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Effects of Problem-Solving, Guided-Discovery and Expository Teaching Strategies on Students' Performance in Redox Reactions

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Abstract

This study investigated the relative effectiveness of problem-solving, guided-discovery, and expository methods of instruction on students' performance in redox reaction, considering their mathematics ability. It was a quasi-experimental research using non-randomized-pre-test–post-test control group design with expository method as control. Two research questions and two hypotheses were formulated for answering and testing, respectively. A sample of 120 SS2 chemistry students drawn from 3-co educational public secondary schools in Uyo Local Government Area of Akwa Ibom State was used for the study. Criterion sampling technique was used in selecting the sample. Two researcher- developed tests – Chemistry Achievement Test (CAT) and Mathematical Ability Test (MAT), with reliability indices of 0.76 and 0.68, respectively, determined using test-retest method were used in collecting relevant data. After investigations, the results showed that those taught using problem-solving method performed significantly better than those taught with guided-discovery and expository methods; expository approach was the least facilitative. Students' performance was observed not to be dependent on their mathematics ability. Consequently, it has been recommended that Chemistry teachers should always adopt problem-solving teaching approach in teaching redox reaction and other quantitative concepts in chemistry in view of its high facilitative effect on the students' performance.

Introduction

Redox reactions are those chemical reactions in which both the oxidation and reduction processes take place simultaneously (Achimugu, 2009). These reactions involve the transfer of oxygen or hydrogen atoms, or electrons from one unit of matter to another. The species which gives out electrons or hydrogen atom(s) is the reducing agent, and is oxidized in the process; while that which receives the electron or hydrogen atom is the oxidizing agent, and is reduced in the process. The species which gives out oxygen atom(s) is the oxidizing agent, and is reduced in the process; while that which receives the oxygen atom is the reducing agent, and is oxidized in the process.

It is worthy of note that in every oxidation process there is a reciprocal reduction process. Every electron, hydrogen or oxygen atom given out by a unit of matter must be taken up by another unit of matter. The net effect of these transfers is a net change in the oxidation state of the species involved in the reaction. Hence, redox reactions could be defined in terms of electron, hydrogen or oxygen transfer; or in terms of change in the oxidation state of the species in the reaction. Common examples of redox processes are burning of substances, rusting and dissolution of metals; the browning of fruits; respiration, and photosynthesis (Olson, 2010).

Redox reactions are of great significance, not only in chemistry but also in geology, biology and chemical technology. The earth crust is largely composed of oxides of metals, and the oceans are filled with water – an oxide of hydrogen. The tendency of nearly all surface materials to be oxidized by the atmosphere is reversed by the life process of photosynthesis which constantly renews life’s complex compounds thereby ensuring their continuous existence. Similarly, much of chemical technology hinges on the reduction of materials to oxidation states lower than those that occur in nature. Basic chemical products such as ammonia, hydrogen and nearly all the metals are produced by reductive industrial processes. Besides, solar radiation is converted to useful energy by a redox cycle that operates continually on a global scale. Photosynthesis converts radiant energy into chemical potential energy by reduction of carbon compounds to low oxidation states, and this chemical energy is recovered either through enzymatic oxidation at ambient temperatures or during combustion at elevated temperatures (Olson, 2010).

Unfortunately, despite the importance of redox reactions in nature, technological development and everyday life, both students and most teachers of chemistry consider the concept difficult. Study reports (WAEC, 2003; Njoku, 2004, Ojokuku & Amadi, 2010) show that students perform poorly in this concept area at public examinations at the secondary school level. Common areas of difficulties include the students' inability to write the correct equation for the reaction, determine which species is oxidized or reduced, determine the oxidation state of the species involved in the reaction, write and balance equations for the reduction and oxidation half reaction correctly, or balance correctly given redox equations; their poor mathematical background (Ekpo & Udo, 2005), as well as inappropriate teaching approaches used by the teachers in communicating the concept to the learners.

