learners could therefore be taught this concept not as a body of abstract ideals which needs only to be memorized without understanding but through effective utilization of these instruments and appropriate teaching strategies. Unfortunately studies have shown that most lecturers and science teachers in Nigeria Institution teach chemistry as a body of abstract ideal with little or no regards for practical work, partly because of some inadequacies on the part of the lecturers/science teachers, non-available of required science equipment and materials, or complete lack of laboratory facilities. [3], [14] and [2].

The deficiency in science education at the secondary and tertiary school level resulting from such factors as inadequacy of right teaching facilities, lack of appropriate teaching facilities affect the attitude of students to science adversely to the extent that it greatly hampered the development of the mental discipline which is the acquisition of scientific and mathematical knowledge demands. The process approach, now on the up – rise suggests that science is a process of investigating the world: and sees the so – called facts of science as merely a bye – product of this process of investigation. In essence, it maintains that science education is concerned with guiding the learners in the process of practicing science. It lays emphasis on inquiry learning in which learners are presented with problems, assisted in proposing one or more hypotheses, and guided in designing strategies for testing the hypotheses and drawing conclusion [15]. Abstract concepts need to be taught in a way that can help learners form appropriate mental models which could help them grasp the concepts easily. Researches have shown that, process based learning yields more effective learning irrespective of gender, or ability [10], students taught by teachers sensitized on the nature of science as an inquiry perform significantly better than those taught by un-sensitized teachers [12].

Emphasis on practical activities in science classroom stems from the fact that science (Chemistry) is a practical subject in nature and its progress therefore depends on practical activities and experimentation. It is also true that when learners learn in ways that are natural to them, it brings better performance academically, improves self – esteem, Self-confidence and improves basic skills. Thus the use of experiments on corrosion of metals as a teaching resource on the concepts of redox reactions and electrochemistry is planned to eliminate the problem of cost and make it possible for teachers to have enough materials and equipment for effective students' participation. [11].

Studies have confirmed the effectiveness of the use of local materials as a resource in science teaching in general and chemistry in particular. [1], pointed out that the value of laboratory work as a means of involving students in concrete experience with objects and concepts cannot be over – emphasized as Students also interpret data as well as appreciate the nature of science.

1.1 Statement of the Problem

Redox reactions and electrochemistry are abstract concepts which students persistently perform poorly in both internal and external examinations [5]. Effective and meaningful teaching and learning of abstract scientific concepts like redox reactions and electrochemistry requires active students' involvement in the teaching – learning process through meaningful and relevant hands – on – activities. The harsh economic realities experienced in Nigeria today, coupled with the high cost of standard commercial equipment and chemicals needed for experiments and the disproportionate increase in students enrolment in our schools have made it virtually impossible for the government at the state and federal levels to provide essential science facilities in the schools, thereby leaving our laboratories as mere demonstration and practical examination centre's where available.

Studies however have shown that improvisation – sourcing, selection and deployment of relevant instructional elements of the teaching/learning process in the absence or shortage of standard or accredited teaching learning elements can always help in filling the gab especially when the materials are drawn from the learners' local environment [4]. A study by [13] indicated that experiments on corrosion of metals – a naturally occurring phenomenon common in Nigerian – environment can effectively be used in teaching chemical kinetics using local materials and familiar techniques. Corrosion of metals is known to be an electrochemical process and could also be adapted for use in teaching electrochemistry and redox reactions. This study sought to use experiments on corrosion of metals and

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improvised materials in enhancing the teaching and learning of redox reactions and electrochemistry.

1.2 Purpose of the study

The study was designed to achieve the following specific objectives.

i. To use the concept of corrosion of metals on the teaching and learning of redox reactions and electrochemistry.
ii. To use corrosion experiments and improvised materials in demonstrating electrochemistry.
iii. To determine whether any difference would exist between the mean scores of male and female students with varying computational ability levels exposed to experiments on corrosion of metals and those exposed to standard galvanic cell experiments on test on the concepts of redox reactions and electrochemistry.
iv. To determine whether any difference would exist between the mean scores of students exposed to metal corrosion experiments using improvised apparatus and those students exposed to standard galvanic experiments on test on the concepts of redox reaction and electrochemistry

1.3 Research Questions

The following research questions were formulated to guide the study.

