

Article

# Use of Activity-Based Method to Evaluate the Teaching and Learning of Redox Reactions among Senior High School Students

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**Abstract:** The purpose of this study was to use an activity-based method to enhance the teaching and learning of Redox reactions among senior high school learners at Christ the King at Obuasi in the Ashanti Region, Ghana. Quantitatively, the study employed an action research design. The population of the study comprised all final-year elective chemistry students of Christ the King Senior High School (CKC) in the Ashanti region of Ghana. A purposive sampling technique was used to select thirty-five (35). The instruments used in the study were tested. Percentages of students who responded correctly to the pre-test items were compared to percentages of students who responded correctly to the post-test items. The pre-test and post-test mean scores were compared to see if there was any difference in their mean scores. The use of an activity-based teaching method in teaching chemistry appears to be used effectively in imparting the content knowledge of chemistry to students to become successful in their learning. Regarding the benefits of the activity-based method. The use of activity-based teaching methods in redox reaction motivates students to be self-learners and improves performance. It is also evident from the findings of this study that the use of the activity-based method of teaching could enhance student performance in a redox reaction. It is recommended that activity-based methods of teaching should be encouraged to be used by chemistry teachers in the Senior High Schools of Ghana in teaching redox reaction concepts to enhance students' performance in redox reactions. It is also recommended that the Ghana education service should collaborate with the chemistry teachers' Association of Ghana to organize professional development programs, seminars, and workshops for chemistry teachers on activity-based to improve their knowledge of teaching skills.

**Keywords:** Activity-Based Method, Assessment, Redox Reactions, Senior High School**How to cite this paper:**

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## 1. Introduction

Chemistry is one subject that provides huge job opportunities for potential students. It features prominently in the areas of oil and gas, agriculture, health, environment, solid minerals, textiles, cosmetics, water supply and sanitation, crime detection, pulp and paper, and waste management [1]. Despite the numerous prospects for job opportunities offered by Chemistry, many students shun it. The uniqueness of Chemistry makes it occupy a pride of place in the scientific and technological development of any nation. Unfortunately, Chemistry is widely perceived as an abstract and difficult subject by both students and teachers. As such, most students essentially engage in rote learning [2]. Besides, the prevailing teaching methods do not actively involve students in the learning process and that could be the reason for students' difficulty in meaningful learning and internalization of chemical concepts [3]. Despite efforts by Chemistry teachers and

educators to improve student's learning outcomes, students have continued to show weakness in meaningful understanding and internalization of chemical concepts, leading to very poor performances in external Chemistry examinations [4]. Activity-based learning commonly as student-centric aims to provide challenging learning tasks, and engaging and flexible learning for all students [5]. Unfortunately, classes become dull while excitement is decreased among students because they are not motivated. Changing the way of teaching is one of the factors that would bring excitement to the learning process and help learners to understand the concepts. Poor and inappropriate teaching methods adopted by science teachers during instruction and the absence of instructional materials in science classrooms have been identified as the principal causes of high rates of failures in science examinations [6].

There must be a drastic change in the method of presentation and delivery of individual concepts in chemistry classrooms and laboratories to catch up with the new world order of scientific and technological innovations. It has therefore become a pedagogical necessity to search for innovative, student-centered approaches such as activity-based strategies which could ensure active involvement of students in the learning process, and perhaps make learning more practical and enjoyable. This strategy helps to promote rapid learning and retention of concepts in Chemistry [7].

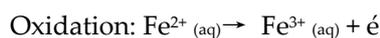
A redox reaction is a very important concept in chemical and biochemical systems and the senior secondary school chemistry curriculum [8, 9]. It is an electron bookkeeping process that involves the transfer of electron(s) from one species (the reducing agent or reductant) to another (the oxidizing agent or oxidant), leading to changes in the electrical charges of the species involved. It provides a framework within which chemical similarities are recognized and chemical properties correlated. A study indicated that redox reaction poses unique and formidable challenges to students [8].

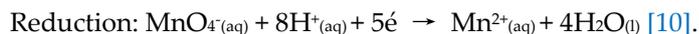
While different types of teaching methods have been studied and identified by other scholars such as inquiry-based learning, problem-based learning, and collaborative learning. They examine their impact on students' achievement and motivation. However, there is a lack of research that investigates the effect of activity-based learning, except for some studies that explore the influence of activity-based learning on motivation. However, there is research addressing the limit in the use of activity-based strategy in teaching and learning Chemistry in senior secondary schools in Ghana. This study is therefore designed to investigate the effectiveness of activity-based strategies in enhancing senior secondary school chemistry students' performance of the redox reaction concept.

The concept of redox reaction has been a challenging topic for most Senior High School students. From my experience of teaching Senior High School science students since 2006, researchers have found that most of my student's lack understanding in writing chemical symbols and formulae. Through different activities like class work, individual and group activities, and tests on the redox reactions, researchers found out that the students perform poorly in the concept of writing chemical formulas as well reactions. It was also observed through class exercises only that, 30% of the students could write correctly the ionic chemical symbol and oxidation number. Furthermore, about only 10% of the students could identify redox reaction equations ad reducing and oxidizing agents.

The WASSCE Chief Examiner's Report on Chemistry has continuously identified the concept of oxidation-reduction reactions as one of the difficult areas for most students. For instance, in 2016, the Chief Examiner's Report explained that although candidates were able to correctly identify the oxidation and reduction reaction, the candidates could not write the correct balanced half-cell reactions.

