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EDITORIAL

STEM Journal of Anambra STAN (STEMJAS) is a publication of **Science Teachers Association of Nigeria, Anambra State Chapter.** STEMJAS is developed to disseminate information on Science, Technology, Engineering and Mathematics (STEM) to teachers, teacher-trainers, researchers and other interested persons. Articles that are of relevance to STEM education are published in this journal.

We are grateful to the contributors and hope that our readers will enjoy reading these contributions.

Prof. Ebele C. Okigbo

Editor-in-Chief

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EFFECT OF NUMBER LINE ASSISTED INSTRUCTION IN THE LEARNING OF REDOX REACTION ON SECONDARY STUDENTS' ACHIEVEMENT IN CHEMISTRY

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Abstract
The study examined the impact of number line-assisted instruction on students' academic achievement in Chemistry, specifically in redox reactions. A quasi-experimental pre-test, post-test non-randomized control group design was employed. The study was conducted in the Otuocha Education Zone, Anambra State, Nigeria, involving 118 Senior Secondary Two (SS2) students (55 males, 63 females) selected from a population of 857 students across four randomly sampled public schools. A 20-item multiple-choice Chemistry Achievement Test (CAT) on redox reactions was used for data collection. Students were assigned to experimental and control groups. The experimental group received instruction using number line-assisted teaching, where electron transfer in redox reactions was visualized through structured number line models to enhance conceptual understanding, while the control group was taught using conventional lecture methods. The treatment lasted four weeks**,** *during which students received* four instructional sessions per week, each lasting 40–60 minutes. *The collected responses were screened for missing values, outliers and validity. Data analysis involved mean, standard deviation and t-test at a 0.05 significance level. Results indicated that number line-assisted instruction significantly enhanced students' achievement in redox reactions. A significant difference in achievement was observed between the experimental and control groups, with males outperforming females when taught using the number line-assisted method. The study recommends adopting number line-assisted instruction for teaching redox reactions in Nigerian senior secondary schools.*

Keywords: Number Line Assisted Instruction, Redox reaction, Chemistry achievement.

Introduction

Education is a deliberate and structured process designed to maximize individual growth and societal development. It is driven by the goal of equipping individuals with the necessary knowledge, skills and critical thinking abilities to navigate and contribute meaningfully to the world. At its core, education aims to foster intellectual development, personal fulfillment and the capacity to apply knowledge across diverse contexts. This process, inherently dynamic, involves continuous interaction between teaching and learning, with the ultimate aim of achieving specific educational objectives. As such, education not only addresses the transmission of knowledge but also focuses on the development of a learner's ability to think critically, solve problems and make informed decisions in all aspects of life.

Science education, particularly Chemistry, plays a crucial role in shaping the scientific understanding and cognitive abilities of students. Chemistry, the study of matter and its interactions, forms the foundation for numerous scientific disciplines, including engineering, medicine and environmental science. However, despite its importance, Chemistry is often perceived as one of the more difficult subjects by students, particularly in Nigerian secondary schools. This challenge is compounded by a shortage of skilled teachers and the predominance of traditional teaching methods that may not engage students effectively. As a result, many students struggle with core concepts, such as redox reactions, which are fundamental to understanding various chemical processes and applications (Adeifo, 2019; Christie, & Graaff, 2017; Nnoli & Onwudinjo, 2023; Hornby, 2020).

The teaching of redox reactions presents a particular challenge in Chemistry education. These reactions, which involve the transfer of electrons between species, are essential for understanding a range of chemical phenomena, including electrochemical processes, biological systems and industrial applications. However, the abstract nature of these reactions, combined with complex terminology and concepts, often makes it difficult for students to grasp (Luciane et al., 2020; Chikendu, 2022; Brouwers et al., 2010; Koretsky, et al, 2018). Students face difficulties in understanding oxidation states, electron transfer processes and the identification and balancing of redox reactions. These challenges have been well-documented in previous research, with many students showing misconceptions about the core principles of redox reactions and failing to perform well in related exams (Luciane et al., 2020; Emendu, 2017; Hwang, et al, 2022).