1) To what extent would exposing students to experiments on corrosion of metals as against standard galvanic cell experiments affect their performance on test on the concepts of redox reaction and electrochemistry?
2) What difference would exist between the mean scores of male and female students exposed to experiments on corrosion of metals and those exposed to standard galvanic cell experiments on test on the concepts of redox reaction and electrochemistry?
3) What difference would exist among the mean scores of students with different computational abilities exposed to experiments on corrosion of metals and those exposed to the standard galvanic cell experiments?

1.4 Research Hypotheses

The study specifically tested the following null hypotheses 0.05 level of significance:

1) Exposing students to experiments on corrosion of metals as against standard galvanic cell experiment has no significant effect on student's performance on test on the concept of redox reaction and electrochemistry.
2) There is no significant difference between the performance of male and female students exposed to experiments on corrosion of metals and those exposed to the standard galvanic cell experiments on test on the concepts of redox reaction and electrochemistry.
3) There is no significant difference among the performance of students with different computational ability levels exposed to experiments on corrosion of metals and these exposed to the standard galvanic cell experiments on test on the concepts of redox reaction and electrochemistry.

2. Research Methods

Research designs. The research adopted a non – randomized pre-test – post-test control group design.

2.1 Area of Study

The study was conducted in tertiary institutions offering accredited Pre- NCE programmes in Cross River State College of Education, Akamkpa and Federal College of Education, Obudu, Nigeria.

2.2 Population

The population of the study was all year one and two Chemistry students in the two Colleges of Education i.e. College of Education Akamkpa and Federal College of Education, Obudu. A total of two hundred and fifty students (250) constitute the study population.

This comprised of both male and female students in the 2021/2022 academic session.

2.3 Sample and Sampling Technique

The sample of the study comprised of one hundred (100) students made up of 79 males and 21 females in the 2021/2022 session in Colleges of Education in Cross River State. Purposive sampling technique was used to select the College from among other Colleges. The criteria was College must be co-educational College must possess well equipped chemistry laboratory

College must have accredited NCE programmes by the National Commission for Colleges of Education (NCCE), College must have well staff and experienced Chemistry teachers.

Four (4) Colleges met the above criteria and, two (2) Colleges from among those that met the above criteria were selected by balloting. The two Colleges were randomly assigned to experimental and control groups. These were Federal College of Education Obudu and College of Education, Akamkpa. They were 69 students in the experimental group and 31 students in the control group.

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2.4 Instrument and Validation

Two researchers made objective test on redox reaction and electrochemistry (TORE) and objective test on computational ability (TOCA) were the instruments used for the study. A total of (40) forty multiple choice items were constructed on the concepts of redox reaction and electrochemistry and was the main instrument used for both pre-test and post-test and also a (25) item computational ability test used in classifying subjects into high, medium and low ability grouping. The instruments were faced and content validated by two Chemistry experts.

Reliability of the instruments was determined using Kuder – Richardson's formula 20. A reliability index of 0.63 was obtained, the tests were used to determine the performance of students on the concept of redox reactions and electrochemistry and also determine their computational abilities.

2.5 Research Procedure

The laboratory activities listed below were carried out by the researchers (i) to demonstrate corrosion of iron metal in the laboratory by action of Hcl(aq) on a clean strip of iron (ii) to show that corrosion is a redox process by action of a mixture of Nacl(aq) Phenolphthalein solution and K3(Fe(CN76) on a clean sheet of iron metal. (iii) To compare the cell voltage of metal – graphite electrodes in different electrolytes using corrosion experiments. On classroom application, "TORE" instrument was administered as pre-test by trained research assistants to the colleges selected under the supervision of the researchers; Also "TOCA" instrument was administered after the pre-test to help classify the respondents according to their computational ability levels. Teaching was done by the research assistants to students in the respective colleges using the prepractical lessons outlined in the notes and the students were re-grouped for experimental activities. The activities for experimental group featured experiments on corrosion of metals, corrosion experiments and standard experiment on redox reactions and electrochemistry.

The teaching of the groups including practical activities lasted for six (6) weeks. Post-test was re-administered on the respondents in all the study groups at the end of all the activities outlined for them.

2.6 Method of data analysis

The data collected were analyzed using descriptive statistics and analysis of covariance (ANCOVA) using pre-test scores as covariates. All hypotheses were tested at 0.05 level of significance.

3. Results and Discussion

The research questions were answered using mean and standard deviation as shown in the table below.

3.1.1 Research question 1:

To which extent would exposing students to experiments on corrosion of metals as against standard galvanic cell experiments affect their performance on test on the concepts of redox reaction and electrochemistry?

