impact International Journals and Publications

© IIJP 2026 | Volume 2, Issue 2, pp. 81-88 | ISSN: 2636-4484

PREDICTING NCE CHEMISTRY STUDENTS' PERFORMANCE IN REDOX TITRATION: A MULTINOMIAL LOGISTIC REGRESSION APPROACH

Ajayi Titilope, Adewumi[1], Oluwatuberu Aderonke, Oluwabukola[2], Abubakar Adiket[3] & Odedokun Omobola, Ajibike[4]

[1,2,3,4]Department of Chemistry, Federal College of Education (Special), Oyo.

[1]titilopeadedeji1@gmail.com, [2]adeolubukky1@gmail.com, [3]adiketabubakar@yahoo.com & [4]bolajibike@yahoo.com

ARTICLE INFO

Article No.: 0269

Accepted Date: 24/03/2026

Published Date: 09/04/2026

Type: Research

ABSTRACT

This study examined the predictive influence of examination scores, class attendance, and practical laboratory performance on students' achievement in redox titration. Using a quantitative ex-post facto design, data were collected from 174 NCE 200-level chemistry students in Oyo, Nigeria. Participants were classified into low, average, and high performance categories using Jamovi (v2.7). Multinomial logistic regression indicated a moderate model fit (McFadden $R^2 = 0.196$), with omnibus tests confirming all predictors were statistically significant ($p < .001$). High performance was significantly predicted by examination scores, attendance, and practical work. While the model distinguished high from low performers, it was less effective for the average category. These findings underscore the importance of integrating attendance monitoring and practical work into chemistry curricula. This study contributes a novel methodological approach to addressing academic performance challenges in Nigerian higher education.

Keywords: Chemistry education, Redox titration, Multinomial logistic regression, Jamovi, Academic performance.

Introduction

Chemistry is vital because everything humans do revolves around it; essentially, the human body is made up of chemicals (Lim, 2020). According to Usselman et al. (2021), chemistry is the branch of science that studies the characteristics, composition, and structure of substances, the changes they undergo, and the energy involved in these processes. Beyond its fundamental nature, chemistry has a significant economic impact, playing a crucial role in providing food, medical services, and other materials essential for improving human life. In the context of Nigerian higher education, mastering specific chemical concepts such as redox titration is foundational for students' academic and professional development. Because of this foundational importance, chemistry is an entry requirement subject taught at the senior secondary education level that students must pass to qualify to earn eligibility for admission to pursue science-based programs, such as agricultural science and medicine in Higher Institutions (UTME, 2021). Similarly, Santos-Díaz and Towns (2020) stated that learning chemistry is essential in every society for citizens to cope with the rapidly evolving development in science and technology.

Despite various contributions made by chemistry, the study of the subject in schools is plagued with poor performance at higher-order thinking levels (Ojengwa et al., 2024). Students have consistently performed poorly in chemistry in public examinations conducted nationwide by the West African Examinations Council (WAEC) and the National Examinations Council (NECO) over the years (Ojengwa et al., 2024). Chemistry students see the subject as abstract and difficult, which is attributed to their low performance in the subject (Kyado et al., 2021).

A redox reaction is a chemical reaction which involves change in the oxidation states of atoms. This reaction involves a change or transfer of electrons which takes place among different chemical species, one species gains the electrons while the other loses the electrons (Oriakhi, 2021). Redox reactions consist of two parts that always occur together which are reduced half and the oxidized half. It consists of two forms of half reactions, which are reduction-half and oxidation-half reactions (Khattak et al., 2020). Kyado et al. (2021) identified certain chemistry concepts such as chemical kinetics, thermodynamics, quantitative analysis, ionization, alkanols, hydrophobic interactions, redox reactions, hydrocarbons, stoichiometry, neutralization, quantum numbers, enantiomers, gas laws, enthalpy, mole concepts, atomicity, and nuclear chemistry as challenging to students. Also, several studies have linked difficulties students face in learning chemistry: redox reactions, understanding of oxidation and reduction half reactions, salt bridges in electrolysis (Adu-Gyamfi et al., 2015; Bong & Lee, 2016; Walanda et al., 2017). Adu-Gyamfi et al. (2015) emphasized that while introducing H^+, OH^-, and H_2O, students experience challenges in balancing redox reactions. Bong and Lee (2016) matched these challenges with the absence of basic knowledge in electrochemistry, language barriers, and reliance on mindless learning.