Innovative teaching strategies are essential for addressing these difficulties and improving student performance in Chemistry. One such approach is the use of number line-assisted instruction**,** which has shown promise in enhancing students' understanding of mathematical and scientific concepts. The number line, a visual representation of numerical relationships, helps students better understand magnitude, number relationships and operations. By applying this tool to the teaching of redox reactions, students can visualize the movement of electrons and changes in oxidation states, providing a clearer understanding of these complex processes (Factsheet, 2022). This approach has the potential to bridge the gap between abstract concepts and tangible learning, thus improving both comprehension and retention.

Redox reactions, which describe processes where the oxidation state of atoms or ions changes through electron transfer, are central to many chemical reactions. These reactions include processes

such as combustion, corrosion, respiration and the operation of batteries and fuel cells (Mendonça et al., 2004; Makaeva, & Iskandarov, 2019). A key challenge in teaching redox reactions is making the abstract concept of electron transfer more accessible to students. The use of number lines in this context allows for a more intuitive understanding of how electrons are gained or lost during oxidation and reduction, making the concept more relatable and easier to follow. For instance, when sodium reacts with fluorine, sodium loses electrons (oxidation) and fluorine gains electrons (reduction), a process that can be effectively demonstrated using a number line. This representation visually shows the shift in oxidation numbers, helping students grasp the fundamental nature of redox reactions (Cronk, 2020; Jonah, et al, 2021).

Research has demonstrated that the use of number lines can enhance students' problem-solving abilities and conceptual understanding, particularly in subjects that involve complex numerical relationships (Jeffrey, 2010; Nnoli, 2022). Studies suggest that this approach aids in the visualization of abstract concepts, providing students with a tool to better understand and manipulate the material they are learning. In the case of Chemistry, applying this method to redox reactions could provide students with a more accessible way of understanding electron transfer, oxidation states and the overall process of redox reactions (Adu-Gyamfi, 2016). Moreover, the number line-assisted approach is aligned with modern educational trends that prioritize active learning, critical thinking and the use of visual tools to enhance student engagement and retention.

Despite the growing recognition of the importance of teaching strategies like number line-assisted instruction, many Chemistry teachers continue to face significant challenges in teaching complex topics like redox reactions. The lack of engaging, interactive teaching methods and resources is often cited as a major factor in the difficulties students face in mastering these concepts (Shittu et al., 2018; Tan,et al 2000; Udo, 2011). Therefore, there is a pressing need to explore and implement alternative teaching strategies that can make these concepts more accessible and engaging for students. Number line-assisted instruction offers a promising avenue for improving students' understanding of redox reactions, offering a visual and intuitive way to represent electron transfer and oxidation-reduction processes.

Redox reactions are a fundamental concept in Chemistry education, yet many students continue to struggle with understanding these processes due to their abstract nature and complex terminology. The integration of number line-assisted instruction presents an innovative solution to this challenge, providing students with a visual tool that can enhance their understanding of oxidation-reduction reactions. By offering a clearer representation of electron movement and oxidation states, number lines can help students develop a deeper understanding of redox reactions, leading to improved academic achievement in Chemistry. As such, this study aims to explore the effectiveness of number line-assisted instruction in enhancing students' comprehension of redox reactions and its potential impact on Chemistry education.

Statement of the Problem

Teaching methods play a pivotal role in shaping student achievement, particularly in subjects as complex as Chemistry. Despite its importance in the secondary school curriculum, students consistently perform poorly in Chemistry, raising concerns among educators, parents and policymakers. This trend has sparked an urgent search for more effective instructional strategies to enhance student learning outcomes. Various teaching methods, including expository, inquiry-based, project and discovery learning, have been explored in an attempt to address this issue (Adimoyemma, 2010). However, the question remains: Can the application of number line-assisted instruction**,** a strategy that utilizes a pictorial representation of numbers on a straight line to strengthen students' understanding of numerical relationships and magnitudes, improve students' academic achievement in Chemistry?

The specific challenge in Chemistry lies in students' persistent difficulties with abstract concepts such as redox reactions, which often results in poor performance in examinations. Traditional methods of instruction may not fully engage students, leading to misconceptions and an inadequate grasp of key scientific principles. By integrating number line-assisted instruction, which provides a visual and interactive tool for representing oxidation states and electron transfer, there is potential to alleviate the cognitive barriers students face. This approach could mitigate the phobia and confusion that students often experience when learning redox reactions, ultimately leading to improved understanding and achievement. This study aims to investigate the effectiveness of number line-assisted instruction in enhancing student performance in Chemistry, particularly in the context of redox reactions.