Table 1: A comparison of means and standard deviation of post-test performance of students classified by treatment, computational ability and gender groups

Var.	Group	Sample size	Mean	Standard Deviation	Standard Error	95% Confidence interval for mean	
Trt(X)						Lower Bound	Upper bound
	1	40	20.45	4.31	0.68	19.07	21.83
	2	30	21.87	3.93	0.72	20.40	23.33
	3	30	19.00	3.47	0.63	17.70	20.33
Compt. Ability (A)	1	39	21.59	4.31	0.69	20.19	22.99
	2	36	20.58	3.59	0.65	19.20	21.90
	3	25	18.44	3.28	0.66	17.09	19.79
Gender (G)	1	79	20.37	3.87	0.44	19.56	21.17
	2	21	20.71	4.86	1.06	18.94	22.79

KEY. X = Treatment 1, 2, 3

A = Computational ability

G = Gender

1 = male

2 = female

X_1 = Treatment group 1

X_2 = Treatment group 2

X3 = Control group

A_1 = High ability group

A_2 = Medium ability group

A_3 = Low ability group

3.1.2 Research question 2:

What difference would exist between the mean scores of male and female students exposed to experiments on corrosion of metals and those exposed to standard galvanic cell experiments on test on the concepts of redox reaction and electrochemistry? Refer to Table 1 for interpretation

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A consideration of the means of the post-test scores on table 1 shows an almost constant mean (20.37 and 20.71) for gender groups 1 and 2 respectively.

3.1.3 Research question 3:

What difference would exist among the mean scores of students with different computational abilities exposed to experiments on corrosion of metals and those exposed to the standard galvanic cell experiments?

Refer to table 1 for interpretation.

For the treatment and ability groups variations in the mean performances are observed with regards to the three treatment groups, students in group 2 (students taught using a combination of experiments on corrosion and standard galvanic cell experiment recorded the highest mean (21.87) compared to 20.45 and 19.00 for treatment groups 1 and 3 (students taught using corrosion experiments alone and students taught using standard galvanic cell experiments) respectively. For the ability groups, the mean performance of students on ability group 1 (high ability) was the highest (21.59) when compared with those in ability groups 2 and 3 (medium and low with means of 20.58 and 18.44 respectively.

Also a comparison of the standard deviation of the post-test scores as presented on table 1 indicates an almost constant mean difference of the scores in all the groups – treatment, ability and gender excepting ability group 3 and gender group 2 with standard deviations of 3.28 and 4.87 respectively as against approximately 4.00 for all the other groups.

3.2.1 Testing of Research Hypotheses

The following hypotheses were tested at 0.05 level of significance.

Hypothesis one (1)

Exposing students to experiments on corrosion of metals as against standard galvanic cell experiments has no significant effect on student's performance on test on the concept of redox reaction and electrochemistry. The result is as presented in table (2).

Table 2: Analysis of covariance (ANCOVA) of students' performance on the concept of corrosion classified by treatment, computational ability and gender

Source of variation	Sum of Squares	Degree of Freedom	Mean Square	F	Sig *
Covariate – Pre-test	27.96	1	27.96	1.92	0.17
Main effects	277.11	5	55.42	3.80	0.00*
(combined)	124.05	2	62.02	4.25	0.02*
Treatment	149.85	2	74.93	5.14	0.01*
Computational Ability	2.02	1	2.02	0.14	0.71
Gender					
2 – way					
interactions	99.93	8	12.49	0.86	0.56
(combined)	26.27	4	6.57	0.45	0.77
Treatment × Ability	21.48	2	10.74	0.74	0.48
Treatment × Gender	55.51	2	27.76	1.90	0.16
Ability × Gender					
3 – way					
interactions	60.79	4	15.20	1.04	0.39
Treatment ×Ability X Gender	465.79	18	25.88	1.78	0.04*
Model	118.85	81	14.58		
Residual Total	1646.64	99	16.63		

(F = Calculated, F value at 0.05 alpha level of significant, performance by treatment, ability, gender with pre-test. As shown in table 2, the calculated probability value (P – value) 0.02 of treatment was less than alpha level 0.05, Therefore, the null hypotheses was rejected. This implies that there exist a significant difference in the mean performance scores of students exposed to experiments on corrosion of metals as against standard galvanic all experiments.

3.2.2 Hypothesis two (2)

There is no significant difference between the performance of male and female students exposed to experiments on corrosion of metals and those exposed to standard galvanic cell experiment on test on the concepts of redox reaction and electrochemistry?