The correct reactions are:





This is an indication that there are underlying problems that require solutions. If the problem is looked into will lead to poor performance of the student in chemistry. Without mastery of these concepts, students are likely to find higher levels of study in Chemistry difficult. Especially, the use of chemical symbols, formulas, writing chemical equations, and the redox reaction. Therefore, the researchers deemed it necessary to employ activity-based instructional approaches to see whether SHS students' performance in the concept of redox reaction would be enhanced. This will develop their insights and understanding and the up-scaling of their self-concepts as well as help in addressing the challenges of the failure rate of science students in Chemistry. This may also help in improving the interest of students towards learning Chemistry and as such science anxiety could be reduced among students. The purpose of this study was to use an activity-based method to evaluate the teaching and learning of Redox reactions among senior high school learners at Christ the King at Obuasi in the Ashanti Region, Ghana. (1) What conceptual difficulties do students encounter in the writing of ionic chemical symbols and the explanation of oxidation numbers? (2) What are the conceptual difficulties students face in identifying redox reaction equations as well as identifying oxidizing and reducing agents? (3) What difficulties do the students have in writing balanced redox reaction equations by the ion-electron method? (4) How will an activity-based strategy enhance students' performance in the concept of redox reaction?

### ***1.1. Conceptual Difficulties Faced by Students in Writing of Ionic Chemical Symbols and Oxidation Numbers***

However, success in studying Chemistry depends upon the familiarity of students with a few basic ideas, conventions, and methods upon which later studies are built. When a student has achieved mastery of them, further studies can be pursued with greater confidence [11]. Another study adds that without mastery of these concepts, it is difficult for students to find higher levels of study in Chemistry. Especially, the use of chemical symbols, Formulae, writing chemical equations, and calculations involving moles (solids, gases, and solutions), etc. are areas where students in Chemistry beginners face the most challenges [12]. "Chemistry is a difficult subject for students. The difficulties may lie in the capabilities of human learning as well as in the intrinsic nature of the subject [12]." "Chemistry is a world filled with interesting phenomena, appealing experimental activities, and fruitful knowledge for understanding the natural and manufactured world. However, it is complex." As a result of the difficult and complex nature of Chemistry and also the fact that it is one of the most conceptually difficult subjects on the school and higher institution curricula, it is of major importance that anyone teaching Chemistry is aware of the areas of difficulty in the subject [13]. The concepts and principles in chemistry range from concrete to abstract. Many students of Chemistry find certain concepts difficult to comprehend. The root of many of these difficulties that students have in learning Chemistry is traceable to inadequate understanding of the underlying concepts of the atomic model, and how these are used to explain macroscopic properties and laws of Chemistry [14].

### ***1.2. Difficulties Faced by Students in Writing Chemical Symbols and Formulae***

Difficulties in the learning of Chemistry can be precipitated by a lack of Chemistry language skills. Students experienced greater problems in interpreting symbols than words correctly [15]. A study on the effects of working memory space and field-dependency on the learning of Chemistry by Greek students. Learning not only Chemistry but all new information will fail if the working memory space is overloaded. This could occur if students are given too much information at once. Moreover, if students study Chemistry in a language other than their mother tongue, difficulties experienced in

Chemical language could be linguistic, contextual, or cultural. The understanding of valency, appreciation of concepts of polyatomic ions and molecules, and ultimately the production of correct chemical formulae will depend on students' knowledge of bonding [16]. Unfortunately, concepts in chemical bonding are highly abstract and it appears that only the most able students will be in a position to apply their knowledge of bonding effectively to scaffold the writing of chemical formulae [17].

### 1.3. Difficulties Faced by Students in Writing Chemical Equations

Chemical equations can be defined as symbolic and quantitative representations of the changes that occur in the process of chemical reactions, based on the principle that matter is neither created nor destroyed during chemical reactions. For example, the chemical equation: shows that A and B are the reactants while C and D are the products. The subscripts x, y, p, and q are the stoichiometric coefficients which represent the relative amount of substance of the reactants and products. The single-headed arrow indicates the direction of the reaction and shows that the reaction is an irreversible one. The arrow means "gives", "yields" or "forms" and the plus (+) sign means "and".

However, studies have shown that the ability to write chemical equations correctly is not a simple one [18]. It requires a functional understanding of the requisite subordinate concepts of atoms and atomicity, molecules, and molecular formula, atomic structure and bonding, valency, use of brackets, radicals, subscripts and coefficient and molar ratio [17]. Studies conducted by researchers reported that chemistry students often have great difficulties in both acquiring and using the skills required to balance chemical equations [17, 20]. A similar study revealed that students in Ghanaian senior high schools have difficulties in learning certain chemical concepts, including chemical combinations [21]. Approximately two-thirds of the students who took part in the study indicated that the topic of the chemical combination was either difficult to grasp or never grasped. Students' persistent difficulties in solving stoichiometric problems are partly associated with their inability to represent chemical equations correctly [22, 23].

### 1.4. Redox Reaction Equations

Redox reactions involve the transfer of electrons from one reactant to another reactant. The valency (oxidation number) of the reactant changes. When there is oxidation, there is also reduction. The substance which loses electrons is oxidised and the substance which gains electrons is reduced. For the example:  $2\text{Fe}^{3+} + \text{Sn}^{2+} \rightarrow 2\text{Fe}^{2+} + \text{Sn}^{4+}$  (8+ each side of the equation). The iron (III) + tin (II) have reacted to give iron (II) + tin (IV). This reaction occurred in the presence of HCl (Hydrochloric Acid), but the oxidation-reduction reaction is only between the iron (iii) and tin (ii).