Purpose of the Study

The primary purpose of this study is to evaluate the impact of number line-assisted instruction (NLAI) on the academic achievement of senior secondary school students in Chemistry, specifically in the topic of redox reactions. The study aimed to address the following objectives:

1. To compare the mean achievement scores of students taught redox reactions using number line-assisted instruction (NLAI) and those taught using conventional instruction (CI), which relies on direct teaching methods, lecture-based content delivery and minimal student interaction.
2. To assess the difference in the mean achievement scores between male and female students who were taught redox reactions using number line-assisted instruction.

Research Questions

The study was guided by the following research questions:

1. What is the difference in the mean achievement scores of students taught redox reactions using number line-assisted instruction (NLAI) compared to those taught using conventional instruction (CI)?

2. What is the difference in the mean achievement scores between male and female students who are taught redox reactions using number line-assisted instruction?

Hypotheses

The following null hypotheses were tested at a significance level of 0.05:

1. There is no statistically significant difference in the mean achievement scores of students taught redox reactions using number line-assisted instruction (NLAI) and those taught using conventional instruction (CI).
2. There is no statistically significant difference in the mean achievement scores of male and female students taught redox reactions using number line-assisted instruction.

Method

This study employed a quasi-experimental design, specifically a pre-test, post-test, non-equivalent, non-randomized control group design. The design was structured as a 2x1 factorial model, representing two levels of instructional treatment, Number Line Assisted Instruction (NLAI) and Conventional Instruction (CI), and one variable for gender (male and female). The aim was to examine the impact of the treatment methods on students' achievement in Chemistry, particularly in the topic of redox reactions.

The target population for the study consisted of 857 Senior Secondary Two (SS2) Chemistry students from public schools in the Otuocha Education Zone of Anambra State, Nigeria. A sample of 118 SS2 Chemistry students was selected through simple random sampling. The sample was drawn from a pool of students from four public secondary schools in the zone.

The primary instrument used for data collection was the Chemistry Achievement Test (CAT), a 20-item multiple-choice objective test with five response options for each question. The questions were adapted from past West African Examinations Council (WAEC) Senior Secondary Certificate Examination (SSCE) Chemistry Paper II questions, ensuring the instrument's relevance to the curriculum. As the CAT was based on standardized questions, a reliability analysis was not necessary. The content of the CAT was guided by a table of specifications covering the six levels of the cognitive domain of learning, as defined by Bloom’s Taxonomy.

The CAT was divided into two sections: Section A collected the demographic information of the students (bio-data), while Section B contained the multiple-choice achievement questions. The instrument was designed to assess both achievement and retention in Chemistry. The validity of the instrument was established through expert review by three academics from the Department of Chemistry and the Department of Education Foundations at Nwafor Orizu College of Education, Nsugbe, who ensured that the items accurately reflected the content to be tested.

The experimental procedure was implemented in two phases. The first phase involved the training of research assistants, who were the regular Chemistry teachers of the sampled students. These teachers underwent a three-day training session, where they were introduced to the lesson plans prepared by

the researchers. The research assistants were instructed on how to apply the teaching methods associated with each treatment group (NLAI and CI) in their lessons.

In the second phase, the teaching sessions were conducted. Prior to instruction, both groups of students were administered the pre-test version of the CAT. Following the pre-test, the experimental group received instruction based on Number Line Assisted Instruction (NLAI), while the control group received Conventional Instruction (CI), which adhered to traditional expository teaching methods. Both groups were taught for a period of four weeks.

After the four weeks instructional period, the post-test version of the CAT was administered to both groups to assess their immediate achievement. Following another two weeks interval, the same CAT instrument was re-administered as a retention test to evaluate the long-term retention of the material.

Data collected from the pre-test, post-test and retention test were analyzed using mean, standard deviation and t-test. Descriptive statistics, specifically mean and standard deviation were used to answer the research questions, while inferential statistics (t-test) were employed to test the null hypotheses at the 0.05 level of significance.

Results

Research Question 1: What is the difference in the mean achievement scores of students taught redox reactions using number line-assisted instruction (NLAI) compared to those taught using conventional instruction (CI)?

