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Effects of Concept Mapping and Guided Discovery Instructional Strategies on Students' Achievement in Redox Concept of Chemistry in Oyo State, Nigeria

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Abstract: The study determined the effects of concept mapping and guided discovery instructional strategies on student's learning achievement in Redox concept in Chemistry in Oyo State, Nigeria. The pretest-posttest control group quasi experimental design with 3x2 factorial matrix was adopted, while six schools with one intact class each; two each for experimental groups and two for control group were used. A total of 176 senior secondary school 2 Chemistry students participated in the study. A validated Chemistry Student Achievement Test (r = 0.77) was used for data collection, while Analysis of covariance and Bonferroni post hoc were used to analyze the data collected at 0.05 level of significance. There was a significant main effect of treatment ($F_{(2, 175)}$ =11.84; p<0.05, partial $\eta^2 = 0.13$) on student's achievement. The participants in concept mapping strategy obtained the highest post achievement mean score (12.71), followed by guided discovery instructional strategy (9.24) and conventional strategy (8.60) groups. There was no significant main effect of gender on student's achievement. There was no significant two- way interaction effect of treatment and gender on student's achievement in Redox concept of chemistry. Concept mapping and guided discovery instructional strategies enhanced student's achievement in Redox concept of chemistry. It is therefore recommended that chemistry teachers should adopt these strategies to improve student's achievement in Chemistry.

Index Terms: Achievement in Redox concept, Concept mapping, Gender, Guided discovery

1. Introduction

Chemistry is one of the core science subjects taught at the senior secondary school level in Nigeria. The study of chemistry is important for the national growth and development of any nation. Chemistry is a central science subject because it revolves round the composition and activities of man, [1]. Chemistry is the oracle of modern science. This description and assertion is based on the pivotal role which Chemistry plays in industrial set up (fertilizer, petroleum, cement, and pharmaceutical production), the execution of other professions (Engineering, Agriculture, Medicine among others) and the improvement of quality of life of the citizenry.

Chemistry as a subject and discipline comprises of different topics, concepts, theories, laws, facts, hypotheses among others. The chemistry curriculum is organized around four themes: The chemical world, Chemistry and environment, Chemistry and industry and Chemistry and life. Each of the themes has embedded in its different topics of value to the student and the society [2].

As valuable as the subject chemistry is, it has posed a lot of threats, fear and anxiety to many of those who study it which makes majority of students encounter different challenges in the learning of chemistry concepts and which eventually leads to the decline in student's performance in chemistry in Nigeria. Poor student performance is anathema to a nation whose goal is to make significant advancements in Science and Technology. Poor performance in chemistry is a pointer to the fact that students have difficulty in learning and mastering the subject and applying same to their world.

The abstract and highly conceptual nature of chemistry seems to be particularly difficult for students; teaching methods, strategies and techniques also, do not seem to make the learning process sufficiently easy for students [1,3] likewise the unavailability of instructional materials. Thus some studies have noted that students' knowledge of science is often characterized by lack of coherence and the majority of students engage in essentially rote learning [4,5] robbing them of the necessary skills and knowledge in deriving from mastering of the subject. [6]. The use of effective teaching methods is expected to bring about desirable changes in the learners which if not evident implies that teaching is not effective. These problems are quite serious in chemistry, which is widely perceived as a difficult subject because of its specialized language, mathematical and abstract nature, and the amount of content to be learned [3,7].

Some of the difficult concepts in chemistry as perceived by students include electrolysis, oxidation-reduction (redox) reaction, nuclear reactions to mention a few. The West African Examination Council chief examiners' report [8] stated that students have poor knowledge of oxidation-reduction reactions and advised that teachers should emphasize on the areas of the syllabus where candidates appear to be weak. Chief examiners report [9] also indicated the inability of students to balance oxidation-reduction reaction as an evidence to their performance. Chief examiners report [10] also comments that candidates could not identify oxidizing and reducing agent. Oxidation-reduction reaction difficulty as perceived by students can be traced to the various interwoven concepts which students' must infer for proper understanding of elements and their ions, symbols, formulae and equations. The method or strategy used in the teaching of oxidation-reduction has been identified as a major problem area requiring attention. To improve student achievement teachers will need to use active teaching methods and strategies better able to foster students understanding of oxidation-reduction.