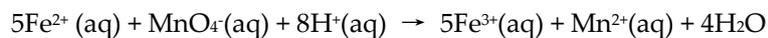
Now, a redox reaction is the release and uptake of electrons. So, the  $\text{Fe}^{3+}$  is reduced to  $\text{Fe}^{2+}$ , and the  $\text{Sn}^{2+}$  is oxidised to  $\text{Sn}^{4+}$ . Conceptualization of the reactions of oxidation and reduction has evolved [24]. Four different redox models are commonly used in chemistry education today. These are the oxygen model, the hydrogen model, the electron model and the oxidation number model (Table 1).

**Table 1. Four Oxidation-Reduction Models Model Reduction Oxidation**

Models	Reduction	Oxidation
Oxygen model	loss of O	gain of O
Hydrogen model	gain of H	loss of H
Electron model	gain of electrons	loss of electrons
Oxidation number model	decrease in oxidation number	increase in oxidation number

How to teach oxidation and reduction has been an issue of discussion for a long time among chemistry educators. Redox models in Table 1 are incompatible [25]. In an

educational context, a rote application of the models may lead to confusion. He illustrates the incompatibility with the following example:



If only the hydrogen ion ( $\text{H}^{+}$ ) in the reaction is considered, then according to the *oxygen model*, oxidation has occurred by gaining oxygen, and a water molecule is formed. According to the *electron model*, hydrogen ions have been *reduced* by the taking up of electrons from the oxide ions, and a water molecule is formed. Neither *oxidation* nor *reduction* has taken place according to the *oxidation number model*. The oxidation number is +I both before and after the reaction. Davies writes further that it is easy for the teacher to underestimate the confusion that may be created when different models are used for a scientific explanation, particularly as students may not have a full understanding of the use of models [25].

### 1.5. Conceptual Difficulties Faced by Students in Redox Reaction

The chemical is generally viewed as a difficult subject by students because the subject involves learning 'abstract and formal explanation of invisible interactions at molecular levels to chemical reasoning, the learner may need to shift between four representational systems (macroscopic, sub-microscopic, symbolic, and algebra) and students often experience difficulty shifting between this system [26]. Redox reactions, in particular, are regarded by students as one of the most difficult topics because, in addition to moving between the four systems, students have to contend with four models of redox reactions, namely the oxygen model, the hydrogen model the electron model and the oxidation number model [27].

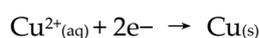
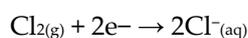
Learners' difficulties in understanding redox reactions are both conceptual and procedural. The conceptual difficulties include the interdependence of the oxidation and reduction process, the relative strength of oxidizing and reducing agents, and the process of electron transfer resulting from students' general inability to understand) the concept of oxidation number [28]. One procedural difficulty is the classification of the reaction as a redox reaction because students who preferred to use the criterion of electron transfer instead of the change in oxidation number did not recognize equations without charges and electrons as redox reactions [24]. In other instances, students believed that they could identify redox reactions based on changes in the charges of polyatomic species in the equation [29]. In a study with first-year university students, the researcher observed that students developed only procedural knowledge about electrochemical reactions as redox reactions merely by memorizing the formula [30]. Another procedural difficulty that has been identified in research studies involved identifying reactants as oxidizing or reducing agents because imprecise terminology and linguistics of some statements used by teachers resulted in confusion among students [31]. For example, in several instances, teachers referred to a substance when they meant particles and vice versa. In another instance, teachers were vague about the oxidizing and reducing agents involved when they referred to for example copper as an oxidant without specifying whether the reference was to the copper atom or copper ion. The mixing of context-specific meanings, especially the phenomenological meaning with the particulate meaning has been a source of difficulty for students when identifying reactants as oxidants or reductants [31].

Electrochemistry is one other chemical concept given attention in high school chemistry. The areas of concentration under electrochemistry at the high school level, as pertained in Ghana, were oxidation-reduction processes, balancing of redox equations, redox titrations, electrochemical cells, electrolytic cells, and corrosion of metals [32]. The area for this study was the oxidation-reduction process. As an interesting area, several research works have identified students' difficulties and alternative conceptions in learning electrochemistry [33, 34-35]. Some students' alternative conceptions are

associated with identifying the cathode and anode, analysing reactions in electrolysis, and writing chemical equations [34]. Also, some students had conceptual difficulties in understanding oxidation and reduction half-reactions and the role of salt bridges in electrolysis [35]. Students' alternative conceptions and conceptual difficulties exist in the introduction of  $\text{H}_2\text{O}$ ,  $\text{H}^+$ , and  $\text{OH}^-$  in balancing redox reactions [33]. Students' alternative conceptions and other conceptual difficulties to a lack of basic knowledge in electrochemistry, challenges with language, and rote learning [34]. Various approaches to teaching have been observed to have effects on students' performance in redox reactions [36, 37]. Notwithstanding how important redox reaction is in chemistry education and the instructional strategies used in teaching, research findings have revealed that there are difficulties associated with the teaching of the concept. Chemistry teachers have difficulty helping students to accept the electron model as the concept for explaining and identifying redox reactions [31]. In addition, researchers observed that considering the number of months the electronic model of explaining and identifying redox reactions was taught in their study, very few students were able to adopt the concept in explaining the situations of redox reactions. This is an indication that we need to look at the chemistry of redox reactions in the context of how best to teach the concept [38].