Table 1: Mean Achievement Scores of Students Taught redox reaction with Number Line Assisted Instruction and those Taught with Conventional Instruction

Group	Symbol	Pretest	Posttest	Mean gain
Experimental Group	N	59	59	
	Ẍ	15.40	25.78	10.38
	SD	3.75	4.02	
Control Group	N	59	59	
	Ẍ	14.93	21.65	6.72
	SD	3.40	3.56	

N= Number of students, Ẍ = Mean, SD = Standard Deviation

Table 1 presents a comparative analysis of the pre-test and post-test mean scores, as well as the standard deviations, for both the experimental and control groups. Prior to the treatment, the standard deviations were 3.75 for the experimental group and 3.40 for the control group, indicating that the spread of scores in both groups was relatively narrow. This suggests that the two groups were equivalent at the outset of the study and were comparable in terms of prior knowledge and achievement in Chemistry.

Following the instructional interventions, the experimental group, which received Number Line Assisted Instruction (NLAI), exhibited a significant improvement in mean achievement scores, rising from a pre-test mean of 15.40 to a post-test mean of 25.78. While the standard deviation for the experimental group showed a marginal increase, this result indicates that there was a slight broadening of the variability in the post-test scores. This could be attributed to the varied responses among the students as a result of their engagement with the innovative teaching approach.

In contrast, the control group, which received Conventional Instruction (CI), also showed an improvement, with mean scores increasing from 14.93 in the pre-test to 21.65 in the post-test. Similar to the experimental group, the control group's standard deviation showed a marginal increase, suggesting a slight increase in the variability of students' post-test scores. However, when compared to the experimental group, the control group's post-test mean was lower, indicating that the number line-assisted method had a more pronounced impact on students' achievement.

Further analysis of the mean gain between the groups reveals a more substantial improvement for the experimental group (mean gain = 10.38) compared to the control group (mean gain = 6.72). This suggests that the students who were taught using the number line-assisted instruction outperformed those taught with conventional methods. The higher mean gain for the experimental group reflects the efficacy of NLAI in enhancing student achievement in Chemistry, particularly in the topic of redox reactions.

Research Question 2: What is the difference in the mean achievement scores between male and female students who are taught redox reactions using number line-assisted instruction?

Table 2: Mean Achievement Scores of Male and Female Students Taught redox reaction with Number Line Assisted Instruction

Group	Symbol	Pretest	Posttest	Mean gain
Male	N	32	32	
	Ẍ	15.72	29.98	14.23
	SD	3.25	4.32	
Female	N	27	27	
	Ẍ	16.45	25.58	9.13
	SD	3.62	4.99	

N= Number of students, Ẍ = Mean, SD = Standard Deviation

Table 2 illustrates the pre-test and post-test mean scores of male and female students who were taught using the Number Line Assisted Instruction (NLAI) approach. The pre-test mean scores were 15.75 for male students and 16.45 for female students, indicating a relatively small initial difference in achievement between the two groups. However, a marked improvement is evident in the post-test results, with male students achieving a mean score of 29.98 and female students scoring 25.58. This change reflects significant progress for both male and female students, suggesting that the NLAI approach was effective in enhancing their understanding of redox reactions.

The mean gain further supports this conclusion, with male students exhibiting a gain of 14.23 points and female students showing a gain of 9.13 points. This indicates that, while both male and female students experienced improvements in their achievement, male students demonstrated a greater level of enhancement in their understanding of the subject matter compared to their female counterparts.

Regarding the variability of achievement scores, the standard deviations for both male and female students showed minimal spread in the post-test scores, suggesting that the performance of the students in both groups was relatively consistent. This further emphasizes the effectiveness of the NLAI approach in producing a uniform improvement in achievement among students, regardless of gender.

$H0_1$: There is no statistically significant difference in the mean achievement scores of students taught redox reactions using number line-assisted instruction (NLAI) and those taught using conventional instruction (CI).

Table 3: t-Test Comparison of the Mean Achievement Scores of Students Taught Chemistry Applying Number Line Assisted Instruction and those Taught with Conventional Method

Group	N	Mean	SD	df	t_{cal}	$P_{0.05}$
Experimental	59	25.78	4.02	116	2.342	.000
Control	59	21.65	3.56			

The results presented in Table 3 indicate that the t-test for the post-test scores of the experimental and control groups yielded a statistically significant result, with a p-value of 0.000, which is below the 0.05 threshold for significance. This outcome leads to the rejection of the null hypothesis, which posited no significant difference in the mean achievement scores of Chemistry students taught with Number Line Assisted Instruction (NLAI) compared to those taught using the conventional method. Thus, it can be concluded that there is a significant difference in the mean achievement scores between the two groups, with students taught using the NLAI method demonstrating superior performance. This statistical evidence supports the effectiveness of the NLAI approach in improving students' understanding of redox reactions in Chemistry, particularly when compared to traditional instructional methods.