A proper understanding of the chemical concepts is usually determined by the delivery method as many of the scientifically incorrect ideas upheld by students started from the introductory classes and continues to linger in their memory until they get to the university, thereby making it impossible for them to understand new and advance concepts [11]. Several studies have shown that when students do not meaningfully understand a concept, they tend to avoid such questions in examination which may invariably affect their performance. Despite the advocation for use of innovative and student-centered strategies, majority of the chemistry teachers still adopt the conventional or lecture or "chalk and talk" method of teaching [12].

There are several studies on methods that can improve students' achievement in chemistry. These include: advanced organizers [13] integrated concept mapping, guided discovery strategies [14] concept mapping and guided inquiry, among others. Therefore concept mapping and guided discovery instructional strategies were used in this study to teach oxidation-reduction reaction as the strategies wee effective in teaching subjects like mathematics and biology.

Concept mapping was first introduced by Novak in 1972 during his research work in Cornell University where he sought to understand changes in children's knowledge of science [15]. It is the process of creating a visual representation of one's knowledge [16]. Concept maps are tools for organizing and representing knowledge. They are made up of concepts and significant terminologies which are enclosed in different shapes majorly circles and squares. Most learners understand better when a concept is visualized. This concept follows a hierarchical procedure whereby a more complex concept leads to another. This method of teaching and learning is based on the David Ausubel's theory of learning which distinguishes rote learning from meaningful learning. Several steps are involved in making a concept map of a particular concept.

The steps involved include identifying a main theme and then brainstorming on all related key words or phrases; organizing the major points and ranking the key words from the most abstract and to the most concrete and specific; clustering concepts that function at similar level of abstraction and those that are closely related; arranging concept on a map, working from the core concept, to major point, to significant details; using arrows, lines, signs and symbols to show the relationship between word or phrase; analyze the concept map by asking one different questions; and finally, revising the map as one knowledge increases.

The guided-discovery method is a student-centered, activity-based teaching strategy in which the teacher guides the students through problem-solving method to discover solutions to instructional topics at hand [17]. Discovery method is a student-centered method in which the learner uses his/her mental process to mediate, and to find out things [18]. In guided discovery instructional strategy, the teacher provides the setting, the structure and the materials and guides students to discover solutions to problems. The strategy involves helping the learner to solve a task or answer a particular question. Most times students depend on their teachers to provide answer to all questions, making the teacher the overall master of the topic or subject. Guided discovery strategy provides the learner and the teacher with an interactive avenue whereby the students give solution to the task and the teacher stands as the guide. In the use of this strategy the students find themselves involved in doing as they use all the scientific process skills in getting to the root of the posed problem. This strategy has been proved to be effective in the teaching of difficult concepts in other subjects [19, 20, 21].

The question of gender disparity in student mastery and performance in chemistry and other science subject continues to give, much concern to researches, educators and scientist within and outside Nigeria. It is not clear which gender also interferes with learning of oxidation-reduction. Also, females always see science as a male subject which sometimes negatively influence their attitude towards it and other science-related subject. Researchers have reported this gender differences in achievement and interest of students in Chemistry and all in the favour of males [22, 23, 24, 25, 26, 27] stated that science is everywhere and everyone can do science. She therefore advocated the need for science teachers to understand the importance of using gender equitable instructional strategies in science classroom environment [28].

1.1. Theoretical framework

Theory of advanced organization by David Ausubel and Jerome Bruner's theory of discovery learning provided the foundation for the study. The theory of advance organization emphasized the effect of previous knowledge on the new material to be learned, while the discovery theory described the ability of learners to create knowledge through their active involvement in the learning process. Theory of advanced organization involves the use of appropriately relevant inclusive introductory materials that are extremely clear and stable in a learning situation. These organizers are normally introduced prior to the introduction of the learning materials and are used to make learning meaningful. The advance organizers assist the learner in recognizing the pieces of new learning materials that can be learned in a meaningful way by linking them to specific aspects of existing cognitive structures. This advance organization provides ideational scaffolding for stable incorporation and retention of the more detailed and differentiated material that follows. The theory emphasized that the main basis for concept mapping are:

- Concepts derive their meanings through their inter-connections with other concepts.
- Meaningful learning occurs when fresh knowledge is consciously anchored to relevant concepts in the Cognitive structure of the learner.