### 1.6. Oxidizing and Reducing Agent

A redox reaction is a chemical reaction that involves a transfer of electrons and changes in oxidation number. An oxidation reaction is a reaction that takes an electron from one substance. A reduction reaction is a reaction that gives an electron to a substance. A redox reaction is a reaction in which one substance gives up an electron and another substance takes that electron. I know it is strange that 'oxidation' means 'giving up' and 'reduction' means 'taking in,' but remember that an electron is negatively charged, so everything is kind of backward. To give up an electron means to become more positively charged. To take in an electron means becoming more negatively charged. An oxidizing agent is a substance that causes the oxidation of another substance. Common oxidizing agents include oxygen, hydrogen peroxide, and halogens. A reducing agent is a substance that causes another substance to reduce. So, to identify an oxidizing agent, simply look at the oxidation number of an atom before and after the reaction. If the oxidation number is greater in the product, then it lost electrons, and the substance was oxidized. If the oxidation number is less, then it gained electrons and was reduced. The substance that is reduced in a reaction is the oxidizing agent because it gains electrons. The substance that is oxidized in a reaction is the reducing agent because it lost electrons. For example, chlorine and copper ions are both oxidising agents which are themselves reduced as follows:



For example, sodium is a reducing agent which is itself oxidised as follows:



### 1.7. Activity-Based Method of Teaching

The activity-based teaching method is a method of teaching where the teacher only acts as the facilitator and learners (students) are at the centre of the learning processes through their involvement in practical activities and discussions. Activity-based learning is supported by one of the strongest research traditions in education, with many hundreds of studies conducted across a wide range of subject areas and age groups [39, 40]. This large body of research suggests that student-to-student collaboration conducted in a

manner consistent with activity-based learning principles produces superior results on a host of variables, including achievement, thinking skills, interethnic relations, liking for school, and self-esteem.

A researcher in his study investigated the impacts of an activity-based learning strategy on the scores of second-grade students. It was stated that students were able to understand the relationships between given data or models more correctly and easily as the activities were performed. Through the implementation of activities, the students explain the relationships gotten from the problems or situations given in the activities correctly and quickly [41]. In another study conducted with students, it was found that activity-based teaching increased the students' success in comparison to traditional teaching [42]. This learning strategy not only made the learning experience fun but also learning became meaningful. conducted a study, the goal of his study was to examine the impacts of activity-based learning on sixth-grade students' achievement of science in comparison to traditional learning strategy and detect their attitudes towards learning activities. He found that there was a positively increased in academic achievement [43].

Relevant studies' findings show the significance of activity-based learning strategy on students' attainment and their views about activity-based learning. On the subject of how the use of activity-based teaching methods helps in boosting the retention level of students, Retention is the process by which information is stored and retrieved. Retention means the storage of information over some time when it will be used. It can therefore be deduced from the above researchers that there is no retention until the recall of stored information is done. Instructional strategies that can enhance retention are the activity-based strategy [44]. Researchers found that students can retain information more easily when the teacher uses discussion in the classroom, and students' interest is sustained when the lesson is taught using the activity-based method. They further found that the activity-based teaching method ensures the development of students' higher-order skills and maximizes students' retention capacity. This implies that students have higher retention levels when taught with activity-based teaching methods than other methods. Activity-based learning strategies significantly improved students' academic performance than the prevalent traditional or expository teaching method. They recommended that activity-based teaching strategies should be used to teach students that are developing higher-order skills to maximize the benefits of these approaches. Activity learning strategy appears to be getting greater acceptance as a method of teaching Science. This might be due to the reported advantages it offers, such as providing the learners with an in-depth knowledge of subject matter content; it develops learners' interest and leads to discovering new facts [45].

Several research studies which have relevance to the employment of activity-based methods of teaching are recounted below. The study generally gave credence to the efficacy of the use of the activity-based method in classroom pedagogy.

In addition, a researcher demonstrated in practical terms that an activity-based teaching strategy has impacted positively students' academic achievements. He researched the impact of the activity-based teaching method on students' achievements in Basic Science amongst remedial students in the Federal College of Education Katsina, Nigeria. Using a sample of 202 students from the parent population of 269, he administered a Basic Science Concept Achievement Test (BSCAT) to two groups of students (experimental and control groups) that featured in the research study. T-test statistics were used to determine whether the activity-based teaching method impacted more positively on students as against the use of the lecture method. His findings revealed that students taught through the use of the activity-based method performed significantly better than those taught using the lecture method [46].

However, his critique of the approach focuses on the view that it does not meet the needs of the individual differences which prevail among learners. The approach also requires a vast array of instructional materials and laboratory resources for curriculum

implementation. Scientists executed a project at the Dublin Institute of Technology which centred on the development of a research methods module that embraces an activity-based approach to learning amongst 82 undergraduate students in a group environment, to determine the extent to which the module improved students' engagement in their studies [47]. The research method module was previously taught through a traditional lecture-based format. Anecdotally, it was felt that the students' engagement was poor and learning was limited. It was established that successful completion of the development of this module would equip students with a deeply learned battery to research skills to take into their further academic and professional careers. To encourage engagement of students, a wide variety of activities were used.