In an article titled: Problem-solving strategy – An effective technique for the teaching and learning of redox reaction and balancing redox equations – Udo (2010a) demonstrated how the 5-step Selvaratnam - Frazer Problem –Solving Model (SPSM) could be used in enhancing the teaching and learning of redox reaction. The steps are:-

1. Clarifying and defining the problem
2. Selecting the key equation or relationship
3. Deriving the relationship for the solution of the problem or calculation
4. Collecting data, checking the units and calculating or solving the problem
5. Reviewing, checking through steps 1-4, confirming the units and learning from the situation.

Each of the steps consists of a number of sub-tasks which the learners must perform. For example, clarifying and defining the problem may involve:

i. Quickly reading through the problem statement;
ii. Identifying the known and the unknown;
iii. Sorting out and arranging the data in convenient manner; and
iv. Focusing on the problem that is to be solved.

The problem of this study, however, is that, there is paucity of empirical studies on the relative effectiveness of this model compared with other innovative approaches as the guided-discovery teaching strategy (Udo, 2010b). It is on this premise that this study was undertaken to determine the relative effectiveness of problem-solving, guided-discovery, and expository teaching strategies in enhancing the performance of the students in the concept.

Objectives of the Study

The objectives of the study were:

1. To determine the relative effectiveness of problem-solving strategy in enhancing students' performance in redox reaction compared with guided-discovery and expository teaching methods.
2. To determine the relative effectiveness of problem-solving strategy in enhancing students' performance in redox reaction compared with guided-discovery and expository teaching methods considering their mathematical background.

Research Questions

1. How do students differ in their performance in redox reaction when taught using problem-solving, guided-discovery, and expository teaching methods?
2. What is the difference in the performance of students with high, average and low mathematics ability in redox reaction when taught using problem-solving, guided-discovery, and expository teaching methods?

Hypotheses

The following null hypotheses were formulated for testing:

1. There is no significant difference in students' performance in redox reaction when taught using problem-solving, guided-discovery, and expository teaching methods.
2. There is no significant difference in the performance of students with high, average and low mathematics ability in redox reaction when taught using problem-solving, guided-discovery, and expository teaching methods.

Methodology

The study was a quasi-experimental research using non-randomized pre-test - post-test - control group design. The expository method was used as control.

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The target population was all the 850 SS2 chemistry students in the 12 public secondary schools in Uyo Local Government Area of Akwa Ibom State during the 2010/2011 school year (State Secondary Education Board, SSEB, 2010).

The sample comprised 120 (SS2) chemistry students in 3 public secondary schools in the study area, drawn using criterion sampling technique. The criteria were:

1. Schools with functional and separate chemistry laboratory.
2. Schools with graduate teachers with at least B. Sc degree in chemistry education.

The instrument used in collecting data for the study were 2 researcher-developed, 25-item multiple choice objective tests – Chemistry Achievement Test (CAT) and Mathematical Ability Test (MAT). The CAT items were drawn from redox reactions and related concepts; while MAT items were based on basic mathematical operations necessary for the understanding of redox reaction. The draft, of the instruments, which contained 40 items each, were submitted to three independent assessors, who are lecturers in chemistry education in the University of Uyo, Uyo for face and content validation. Their inputs were used in restructuring of the items. The final form of CAT had difficulty and discrimination indices ranging between 0.25 and 0.70 respectively, and a reliability index of 0.76 determined using test-retest method; while the final form of MAT had difficulty and discrimination indices ranging between 0.20 and 0.70 respectively, and a reliability index of 0.68 determined using test-retest method. Each item answered correctly was scored 4 marks. Incorrect answers were scored zero. Hence, the maximum score was 100 marks and the minimum was zero. CAT was used in assessing the students' pretest and posttest performances; while CAT was used in measuring the students' mathematical ability.