Titration, also referred to as volumetric (quantitative) analysis, is frequently used to determine how much of an analyte's solute is in its solvent. Analysis of neutralization reactions between acids and bases is one of its most important applications. It involves the titration of an acid against base, the end-point of this reaction is determined by colour changes according to the pH of the solution by a substance known as indicator (Harris, 2020). In higher education, class attendance is regarded as a key to academic success, particularly where students' engagement in the learning process significantly influences their performance (Büchele, 2021). Regular attendance not only ensures that students have access to critical course material but also fosters active participation, engagement with instructors and classmates, and the development of essential skills (Muir et al., 2022). In chemistry, learning by doing is very important in enabling science students to understand what they are learning (Shana & Abulibdeh, 2020). Practical work enhances students' motivation, interest, and understanding of chemistry concepts. It helps students in developing various skills like observational skills, communication, questioning skills, and problem-solving (Tesfamariam et al., 2014).

Jamovi is open-access statistical analysis software designed to be user-friendly and available to researchers, educators, and students (Navarro et al., 2022). It provides a graphical user interface that facilitates the process of conducting statistical analyses. This study utilizes Jamovi to apply multinomial logistic regression in analyzing students' academic performance in redox titration. By doing so, it provides a more comprehensive understanding of how attendance, practical work, and examination performance collectively influence students' outcomes. This approach contributes to improving data-driven decision-making in chemistry education and addressing the persistent challenge of poor academic performance.

To effectively leverage such tools, it is crucial to understand the role of predictive analysis in education. The key steps in enhancing the quality of education are accurate prediction and analysis of students' academic performance. Advances in big data technology and the spread of educational digitization have led to the recording of a growing volume of multidimensional data (Shen et al., 2023; Zhao et al., 2023). Predictive analysis focuses on extracting valuable information from educational data to gain insights into teaching and learning patterns and support educational decision-making (Perkash et al., 2024). Despite the growing use of predictive analysis in education, traditional statistical methods often fail to capture the complexity of students' academic performance when it is categorized into more than two levels. Many existing studies focus on linear relationships or binary outcomes, which limit the ability to fully understand variations in students' performance across multiple categories such as low, average, and high achievement levels.

Given these limitations, more advanced analytical techniques are needed. Multinomial logistic regression provides a more advanced analytical approach by allowing the simultaneous analysis of multiple independent variables in relation to a categorical dependent variable with more than two outcomes. This makes it particularly suitable for educational data where performance is naturally grouped into levels. Recent studies have demonstrated the effectiveness of multinomial logistic regression in predicting academic outcomes and identifying key influencing factors across different performance categories (Ajeka & Shofoluwe, 2025). However, its application in chemistry education, especially in predicting students' performance in specific concepts such as redox titration, remains limited. Therefore, the use of multinomial logistic regression in this study represents a novel methodological contribution by providing a comprehensive framework that integrates attendance, practical performance, and examination scores to predict students' achievement levels.

Statement of the Problem

Despite the importance of chemistry in science education, students continue to perform poorly in key areas such as redox titration, largely due to its abstract nature and ineffective instructional approaches. Current research gaps exist because many existing studies rely on traditional statistical methods that fail to adequately capture performance variations across multiple achievement levels specifically low, average, and high performance. While attendance, examination performance, and practical skills are identified as influencing factors, the precise way these variables simultaneously predict categorical outcomes in chemistry remains unknown.