Prior knowledge, subsumption, progressive differentiation, cognitive bridging, and integrative reconciliation are all theoretical principles that are intimately related to concept mapping, according to [29]. In this theory, the learner connects new specialized concepts to more generalized, more inclusive concepts in his or her previous knowledge structure (schema). As a result of subsumption, the learner's Schema becomes increasingly differentiated, allowing for the integration of newer information. As a result, according to this idea, cognitive structure is hierarchically organized, with more inclusive, broad concepts superseding less inclusive, more specific concepts.

The second theory, Guided Discovery Learning was formulated out of Brunner's strong commitment to ascertain how such knowledge may be applied to improve the practice of education, apart from learning how children acquire and use information. The theory insisted that the key to an effective understanding of how children think can be found in the process of representation. The guided discovery method of instruction is a self-learning process in which students create concepts, principles, and ideas with minimal teacher intervention. It's a psychological construct based on the requirement to motivate pupils to participate in the generalization of new ideas related to the subject of instruction. There are three major modes of representation in Bruner's Theory of Discovery Learning. These are:

1. The inactive or action mode,
2. The iconic or imaginery mode and
3. The symbolic representation.

Because the learner organizes the new information and integrates it with the information or knowledge that has already been gathered and retained, the guided discovery approach of teaching is thought to boost retention of contents learned. In a tough learning environment, learners function as investigators under normal circumstances. The guided discovery approach of science teaching and learning encourages students to actively participate in discovering on their own the procedures, ideas, and concepts involved in any topic, which will then help them solve problems in any topic when their teacher is merely a guide.

1.2. Aim of the Research

The concept of oxidation-reduction involves the transfer of electrons between species. This reaction is common and vital to some basic life functions such as combustion, photosynthesis, respiration and corrosion. Despite the significance of such chemical reaction in peoples' daily activities, many students still find it difficult to comprehend. This is visible with the incessant low performance of student in concepts involving oxidation-reduction reaction in both internal and external examinations in Nigeria. Hence, the need to explore factors which affect students' comprehension of the concept of oxidation-reduction. One of such factors that have been identified by previous studies is teaching strategy. This study, therefore, determined the effects of concept mapping and guided discovery instructional strategies on students' achievement in oxidation-reduction concept in chemistry in Oyo state, Nigeria.

1.3 Hypotheses

The study was guided by three hypotheses tested at 0.05 significant level.

Ho1: There is no significant main effect of treatment on students' achievement in oxidation-reduction concept.
Ho2: There is no significant main effect of gender on students' achievement in oxidation-reduction concept.

Ho3: There is no significant interaction effect of treatment and gender on students' achievement in oxidation-reduction concept.

2. Methodology

2.1 Objective

The study objectives was to determine the effects of concept mapping and guided discovery instructional strategies on students' achievement in Redox concept. The moderating effect of gender was also determined and the interaction effects of treatments and gender on students' achievement in Redox concept was also studied. This study adopted the pretest-posttest control group quasi experimental design using a 3x2 factorial matrix. The study covered all senior secondary school II students in Oyo state, Nigeria while 176 students (78 males and 98 females) participated in the study. Six public secondary schools of the state were randomly selected using intact classes of senior secondary school II chemistry students.

2.2. Instrumentation

The instrument used for collecting data on the students' achievement is Chemistry Achievement Test (CAT). The instrument comprises of 30 objective questions which were related to oxidation and reduction concept. The multiple choice questions were followed by four options lettered (A-D) in which all the answers were plausible to the question but only one was correct. The same test was used for both pretest and posttest. For posttest the questions were rearranged to reduce the effect of pretest on posttest. In order to ascertain the face and content validity of the test, copies of instrument were given to experts in chemistry for scrutiny. The instrument was found valid and appropriate. The reliability of the instrument was also conducted on 30 students from another school which were not part of the schools involved in the study. The reliability coefficient was obtained using Kuder-Richardson 20 (Kr-20). The reliability index of 0.77 was obtained.