First, the researcher visited the selected schools and obtained permission from their principals to use the schools for the study. Thereafter, he took two weeks to train the subject teachers of the selected schools as research assistants using validated instructional packages developed by the researcher for the experimental and control groups. The instructional packages were also validated by the assessors who validated the instruments. This was followed by the administration of CAT as pre-test, and the MAT on the sample by the assistants, under strict supervision of the researcher. Thereafter, the assistants taught the selected concepts to their groups using the instructional packages from the researcher. Those in experimental group I were taught using problem-solving approach; those in experimental group 2 were taught using guided-discovery; and those in the control group were taught using the conventional traditional expository approach. At the end of the class activities the students were given a reshuffled version of CAT as post-test. Both the pre-test and post-test scripts from all the groups were scored by the researcher; and the data generated were analyzed using Analysis of Covariance (ANCOVA).

Results

In this section the two research questions raised were answered using the results in Tables 1 and 2

Research Question 1: *How do students differ in their performance in redox reaction when taught using problem-solving, guided-discovery, and expository teaching methods?*

In Table 1, the results displayed show that the students taught using problem-solving method had mean gain score of 29.30; those taught using Guided-discovery, 21.91; and those taught using the conventional expository method 19.03. This observation shows that the students taught by Problem-Solving method had the best performance while the least performance was recorded by those taught by expository method. This observation, therefore, answered research question 1 – How do students differ in their performance in redox reaction when taught using problem-solving, guided-discovery, and expository teaching methods?

Research Question 2: *What is the difference in the performance of students with high, average and low mathematics ability in redox reaction when taught using problem-solving, guided-discovery, and expository teaching methods?*

In Table 2, the results show mean gains of 27.51; 29.00; and 30.00 for the high; average and low ability students, respectively, in the problem-solving group; 22.31; 20.24; and 24.50 for the high average and low ability students, respectively, in guided-discovery group; and 18.22; 20.30; and 18.72, respectively, for the high, average and low ability students, respectively, in the expository group. A comparison of these results shows that, in the problem-solving group, the low ability students had the best mean gain followed by those of average and high ability in decreasing order; in the

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guided-discovery group, students with low ability had the best mean gain followed by those with high and average ability in decreasing order. However, in the expository group, the students with average ability had the best mean gain; while those of high and low were almost comparable. These observations show that the students with low mathematics ability are favored most when taught with problem-solving or guided-discovery approach; and that the expository approach has the least enhancing effect considering the students mathematics ability. These findings answer research question two: What is the difference in the performance of students with high, average and low mathematics ability in redox reaction when taught using problem-solving, guided-discovery, and expository teaching methods?

Testing the Hypotheses

The results in Table 3 were used in testing hypotheses 1 and 2.

Hypothesis One: There is no significant difference in students' performance in redox reaction when taught using problem-solving, guided-discovery, and expository teaching methods.

With respect to hypothesis one, the results in Table 3 show that the F-ratio for the main effects of the instructional methods (problem-solving, guided-discovery, and expository) is 21.15, while its significance level is 0.00 alpha at df 2,119. This level of significance (0.00 alpha) is less than 0.05 alpha indicating that the effect of the teaching methods used on the students' performance is statistically significant. Consequently, the null hypothesis one was rejected. The Scheffe post-hoc comparison of means in Table 4 shows which of the methods was most effective.

The mean differences in Table 4 show that those taught using problem-solving method performed significantly better than those taught with guided-discovery and expository method, respectively; the expository approach was the least facilitative.

Hypothesis Two: There is no significant difference in the performance of students with high, average and low mathematics ability in redox reaction when taught using problem-solving, guided-discovery, and expository teaching methods.

With respect to hypothesis two, the results in Table 3 show a calculated F-ratio for the main effect of Mathematics ability as 1.05 and a significance level of 0.35 at df 1,119. The observed level of significance is greater than 0.05 alpha. This indicates that the F-cal is not statistically significant; that is, Mathematics ability had no significant effect on the students' performances. Hence, the hypothesis was upheld.