Researcher conducted a study in Islamabad, Pakistan to determine the effectiveness of the activity-based teaching method on the learning of science students. The purpose of the research was also to explore the linkage between teaching techniques and student learning. The measuring instrument used for the learning was an achievement test (post-test). Students were divided into two groups; the experimental and the control group. Each group consisted of 25 students. These groups were equated based on marks achieved by students in a test of 4th class Science conducted by a District Teacher Educator (DTE). The control group was taught by the lecture method while the experiment group was taught by an activity-based method. The duration of the teaching for both groups was 30 minutes per day for one month (30 days). At the end of one month, the post-test was administered. The data of the study comprised the scores of the experimental as well as the control group obtained on the post-test. The study revealed the performance of the experimental group was better than the performance of the control group: there was a significant difference between the performance of the experimental group as compared to the control group concerning knowledge, comprehension, and application skills. The findings revealed that the activity-based method was more effective than the lecture method of teaching science at the elementary level. A study on activity-based learning strategies in Mathematics classrooms found that students understood Mathematics concepts and had higher retention rates when they actively participated in lessons. She stresses that teachers should move away from the "telling method" and select strategies that will promote active learning in the classrooms [44]. A similar study conducted research on the "effects of activity-based instructional strategy and traditional method" on the academic performance of students in Integrated Science in Junior Secondary Schools, in Kaduna North Local Government Area, Kaduna State, Nigeria. She employed a quasi-experimental research design, where pre-tests and post-tests were administered to the population. A sample of 218 junior secondary school students from two government schools comprised the study. The finding revealed that the students who were exposed to activity-based learning performed better than their counterparts who were taught through the use of expository methods [49].

Also, another research on "the effect of group instructional strategy on student performance in selected science concepts". He used a purposive sample of 365 senior secondary science students who were selected from a School of Science in Ile-Ife, Osun State, Nigeria. His study revealed that those exposed to a group instructional strategy performed better than those who were subjected to individual learning treatment; the below-average students exposed to the group instructional strategy registered 'gain scores' over what they scored when they were not exposed to the method. This development revealed that there was an improvement in their performance; hence they registered more understanding of science concepts. Also, there was a significant difference in the collective work done by students who were exposed to group instruction; their performances on an individual basis revealed that the students gained better academically when they worked on assignments together than when they executed assignment tasks individually [50].

## 2. Materials and Methods

### 2.1. Research Approach and Design

Quantitatively, the study employed an action research design. The population of the study comprised all final-year elective chemistry students of Christ the King Senior High School (CKC) in the Ashanti region of Ghana. A purposive sampling technique was used to select thirty-five (35) elective chemistry students consisting of twenty (20) males and fifteen (15) females. This sampling strategy was used because the researchers were assigned to teach their class and therefore the intervention had to be specifically tailored to them.

### 2.2. Instruments of the Study

The instruments used in the study were tested. Both the pre-test and post-test consisted of 5 items on which students were expected to give certain deductions, explanations, and calculations. The post-test was the same as the pre-test. The sampled groups were given two different test items which were a pre-test to discover more facts about the problem at hand and a post-test which was answered by the students to assess the effectiveness of the lesson delivery from which a conclusion was drawn.

### 2.3. Reliability and Validity of the Study

To improve the reliability of the instrument, an assessment of the consistency of the instrument was made to make a judgment on its reliability. The pre-test was first pilot run at Fr. Augustine Murphy High School and then given to the sample group. The Cronbach alpha coefficient of reliability for the items with an alpha value of 0.77 was obtained using SPSS (statistical package for social scientists) and which indicated that the instrument was reliable according to Bork, Gall, and Gall (1993). The post-test was pilot run in the same manner and the alpha coefficient of reliability was 0.75. All instruments were validated and peer-reviewed by Chemistry teachers at Fr. Augustine Murphy High School.

### 2.4. Data Collection Procedures

The researchers conducted the pre-test which lasted for one hour during the first period. The pre-test instrument had 5 items on which students were expected to make certain deductions, give explanations, and do calculations. The pre-test was based on a 100% score indicating the percentage of correctly answered items. A lesson plan on the redox reaction concept was prepared by the researcher and presented to the chemistry teacher for their comments and suggestions. Ultimately corrections to the plans were done before being used for the intervention. The topics focused on oxidation number, oxidation, and reduction as well as oxidizing and reducing agents, and balancing of redox reactions.

### 2.5. Pre-Intervention

The researcher used tests to diagnose the perceived problem which resulted in finding an approach which is feasible in terms of its reliability to solve the problem which was later termed an intervention. The researchers, however, administered the pre-test to get the background information about the student's knowledge on the various aspect of redox reaction; oxidation number, oxidation, and reduction as well as oxidizing and reducing agents, and balancing of redox reactions to find out. There were five (5) questions in all, where learners were required to give appropriate responses. This was done to order to eliminate guesswork and determine the learner's true performance. All the questions were to test students' understanding of the redox reaction concept. The questions were printed and administered to the class sample of thirty-five (35). Forty-five minutes were allotted for the work, after which the scripts were collected for marking. After the scripts were marked, the researcher diagnosed that most of the students close to 45% could respond correctly to items 1 and 2 with no able to respond correctly to items 4

and 5. This was clear from the pre-intervention results that the students lacked the concept of those test items and therefore found it difficult to give response to questions.

### 2.6. Intervention

The researchers introduced the use of activity based-teaching to aid the student enhance their performance. The intervention covered the chemical symbols and oxidation numbers, writing of ionic chemical symbols and oxidation numbers oxidizing and reducing agents and redox reaction equations. The researchers visited the class five times a week and taught a lesson to the class. At the end of the week, a total of five hours twenty minutes (5hrs20mins) contact time was made by the researcher with students with the lesson lasting for 80 minutes.

#### 2.6.1. Lesson presentation

##### *Day one*

##### *Oxidation number*

The researchers introduced the lesson by asking the learners the meaning of the oxidation number. Learners gave answers which included, the oxidation number as the number on the atom. The researchers explained the meaning of oxidation number. The oxidation number is the hypothetical or real charge of an atom in a pure state or a compound based on given rules. With the aid of a chart, the researcher explained how atoms obtained charges and how to write chemical symbols. The researcher explained the rules governing how to assign oxidation numbers to elements. Using the jigsaw method students taught each other about the oxidation number rules. Students were given these activities.