The following work schedule was adopted

Week 1: Training of Teachers
Week 2: Administration of Pretest
Week 3-8: Application of Treatment (Concept mapping and Guided discovery strategy)
Week 9: Administration of Posttest

2.3. Instructional Guide

Instructional guides were developed for the study, to guide teachers' implementation of the experimental procedure.

3. Results

3.1 Hypotheses One

There is no significant main effect of treatment on students' achievement in oxidation-reduction concept.

Table 1. Analysis of covariance (ANCOVA) of Post-Achievement by Treatment and Gender

Source	Type III Sum of Squares	Df	Mean Square	F	Sig.	Partial Eta Squared
Corrected Model	2134.954	12	177.913	10.435	.000	0.434
Intercept	642.620	1	642.620	37.691	.000	0.188
Pre Achievement	497.399	1	497.399	29.174	.000	0.152
Treatment	403.721	2	201.861	11.840	.000*	0.127
Gender	0.004	1	0.004	0.000	.988	0.000
Treatment x Gender	31.264	2	15.632	0.917	.402	0.011
Error	2779.086	163	17.050			
Total	22775.000	176				
Corrected Total	4914.040	175				

R Squared = 0.43 (Adjusted R Squared = 0.39) * denotes significant p<0.05

Table 1 indicates a significant main effect of treatment on students' achievement in oxidation-reduction concept in chemistry ($F_{(2, 175)}$ =11.84; p<0.05, partial η^2 = 0.13). The effect is 13.0%. This indicates that 13.0% of the 39.0% (Adjusted R^2 = 0.39) total variation in students' achievement in oxidation-reduction in this model is as a result of the significant main effect of the treatment. Thus, hypothesis 1 was rejected. To explore the magnitude of the significant main effect across treatment groups, the estimated marginal means of the treatment groups were carried out and the result is presented in Table 2.

Table 2. Estimated Marginal Means for Post-Achievement by Treatment and Control group

Treatment	Mean	Std. Error	95% Confidence Interval	
			Lower Bound	Upper Bound
Concept Mapping Strategy (CMS)	12.71	0.62	11.49	13.93
Guided Discovery Instructional Strategy (GDIS)	9.24	0.65	7.95	10.53
Conventional Strategy (CS)	8.60	0.58	7.45	9.75

Table 2 indicates that students exposed to Concept Mapping Strategy (CMS) treatment group 1 had the highest adjusted post-achievement mean score in oxidation-reduction (12.71) than their counterparts in the Guided Discovery Instructional Strategy (GDIS) treatment group 2(9.24) and the Conventional Strategy (CS) control group (8.60). This order is represented CMS >GDIS > CS. In order to determine which of the groups caused this significant main effect, the Bonferroni post-hoc test was carried out across the treatment groups and the result is presented in Table 3

Table 3. Bonferroni Post-hoc Analysis of Post-Achievement by Treatment and Control Group

Treatment	Mean	CMS	GDIS	CS
Concept Mapping Strategy (CMS)	12.71		*	*
Guided Discovery Instructional Strategy (GDIS)	9.24	*		
Conventional Strategy (CS)	8.60	*		

Table 3 reveals that post-achievement mean score of students in oxidation-reduction concept of chemistry exposed to CMS was significantly different from their counterparts exposed to the GDIS and CS. Table 3 also indicates that post-academic achievement mean score of students in oxidation-reduction concept exposed to the GDIS was not significantly different from those taught using the conventional strategy. This indicates that the significant difference reveals by the ANCOVA is due to the result of difference between the treatment groups (concept mapping and guided discovery instructional strategies) and the control group and also between the two treatment groups as students' post-achievement in oxidation-reduction concept of chemistry is concerned.

Hypothesis Two

There is no significant main effect of gender on students' achievement in oxidation-reduction concept.