Discussion

This study investigated the effectiveness of problem-solving teaching approach in facilitating students' achievement in redox reaction compared with guided-discovery and traditional expository methods given the students mathematics ability. The results in Tables 3 and 4 showed that those taught using problem-solving method performed significantly better than those taught with guided-discovery and expository methods, respectively; while the expository approach was the least facilitative. The better performance of students taught using problem-solving method is explained in terms of its ability to help the learners think through the various steps to the solution of the problem at hand.

On the effect of the students' mathematics ability the results in Table 3 showed that the students' performance was not dependent on their mathematics ability. Hence null hypothesis 2 was upheld. The comparable performance of the students by mathematics ability observed indicates that with the right teaching method students of all ability groups could be helped to improve in their performances. As was observed, the low ability students taught with problem-solving method benefited most from the instructions given followed by those taught with guided-discovery method; while the expository method was the least effective method. This further stressed that it is how the students are taught the concepts and not the students' mathematics ability that determine their performance.

Conclusion

Consequent upon the findings from this study, it is hereby concluded that problem-solving method is the most effective teaching strategy in enhancing students' performance in redox reaction followed by guided-discovery; and that students' mathematics ability is not a strong determinant of their performance in the concept.

Recommendations

Based on the observations made, it is recommended that Chemistry teachers should always adopt problem-solving teaching approach in teaching redox reaction and other quantitative concepts in chemistry in view of its high facilitating effect on the students' performance instead of considering the students poor mathematics background as a barrier to their goals attainment.

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Table 1: Summary of mean and standard deviation scores of the students in pre-test and post-test classified by treatment groups

Treatment Group	N	Pre-test		Post-test		Mean
		X	SD	X	SD	Gain
Problem-Solving	43	30.35	8.62	59.65	5.05	29.30
Guided-discovery	44	33.89	7.39	55.80	6.49	21.91
Expository	33	32.42	8.30	51.45	4.59	19.03
Total	120	32.22	8.17	55.98	6.36	23.76

X = mean score; SD = standard deviation score

Table 2:Summary of mean and standard deviation scores of students in pre-test and post-test classified by treatment groups and MAT ability

Treatment Group/ Ability		N	Pre-test		Post test		Mean
			X	SD	X	SD	Gain
Problem-Solving:	High	13	29.08	8.30	57.31	2.59	27.51
	Average	20	32.50	8.19	61.50	4.62	29.00
	Low	10	29.00	9.66	59.00	6.99	30.00
Guided-discovery:	High	19	33.74	6.85	56.05	6.86	22.31
	Average	17	36.47	7.45	56.71	6.83	20.24
	Low	8	28.75	6.41	53.25	4.65	24.50
Expository:	High	12	32.92	7.82	51.17	5.49	18.22
	Average	10	31.50	8.18	51.80	4.96	20.30
	Low	11	32.73	9.58	51.45	3.45	18.72

X = mean score; SD = standard deviation score

Table 3: Summary of Analysis of Covariance (ANCOVA) of students' post-test scores classified by instructional methods and gender with pretest as covariate

Source of Variance	Sum of Squares	df	Mean Square	F	Sig. of F
Covariate (Pre-test)	206.72	1	206.72	7.25	0.01
Main Effects:					
Treatment (methods)	1205.60	2	602.80	21.15	0.00
MAT Ability	60.05	2	30.03	1.05	0.35
Interaction Effects					
Treatment * Ability	61.40	4	15.35	0.54	0.71
Error	3135.02	110	28.50	-	-
Total	4811.97	119	-	-	-

F is significant at p < 05 alpha

Table 4: Summary of Scheffe post-hoc comparison of the students' post test performance classified by teaching methods

Method (i)	(J)	Mean Difference	Standard Error	Sig.
Problem-Solving	Guided-discovery	3.86*	1.18	0.01
	Expository	8.20*	1.28	0.00
Guided-discovery	Problem-Solving	-3.86*	1.18	0.01
	Expository	4.34*	1.27	0.00
Expository	Problem-Solving	-8.20*	1.28	0.00
	Guided-discovery	-4.34*	1.27	0.00

* = significant at p <. 05 alpha.