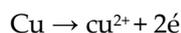
Learners were asked to write the chemical symbol and indicate whether the atom would lose or gain an electron as well as to write the ionic symbol for the various atoms-sodium, potassium, calcium, oxygen and fluorine. Find the oxidation number of the underlined elements,  $\underline{\text{C}}\text{O}_2$ ,  $\text{H}_2\underline{\text{S}}\text{O}_4$ ,  $\underline{\text{S}}\text{O}_2$ ,  $\text{Ca}\underline{\text{C}}\text{O}_3$  and  $\underline{\text{Fe}}_2\text{O}_3$ . Think-Pair-Share: Individually, students found the oxidation numbers of elements, showing each step they made to arrive at the answer. In pairs, they assessed each other's answers. The research took up correct answers with the entire class.

##### *Day two*

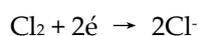
##### *Oxidation and reduction*

The researchers introduced the lesson by asking the students the following questions based on previous knowledge. *What is oxidation and reduction?*

The researchers present the topic and explained oxidation as the loss of electrons by a species. He also explained oxidation in terms of the addition of oxygen or the removal of hydrogen from a species. For example:



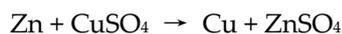
Reduction is the gain of electrons by species or the addition of hydrogen or removal of oxygen from a species.



The researchers showed students a video clip that explained the redox reaction of Coke can. Ask several students to break an empty can of Coke that has been oxidized. Others were asked to break one that has not been oxidized. Learners were shown a video clip that explained the redox reaction of coke and other metals.

**Day 3*****Oxidizing and reducing agents***

The researchers guide students in groups to add Zn dust carefully to the CuSO<sub>4</sub> solution in test tubes until the blue color is faded. The ions present in CuSO<sub>4</sub> solution are Cu<sup>2+</sup> and SO<sub>4</sub><sup>2-</sup> ions and as such when Zn dust is added, the Zn donates 2 moles of electrons to the Cu<sup>2+</sup> (blue) and the Cu<sup>2+</sup> accepts the electrons and becomes elemental copper (brown) and deposited at the bottom. The redox equation is:



As Zn donates electrons to reduce Cu<sup>2+</sup> in CuSO<sub>4</sub>, it is known as a reducing agent and CuSO<sub>4</sub> accepts electrons, the whole compound CuSO<sub>4</sub> is an oxidizing agent.

Given equations, student groups identify oxidizing and reducing agents.

**Day 4*****Oxidation and reduction half equation***

The researcher introduced the lesson by asking the students the following questions.

*What is half an equation?*

The researchers presented the topic to students explaining that half equation as well as oxidation half and reduction half equations and give several examples. The researchers explained that any redox reaction is made up of two parts, oxidation and reduction parts. These two parts are separable and when this is done, each half is called a half equation. He added that a half equation is a separate equation from a redox equation showing which substance gains or loss electrons in the redox reaction.

$\text{Cu}^{2+}_{(\text{aq})} + \text{Zn}_{(\text{s})} \rightarrow \text{Cu}_{(\text{s})} + \text{Zn}^{2+}_{(\text{aq})}$ , the oxidation half equation is given by  $\text{Zn}_{(\text{s})} \rightarrow \text{Zn}^{2+}_{(\text{aq})} + 2\text{e}^-$  and reduction half equation is:



The researchers explained the rules governing the balancing of redox reaction equations by the-electronic method. For example, balance half equations.

**Day 5*****Balancing of redox equation***

Through research-student interaction with several examples, the researcher guides learners to separate and balance half equations and overall redox reaction equations while concentrating much on stoichiometric moles to conserve charges. Several sample questions were made available to the learners to practice. After the hand on, each was asked to present one question and show step by step how they arrived at that answer. The rest of the class was asked to confirm whether or not it is correct. Learners' comments were discussed when learners are given enough activities to try their hand on enhance their understanding

After the lesson, the researcher guided the learners to write balanced oxidation half and reduction half equations and hence overall balanced equation for the redox equations below.

- i.  $\text{HNO}_3 + \text{Cu}_2\text{O} \rightarrow \text{Cu}^{2+} + \text{NO} + \text{H}_2\text{O}$
- ii.  $\text{Bi}^{3+} + \text{OH}^- + \text{MnO}_4^- \rightarrow \text{MnO}_2 + \text{BiO}_3^-$

**2.7. Post-Intervention**

After the intervention, those questions that were administered to the class sample during the pre-test were given to the learners in the post-test but items were altered in numbering. This was to determine how the learners understood the concept. There were five (5) questions, to which learners were required to give appropriate responses. This was

done to order to eliminate guesswork and determine the learner's true performance. All the questions were to test students' understanding of the redox reaction concept. Forty-five minutes were allotted for the test. The results from the marked script showed that the student performed well on average close to 88% of the students could respond correctly to items 1 and 2 and 77% could respond to items 3, 4 and 5. This was clear from the post-intervention results that the intervention was successful.

### 2.8. Data Analysis

Data from the pre-test and the post-test were analyzed quantitatively. Comparisons of percentages of students with correct responses on post-test items to the percentages of students who gave correct responses to the same items on the pre-test within the same is a measure of the student's performance of some aspects of redox reactions. When these comparisons are done, the researchers could deduce the usefulness of the instructional approaches used. The mean scores of the pre-test and post-test of students were compared to see the effect of using activity-based instructional approaches, and whether it enhances students' performance in redox reactions.