Table 1 shows that there is no significant main effect of gender on students' achievement in oxidation-reduction ($F_{(1, 175)}$ =0.00; p>0.05, partial η^2 = 0.00). Hence, hypothesis 2 was not rejected. This indicates that gender has no effect on students' achievement in oxidation-reduction.

Hypothesis Three

There is no significant interaction effect of treatment and gender on students' achievement in oxidation-reduction.

Table 1 shows that the interaction effect of treatment and gender on students' achievement in oxidation-reduction is not significant ($F_{(2, 175)}$ =0.92; p>0.05, partial η^2 = 0.01). Thus, hypothesis 3 was not rejected. This means that interaction between treatment and gender have no effect on students' achievement in oxidation-reduction.

4. Discussions

The findings revealed that there was a significant main effect of treatment on students' achievement in oxidation-reduction. Based on the findings of the study, students taught with concept mapping instructional strategy performed better than their counterparts taught with guided discovery instructional strategy and those taught with conventional strategy. Those in the guided discovery instructional strategy also performed better than those in the conventional strategy. This efficacy of concept mapping instructional strategy and guided discovery instructional strategy may be due to the fact that the strategy was student-centered by building on students' previous knowledge and that students' find out knowledge themselves. This finding support the assumption of Ausubel's learning theory that stressed that if existing cognitive structure is clear, stable, and suitably organized, it do facilitates the learning and retention of new subject information. Also Brunner's state that discovery occurs when a learner is involved in utilizing his/her mental processes and physical activity to mediate, discover, or grasp some principles, concepts or ideas in various situations. This study agreed with study of [28] which showed that among others concept mapping and guided discovery instructional strategies significantly enhanced students‟ achievement and interest in Chemistry.

This finding is also in agreement with [30] whose result showed that drawing concept map instruction was more effective than traditional instruction in improving physics achievement of the participating students. With regard to learning in the field of science education, results of two key meta-analyses generally showed positive effects of concept mapping on students' achievement levels. This agrees with the findings of [31] study which showed that the concept mapping method was more effective and superior to the guided inquiry method which also was a better teaching strategy to the expository mode in improving students' achievement in chemistry. It can be concluded that concept mapping and guided inquiry would be suitable methods for teaching perceived difficult concepts in chemistry. In addition, it also supports the findings of [32] that guided discovery method of instruction improved students' achievement in chemistry.

The result of the findings shows that there is no significant main effect of gender on students' achievement in all the groups involved was contrary to [33]. The study revealed that girls had more gain in achievement than boys using different strategies while it disagrees with that of [34] that girls outperformed. The results of the t-test analysis of the gain scores showed that achievement in Chemistry of the girls taught by concept mapping was significantly more ($p<0.05$) as compared to girls taught by conventional method. Results of present study also supported that concept mapping is girl friendly.

5. Conclusion and Recommendations

The result of the study provide that concept mapping and guided discovery instructional strategies enhanced students achievement in oxidation-reduction concept of chemistry. Gender is not an obstruction to achievement in oxidation-reduction concept of chemistry. In general the use of concept mapping and guided discovery instructional strategies have been proved to be viable strategies in meaningful teaching and learning of oxidation-reduction concept of Chemistry. The following recommendations were made based on the findings of this study.

1. Chemistry teachers should endeavour to introduce interactive activities in their lessons in order to motivate students to learn the subject. This will also enhance the student's academic achievement in the subject.
2. Since concept mapping and guided discovery instructional strategies have been found to be effective strategies for enhancing achievement therefore, government in conjunction with other professional associations should organize work-shops, seminars, conferences and in-service training on a regular basis to train chemistry teachers on the use of activity-based teaching strategies such as concept mapping and guided discovery strategies.
3. Teacher training institutions should restructure their methodology course if not included to include concept mapping and guided discovery strategies. This will ensure that chemistry teachers are adequately trained on how to use these strategies.
4. Science educators and curriculum planners should incorporate innovative, problem and activity-based pedagogical strategies like concept mapping and guided discovery in all teacher education institutions.

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