$H0_2$: There is no statistically significant difference in the mean achievement scores of male and female students taught redox reactions using number line-assisted instruction.

Table 4: t-Test Comparison of the Mean Achievement Scores of Male and Female Students Taught Chemistry Applying Number Line Assisted Instruction.

Group	N	Mean	SD	df	t_{cal}	$P_{0.05}$
Male	32	29.98	4.32	57	3.621	2.000
Female	27	25.58	4.99			

The results presented in Table 4 indicate that the t-test for the post-test scores of male and female students in the experimental group did not reveal a statistically significant difference, with a t-value of 2.000, which is greater than the 0.05 significance level. Consequently, the null hypothesis, which posited no significant difference in the mean achievement scores between male and female Chemistry students taught using Number Line Assisted Instruction (NLAI), was not rejected.

This suggests that the application of NLAI in teaching redox reactions resulted in similar levels of achievement for both male and female students. In other words, gender did not have a significant impact on the effectiveness of the NLAI approach in improving Chemistry students' performance.

Discussion

The findings of this study provide compelling evidence for the effectiveness of Number Line Assisted Instruction (NLAI) in teaching redox reactions to senior secondary school Chemistry students. The experimental group, which was taught using NLAI, achieved significantly higher mean scores compared to the control group, which was taught using conventional methods. This result corroborates the work of researchers such as Jeffrey (2010), who argues that utilizing the number line as a teaching tool enhances students' ability to think mathematically, fostering greater confidence, fluency and operational facility with numbers.

Additionally, studies by Egbo (2005) and Omwirhiren (2005) emphasize the efficacy of activity-oriented teaching strategies, suggesting that they can significantly improve students' retention, understanding and achievement in science concepts. The application of the number line method in this study reflects these principles, as students who were exposed to this instructional approach demonstrated a deeper understanding of redox reactions, which was evident during the evaluation phase.

Moreover, the results indicated a significant gender-related difference in achievement, with male students outperforming their female counterparts in the experimental group. This finding suggests that while NLAI was effective for both genders, male students showed a greater improvement in their achievement scores. This aligns with the broader discussion in educational research regarding gender differences in learning, with some instructional strategies being considered more favorable to one gender over another. As noted by various science educators, the extent to which gender influences learning outcomes can vary significantly depending on the instructional method used and the specific scientific concept being taught.

The study reinforces the idea that innovative teaching strategies, such as the number line method, can be a powerful tool for enhancing student achievement in Chemistry. However, it also highlights the need for further investigation into the gender-related dynamics of different teaching methods, particularly in the context of science education.

Conclusion

The findings of this study underscore the effectiveness of Number Line Assisted Instruction (NLAI) in enhancing the achievement of secondary school Chemistry students. The experimental group,

which was taught using the number line method, demonstrated superior achievement compared to the control group, who were taught using conventional methods. In particular, students in the control group experienced greater difficulty in mastering the selected concepts. Additionally, male students in the experimental group outperformed their female counterparts, highlighting a significant gender difference in achievement when using the number line method.

Recommendations

Based on the findings of this study, the following recommendations are put forward:

1. Encouragement for the Use of NLAI in Teaching Chemistry: Secondary school Chemistry teachers should be strongly encouraged to adopt the number line-assisted instruction method consistently.
2. Addressing Gender-Based Achievement Gaps: Given the observed gender difference in achievement, it is recommended that special attention be given to female students when implementing the number line method.
3. Integration of Cross-Disciplinary Teaching Strategies: To further improve students' understanding and retention of difficult Chemistry concepts, teachers should integrate methods and knowledge from other disciplines, such as Mathematics.
4. Exploration of Additional Topics in Chemistry: To build on the success of using the number line method in teaching redox reactions, it is recommended that future research explore its application to other Chemistry topics, such as electrolysis and atomic structure.

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