## 3. Results and Discussion

### 3.1. Difficulties Students Encounter in the Writing of Ionic Chemical Symbols and the Explanation of Oxidation Numbers

This section presents results and discussion on research question 1: What conceptual difficulties do the students encounter in the writing of ionic chemical symbols and the explanation of oxidation numbers? The results of students' understanding of writing ionic chemical symbols and their understanding of oxidation numbers are summarised in Tables 2(a), 2(b), 3(a), and 3(b). Students' conceptual problems of writing ionic chemical symbols are also summarized in Table 4. Table 2(a) shows the percentage of students who gave correct responses to each of the items in the pre-test while 2 (b) combines the related items and shows the number and percentage of students who gave correct responses to the combined items in the pre-test. Table 3(a) shows the percentage of students who responded well to each of the items in the post-test while 3 (b) combines the related items and shows the number and percentage of students who gave correct responses to the combined items in the post-test.

**Table 2a. Number and percentage of students who gave correct responses to the items of the pre-test.**

Item number	Number and percentage of students (N = 35)
1	17(49%)
2	15(43%)
3	3(0.1%)
4	0
5	0

**Table 2b. Number and percentage of students who gave correct responses to the combined items of the pre-test.**

Item number	What items measure?	Number and percentage of students
1 and 2	Students' understanding of writing chemical symbols of ions and their understanding of oxidation numbers	15 (43%)
3 and 4	Students' ability to identify redox reaction equation and oxidizing agents and reducing agent	0
5	Students' ability to write balanced redox reaction equations	0

**Table 3a. Number and percentage of students who gave correct responses to the items of the post-test.**

Item number	Number and percentage of students (N = 35)
1	31(88%)
2	31(88%)
3	26(74%)
4	32(91%)
5	22(63%)

**Table 3b. Number and percentage of students who gave correct responses to the combined items of the post-test.**

Item number	What items measure?	Number and percentage of students
1 and 2	Students' understanding of writing chemical symbols of ions and their understanding of oxidation numbers	31(88%)
3 and 4	Students' ability to identify redox reaction equation and oxidizing agents and reducing agent	26(74%)
5	Students' ability to write balanced redox reaction equations	21(62%)

**Table 4. Students' reasons for writing the ions present in molten alumina and lead trinitrate (V) solution incorrectly.**

Ions present in:	Reasons	Number of students
(a) $Al^{2+}$ , $O^{3-}$	aluminium has lost 2 electrons and oxygen has gained 3 electrons in the compound	2
$Al_2^{3+}$ , $O^{2-}$	there are 2 aluminium atoms and they lost 3 electrons and there are 3 oxygen atoms and they gained 2 electrons	3
$Pb_2^{+}$ , $NO_3^{2-}$	there are 2 lead atoms in the compound	1

In Table 2(a), item 1 measured how many students understood oxidation numbers and item 2 in Table 2(a). Also, measured how many students understood the writing of ionic chemical symbols before the intervention. Therefore, the combined item 1 and 2 of Table 2 (b) measured how many students understood oxidation numbers and writing of ionic chemical symbols before the intervention. Similarly, item 1 in Table 3(a) measured the number of students who understood how to write ionic chemical symbols only and item 2 of 3 (a) measured the number of students who obtained the concept of oxidation numbers only after the intervention. In 3 (b) the combined items 1 and 2 measured the number of students who obtained an understanding of writing ionic

chemical symbols and an understanding of oxidation numbers. Table 2 (a) shows that only 49% of the students had an understanding of the writing of chemical symbols of ions before the study. Similar cases were reported by researchers that students' inability to write correct formulae of some radicals and some ions [11]. Table 2 (a) shows that only 43% of students understood what oxidation numbers meant and could explain oxidation numbers. Similar results about students having conceptual problems with oxidation numbers of atoms [31]. In Table 3 (a), there has been an improvement in obtaining the concept of oxidation numbers that is 88% of the students understand oxidation numbers of atoms. Table 2(b) shows that before the intervention, 43% of the students understood writing ionic chemical symbols and understanding oxidation numbers. Table 3 (b) shows that 88% of the students understood the writing of ionic chemical symbols as well as oxidation numbers after the intervention. It is observed that students taught using the activity-based instructional approach performed very well.

However, some students still faced conceptual problems so far as oxidation number is concerned and results from student's pre-test revealed that some students merely neglected to indicate the sign. Though some students were able to determine the oxidation numbers of atoms, they failed to indicate the + or – sign. Not only that but also some students also faced conceptual problems of writing chemical symbols of ions. Table 4 gives the incorrect responses of students when interviewed about writing the chemical symbols of ions present in molten alumina and lead tritrate (V) solution.

### 3.2. Conceptual Difficulties Students Face in Identifying Redox Reaction Equations as well as Identifying Oxidizing and Reducing Agents

This sub-section also presents results and discussion on research question 2: What are the conceptual difficulties students face in identifying redox reaction equations as well as identifying oxidizing and reducing agents? In Table 2(a) item 5 measured the percentage of students with the ability to identify redox reactions before the intervention. Item 3 of Table 2(a) also measured the percentages of students who could identify oxidizing and reducing agents before the intervention. Item 4 of Table 3(a) also measured the percentage of students who could identify redox reactions after the intervention. Item 3 of Table 3 (a) measured the percentage of students who could identify oxidizing and reducing agents after the intervention. Table 5 shows the misconceptions several students had towards oxidizing agents and reducing agents.