As shown in table 2, the calculated probability value (P – value) 0.71 of gender was more than alpha level 0.2, therefore the null hypotheses is uphold this implies that there is no significant difference between the performance of male and female students exposed to experiments or corrosion of metals as against standard galvanic cell experiments.

3.2.3 Hypothesis three (3)

There is no significant different among the performance of students with different computational ability levels exposed

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to experiments on corrosion of metals and those exposed to the concepts of redox reaction and electrochemistry.

As shown in table 2 the calculated probability value (P – value) 0.01 was less than alpha level 0.05. Therefore the null hypothesis was rejected, this implies that there exist a significant difference in the mean computational ability of students exposed to experiments on corrosion of metals as against standard galvanic cell experiments.

Based on the observation in table 2 multiple classification analysis (MCA) was used to determine whether the observed difference between the unadjusted means for performance by treatment, computational ability and gender with pre-test were largely due to the effects of the covariate – pre-test.

Table 3: Multiple classification analysis (MCA) of performance scores of students by treatment, ability, and gender with pre-test (Covariates)

Variable	Sample size	Predicted Mean		Deviation	
		Unadjusted	Adjusted for factors and covariate	Unadjusted	Adjusted for factors and covariates
Treatment					
(X)					
1	40	20.45	20.59	1.00E – 02	15
2	30	21.77	21.77	1.43	1.33
3	30	19.00	18.91	1.44	-1.53
Ability					
(A)					
1	39	21.59	21.59	1.15	1.15
2	36	20.58	20.57	0.14	0.13
3	25	18.44	18.46	2.00	-1.98
Gender					
(G)					
1	79	20.37	20.37	-7.29 HE-02	-7.40E -02
2	21	20.71	20.72	0.27	0.28

(Treatment Group 1 = Students taught using experiments on corrosion alones. Treatment Group 2 = Students taught using a combination of experiment on corrosion and galvanic cell experiment. Treatment Group 3 = Students taught using galvanic cell experiments alone.

Ability Group 1 = High computational ability;
Ability Group 2 = Average computational ability
Ability Group 3 = Low computational ability
Gender 1 = males, Gender 2 = female.

Results on table 3 indicate that only the main effects of treatment and computational ability are statically significant. The first and second order interactions (Joint) effects are all not statically significant.

However, the combined main effects of the three independent variables are statistically significant, but that of the two – way interaction is not.

The multiple classification analysis (MCA) of performance scores of the students classified by treatment, ability and gender with covariates (pre-test) presented in table 3 indicates that the adjusted means for the treatment and ability groups vary widely from one another just as in the unadjusted means; whereas those of the gender groups show very little variations.

3.3 Discussion

The results were discussed under the following subheadings

Laboratory findings

Investigation from activities on corrosion of metals, it was evident that corrosion of iron is a practical demonstration of redox and electrochemical processes, involving spontaneous oxidation of iron from zero oxidation state in the metal to +2 oxidation state in Fe2+ ion, and a simultaneous reduction of oxygen atom from zero oxidation state in the gaseous form to -1 state in the OH-. This is in agreement with the earlier works of [8] who predicted that corrosion experiment can be used to teach reactivity of elements, and arrangement of elements in order of increasing or decreasing reducing strengths. Effectiveness of corrosion experiments on students' academic performance on the concept of redox reactions and electrochemistry.

Finding from the testing of the hypotheses as presented in table 2 show that corrosion experiments had a significant main effect at P< 0.5. This is because the calculated 4.25 was greater than 0.01.

The above finding appeared consistent with those of [10], [6]. These studies pointed out that corrosion of metals from the environment were effective in enhancing achievement and interest in science (Chemistry).

4. Conclusion

On the basis of the findings in the study, it can be concluded that students, irrespective of gender benefit equally from process based learning. Corrosion of metals and students mathematical ability exerts significant effect on students' academic performance in chemistry. Also student's performance on test on the concepts of redox reaction and electrochemistry can greatly be enhanced by combining experiments on corrosion of metals with standard redox and galvanic cell experiments.

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5. Recommendations

Based on the results of the study, the following recommendations were made.

1) The inclusion of experiments on corrosion of metals among the learning experiences for teaching redox reactions and electrochemistry in Nigeria schools and colleges should be encouraged.
2) Teachers of chemistry in tertiary institutions should combine experiments on corrosion of metals with standard redox and galvanic cell experiments to enhance student's performance on test on the concepts of redox reaction and electrochemistry.

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