Furthermore, limited research has applied advanced predictive models, such as multinomial logistic regression, in chemistry education. This gap restricts the development of accurate, data-driven strategies specifically, targeted instructional interventions and early-warning systems for at-risk students needed now to address persistent failure rates. Therefore, the problem of this study is the lack of a comprehensive predictive framework that integrates attendance, practical performance, and examination scores to categorize and predict students' achievement levels in redox titration.

Research Questions

1. To what extent do students' exam scores predict their performance levels in redox titration?
2. How do students' practical scores affect their performance in redox titration?
3. To what extent does attendance influence students' performance in redox titration?
4. How well do exam scores, practical scores, and attendance collectively predict students' performance in redox titration?

Methodology

This study employed a quantitative ex-post facto to examine how exam scores, attendance, and practical scores influence students' performance in redox titration. Ethical approval was obtained from Management Information System Department of the Institution, and data were handled confidentially. Participants were 174 NCE 2 level students at the Federal College of Education (Special), Oyo, selected via total enumeration. Ages ranged from 18 to 25 years, and all participants had completed assessments in redox titration exams, attendance, and practical laboratory work. Data were retrieved from institutional records. The dependent variable, students' performance, was categorized using percentiles: low (≤42, ≤33rd), average (43–52), and high (≥53, ≥66th). Independent variables were exam score, attendance, and practical score. Analyses were conducted in Jamovi (v2.7). Descriptive statistics summarized the data, and multinomial logistic regression assessed the predictive effects of the independent variables on performance levels, comparing average and high against low performance, here, "Low performance" is the reference category. Model fit was evaluated with Deviance, AIC, and McFadden's R^2, and predictor significance was tested using Omnibus Likelihood Ratio Tests, coefficients (β), standard errors, and odds ratios.

Data Analysis

Table 1: Descriptive Statistics of Students' Total Scores

Descriptives

	N	Mean	Median	SD	Minimum	Maximum	33th percentile	66th percentile
Total Score	174	47.3	47.0	10.7	2.00	74.0	42.0	52.0

Table 1 summarizes the performance of 174 students, with only one missing value. Total scores were relatively balanced, with a mean of 47.3, median of 47.0, and standard deviation of 10.7, indicating moderate variability. Using the 33rd (42.0) and 66th (52.0) percentiles, students were categorized into low, average, and high performance groups, providing a data-driven classification.

Table 2: Model Fit for exam score, attendance, and practical score

Model Fit Measures

Model	Deviance	AIC	R^2_{McF}
1	143.0	175.4	0.196

Note. Models estimated using sample size of N=174

Table 2 presents the multinomial logistic regression model fit indices. The model yielded a Deviance of 143.0 and an AIC of 175.4, suggesting an adequate fit. The McFadden R^2 of 0.196 indicates that the predictors explain approximately 19.6% of the variance in performance levels, a reasonable value that avoids overfitting.

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Table 3: Omnibus Likelihood Ratio Tests (Overall Predictor Significance)

Omnibus Likelihood Ratio Tests

Predictor	χ^2	df	P
EXAM SCORE	209.6	2	<.001
ATTENDANCE	40.1	2	<.001
PRACTICAL	201.1	2	<.001

Omnibus Likelihood Ratio Tests (Table 3) confirmed that exam score (χ^2 = 209.6, p < .001), attendance (χ^2 = 40.1, p < .001), and practical score (χ^2 = 201.1, p < .001) significantly contribute to the model.

Table 4 : Model Coefficients for exam score, practical score and attendance score.

Model Coefficients - PERFORMANCE LEVEL

							95% Confidence Interval	
PERFORMANCE LEVEL	**Predictor**	**Estimate**	**SE**	**Z**	**p**	**Odds ratio**	**Lower**	**Upper**
Average – Low	**Intercept**	-273.13	143.61	-1.90	0.057	2.42e-119	1.39e-241	4198
	EXAM SCORE	6.58	3.46	1.90	0.057	7.21	0.8149	637879
	ATTENDANCE	5.82	4.47	1.30	0.192	3.38	0.0533	2.15e0+6
	PRACTICAL	6.54	3.45	1.89	0.058	6.93	0.7969	602089
High – Low	**Intercept**	-671.50	230.76	-2.91	0.004	2.36e-292	0.0000	6.25e-96
	EXAM SCORE	14.10	4.91	2.87	0.004	13.3e00+6	88.6222	1.99e+10
	ATTENDANCE	13.82	5.90	2.34	0.019	10.0e00+6	9.4906	1.06e+11
	PRACTICAL	14.06	4.89	2.87	0.004	12.8e00+6	87.2688	1.88e+10