**Table 5. Students' incorrect responses and reasons**

Students' incorrect Responses	Reasons	Number of students
Oxidizing agent oxidizes whereas a reducing agent reduces in a chemical reaction	it has oxygen atoms	2
oxidizing agent: I Reducing agent: Cl <sub>2</sub>	it oxidises in the equation it reduces the equation	3
Oxidizing agent: CO Reducing agent: Fe <sub>2</sub> O <sub>3</sub>	it oxidises in the equation it reduces the equation	

Before the study, the students did not know anything about redox reactions as no student could identify a redox reaction (item 6 in Table 2 (a)). After implementation of the intervention, students could identify redox reactions with 91% of students gaining an understanding of the nature of reactions. However, some fewer students still faced problems since they selected all the equations to be redox reactions and obtained zero scores (since a wrong selection nullified one correct selection). One explanation the student gave for not selecting  $\text{MnO}_2 + 4\text{HCl} \rightarrow \text{MnCl}_2 + \text{Cl}_2 + 2\text{H}_2\text{O}$  as a redox reaction equation is that since there are water and a salt (MnCl<sub>2</sub>) at the right-hand side of the

equation, the equation is a neutralization reaction equation rather than redox reaction equation.

Table 2 (a) shows that before the study, the students did lack the concept of oxidizing and reducing agents while Table 3 (a) shows that 74% of the students gained an understanding of oxidizing agents and reducing agents. Despite the laboratory activity to enhance students' conceptualizing of oxidizing agents and reducing agents, some students still had difficulties in identifying oxidising agents and reducing agents. A similar study supported current findings that students regard oxidation and reduction as independent reactions; they have problems with the meaning and assignment of oxidation numbers and the identification of reactants as oxidizing or reducing agents [31]. Table 5 revealed their conceptual difficulties. What adds to the significance of students having problems in conceptualizing redox reactions in this study are similar cases of students' difficulties in conceptualizing redox reactions [31]. It was also revealed that students who got some of the post-test items wrong had the misconception that oxygen must take part in redox reactions and if one of the reactants contains oxygen, then that reactant is the oxidizing agent. These findings conform with an earlier study that many students believe that oxygen always takes part in all redox reactions and that oxygen is a prerequisite for a redox reaction [51]. Table 3 (b) shows that the percentages of students that gained an understanding of redox reactions and oxidizing and reducing agents were 73%% indicating that the number of students who understood the nature of redox reactions and oxidizing and reducing agents had improved.

### ***3.3. Difficulties Students Have in Writing Balanced Redox Reaction Equations by the Ion-Electron Method***

This sub-section presents results and discussion on research question 3: what difficulties do the students have in writing balanced redox reaction equations by the ion-electron method?

Item 5 of Table 2(a) measured students' understanding of writing balanced redox reaction equations before the intervention. Item 5 of Table 3 (a) measured the percentage of students understanding writing balanced redox reaction equations immediately after the intervention. Students' inability to determine oxidizing and reducing agents persisted well into balancing redox reaction equations since the first step in balancing requires that oxidation and reduction half equations are separated and balanced before combining to obtain the overall balanced equations. Table 2 (a) shows that before the study the students did not know how to write balanced redox reaction equations as none of the students could write a correct balanced redox equation as the item demanded. Table 3 (a) shows that immediately after the study many students gained an understanding of writing balanced redox reaction equations. The difficulties students faced when balancing redox reaction equations were their inability to identify oxidation and reduction half equations, their inability to remove spectator ions, and their lack of understanding to use stoichiometric coefficients to conserve charges. Different items were used to measure students' understanding of writing balanced redox equations. Item 5 of Table 3 (a) measured the student's ability to write balanced half equations (oxidation half and reducing half equations) and overall balanced equations. Table 3 (a) shows that 62% of students gained an understanding of writing balanced half equations and overall balanced equation.

### ***3.4. Activity-Based Strategy Enhance Students' Performance in the Concept of Redox Reaction***

This section also presents results and discussion on research question 4: How will an activity-based strategy enhance students' performance in the concept of redox reaction?

**Table 6. Comparison of pre-test mean and post-test mean**

Test	Mean
Pre-test	2.23
Post-test	9.08
Mean difference	6.85

Table 6 shows the responses of the student before and after the intervention. This shows that the activity-based teaching which was used for the intervention was effective and has translated to improved performance of the students. The mean value indicated that participants showed more achievement in the post-test 9.08 while the pre-test scored 2.23. This suggests that students taught using activity-based methods had higher mean scores in a redox reaction. This implies that the experimental group that was taught redox reaction concepts using an Activity-Based teaching strategy achieved significantly positive academic performance. The results from the study confirm the assertion of previous studies that activity-based teaching featuring active students' participation in the learning process produces superior results than other methods. The activity-based method has great effects on students' interest in redox reactions more so that it helps to practicalise those concepts in redox reactions [52].

#### 4. Conclusions and Recommendations

The use of activity-based teaching methods in teaching chemistry appears to be used effectively in imparting the content knowledge of chemistry to students to become successful in their learning. Regarding the benefits of the activity-based method. The use of activity-based teaching methods in redox reaction motivates students to be self-learners and improves performance. It is also evident from the findings of this study that the use of the activity-based method of teaching could enhance student performance in redox reactions. It is recommended that activity-based methods of teaching should be encouraged be used by chemistry teachers in the Senior High Schools of Ghana in teaching redox reaction concepts to enhance students' performance in redox reaction. It is also recommended that the Ghana education service should collaborate with the chemistry teachers' Association of Ghana to organize professional development programmes, seminars and workshops for chemistry teachers on activity-based to improve their knowledge of teaching skills.

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