Table 4 shows the relationship between predictors and performance, Average vs Low Performance: Exam score (OR = 7.21, p = .057) and practical score (OR = 6.93, p = .058) showed positive trends but were marginally non-significant; attendance was also non-significant (OR = 3.38, p = .192). High vs Low Performance: All predictors significantly increased the likelihood of high performance: exam score (OR = 13.3, p = .004), attendance (OR = 10.0, p = .019), and practical score (OR = 12.8, p = .004).

Discussion of findings.

The findings indicate that exam scores, attendance, and practical scores significantly influence the likelihood of achieving high performance in redox titration. This suggests that students who excel in structured examinations possess a stronger cognitive mastery of subject content. This aligns with Ajeka and Shofoluwe (2025), who demonstrated that multinomial logistic regression is a robust tool for predicting academic performance categories based on structured student data.

Attendance emerged as a significant predictor of students' academic performance in this study ($p < 0.05$). This agrees with Onuegbu and Offor (2025), who reported a significant relationship between lecture attendance and achievement in chemistry, highlighting the role of regular attendance in enhancing students' understanding of concepts such as redox reactions.

Practical score was found to be a significant predictor of students' academic performance in this study ($p < 0.05$). This finding agrees with Adarkwah et al. (2022), who reported that students exposed to practical-based titration instruction achieved significantly better academic outcomes. Similarly, Wang et al. (2024) emphasized that structured laboratory engagement enhances students' conceptual understanding and analytical skills in titration, including redox processes. This difficulty in predicting intermediate categories is documented by Osei-Asibey et. al (2024), who noted that while multinomial models excel at identifying extreme performance groups, variability within middle categories often reduces statistical significance.

Conclusion

This study demonstrated that multinomial logistic regression can effectively predict students' performance levels in redox titration using exam scores, class attendance, and practical laboratory performance. The analysis showed that these predictors are particularly useful in distinguishing high performers from low performers, highlighting the importance of consistent engagement across academic, behavioral, and applied learning dimensions. These findings contribute to knowledge by providing an evidence-based framework for identifying key factors influencing student achievement and guiding targeted interventions to support academic success.

Recommendations

Based on the findings of this study, the following recommendations are offered to chemistry educators, curriculum planners, and educational policymakers:

1. Enforce structured attendance policies: Institutions should implement a minimum 75% attendance requirement and incorporate it as a continuous assessment component worth at least 10% of the total score. Attendance monitoring systems should be linked to early warning mechanisms to identify at-risk students and provide timely academic support, as attendance significantly predicted high performance.
2. Enhance practical laboratory training: Practical laboratory work should carry greater weight in chemistry curricula and continuous assessment schemes. Since practical performance strongly predicted high achievement in redox titration, institutions should invest in well-equipped laboratories and provide regular, structured practical sessions to reinforce conceptual understanding through hands-on experience.
3. Promote data-driven decision-making: Institutions should adopt evidence-based approaches to monitor and predict student performance. Tools like Jamovi can facilitate predictive analyses, but the focus should remain on using data effectively for academic planning. Chemistry departments and education research units should provide faculty training to enable systematic, data-informed decisions.

Limitations

This study provides insights into predictors of student performance in redox titration, several limitations should be acknowledged. First, the sample was limited to 174 NCE 200-level students from a single institution, which may affect generalizability. The study relied on existing administrative records, which may omit contextual factors such as student motivation or teaching quality that could influence performance. Future research could address these limitations by including larger, multi-institutional samples and additional qualitative or contextual variables.

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