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Effects of Gamification on Academic Performance and Motivation in Learning Electrochemistry among SS2 Students in Sokoto Metropolis, Nigeria

Mustapha Aliyu, Hassan Aliyu* and Bilkisu Umar Mani

Department of Science Education, Sokoto State University, Sokoto State, Nigeria

***Corresponding author:** nagoronyo@gmail.com

Abstract

Chemistry is an important science subject, but students often experience difficulties in understanding abstract topics such as electrochemistry. The use of conventional teaching methods may not adequately promote students' active participation and motivation. Gamification, which incorporates game elements such as points, badges, leaderboards, rewards, and quizzes into learning, has emerged as an innovative strategy for improving students' engagement and academic outcomes. Previous studies have reported that gamified instruction can enhance students' motivation and achievement in science education. However, its application in teaching electrochemistry among secondary school students in Nigeria remains limited. Therefore, this study investigated the effects of gamification on academic performance and intrinsic motivation among SS2 students learning Electrochemistry in Sokoto Metropolis, Nigeria. A quasi-experimental pretest-posttest, non-equivalent control group design was adopted, guided by Self-Determination Theory. From a population of 6,053 SS2 Chemistry students across 48 public schools, 91 students were purposively sampled from two schools: 43 experimental, 48 control. The experimental group received six weeks of gamified instruction incorporating leaderboards, digital badges, a point reward system, and game-based quizzes, while the control group received conventional chalk-and-talk instruction on identical content. Data were collected using the Electrochemistry Achievement Test (EAT, PPMC = 0.81) and the Electrochemistry Students' Motivation Questionnaire (ESMQ, $\alpha = 0.86$), and analysed using ANCOVA at the 0.05 level of significance. The gamified group recorded significantly higher post-test academic performance, $F(1,88) = 184.30$, $p < 0.001$, partial $\eta^2 = 0.68$, and significantly higher intrinsic motivation, $F(1,88) = 601.75$, $p < 0.001$, partial $\eta^2 = 0.872$, than the control group. Both null hypotheses were rejected. The study concludes that gamification is an effective, contextually adaptable strategy for improving Electrochemistry outcomes and recommends its structured adoption alongside teacher training and infrastructural support.

Keywords: gamification, electrochemistry, academic performance, intrinsic motivation, Sokoto metropolis

1 Introduction

Chemistry occupies a foundational position in the Nigerian Senior Secondary School curriculum, providing the disciplinary basis for further studies in medicine, pharmacy, engineering, and the natural sciences. Among the topics prescribed for SS2 Chemistry students, Electrochemistry is consistently identified as one of the most conceptually demanding, requiring simultaneous engagement with abstract processes, mathematical reasoning, and applied scientific principles. These demands create a cognitive load that many students in Nigerian public secondary schools find difficult to manage effectively, resulting in persistent underperformance and motivational disengagement in Electrochemistry (Adegoke, 2021; Yusuf & Adesope, 2022; Zubairu & Sani, 2021). Data from the West African Senior School Certificate Examination (WASSCE) consistently show that a substantial proportion of SS2 Chemistry candidates fail to attain credit passes, with Electrochemistry topics identified as particularly problematic areas (Bello & Musa, 2023; Muhammed & Garba, 2022). Beyond academic underperformance, researchers and educators have documented a marked decline in students' intrinsic motivation toward Electrochemistry learning, characterised by anxiety, disinterest, and passive classroom engagement. These difficulties are compounded by the near-universal reliance on conventional chalk-and-talk instructional methods in public secondary schools across Sokoto State, an approach that prioritises content delivery overactive student engagement and higher-order thinking (Abubakar & Danladi, 2022; Ibrahim & Suleiman, 2022).

Gamification, defined as the deliberate integration of game design elements, such as leaderboards, digital badges, point reward systems, and interactive quiz platforms, within non-game educational contexts (Deterding et al., 2011; Kapp, 2012), has gained increasing scholarly recognition as a viable and contextually adaptable response to these challenges. Rooted in Self-Determination Theory (SDT), which identifies competence, autonomy, and relatedness as the three psychological needs essential for intrinsic motivation (Deci & Ryan, 1985; Ryan & Deci, 2000), gamification is theorised to nurture each of these needs through structured, lesson-embedded game mechanics. A growing body of Nigerian and international research confirms gamification's positive effects on science achievement and motivation (Adeyinka & Fashola, 2023; Hamari et al., 2014; Subhash & Cudney, 2018). This study was therefore designed to investigate effects of gamification on academic performance and Motivation in Learning Electrochemistry SS2 Students in Sokoto Metropolis.

2 Literature Review/Theoretical Framework

Gamification in education involves the systematic integration of game mechanics into instructional settings to enhance learner engagement and academic outcomes (Deterding et al., 2011; Kapp, 2012; Seaborn & Fels, 2015). Unlike full game-based learning, which uses complete educational games, gamification embeds targeted elements, such as points, badges, and leaderboards, into existing classroom activities, making it adaptable to the resource-constrained conditions of Nigerian public secondary schools (Dicheva et al., 2015). A growing body of recent Nigerian research has examined how gamification and closely related motivational constructs affect academic performance, engagement, and attitude in science subjects, providing a useful empirical basis for the present study.

2.1 Gamification and Academic Performance

Several recent quasi-experimental studies converge on the finding that gamified instruction produces measurably higher academic achievement than conventional or comparison teaching methods across a range of science subjects. Ntegwung, Sunday, Ukafia, and Edet (2026), working with 97 Senior Technical students in Akwa Ibom State, found that a gamification strategy produced significantly higher achievement in Periodic Table concepts than collaborative teaching, with no significant gender difference. A similar pattern emerged in Cross River State, where Ashiwere, Etim, Aricha, Imong, Obi, and Ismaila (2026) found that 112 Senior Secondary Biology students taught with gamification significantly outperformed those taught conventionally, with the advantage holding consistently across urban and rural school settings. Ashaolu and Dada (2025) similarly reported that a gamified approach significantly raised both academic performance and motivation among upper-basic Basic Science students Kaduna Metropolis, with points, badges, and leaderboards rated as the most effective individual game elements. Taken together, these three studies, spanning technical, biological, and basic science content across three geopolitical zones, offer converging evidence that gamification reliably improves measured achievement relative to conventional instruction, regardless of subject area or school locality. This performance advantage extends to technology-enhanced variants of gamification. Sayyadi and Galadanchi Abubakar (2026) compared gamification and Virtual Reality against conventional teaching among 240 Senior Secondary II students in Katsina State, finding that both gamified and VR-based instruction produced significantly higher engagement and academic performance than the control condition, with a moderate overall effect size across the three groups. This finding suggests that the performance benefits associated with gamification are not confined to simple point-and-badge systems but extend to more technologically sophisticated implementations; reinforcing the broader pattern that active, game-structured engagement outperforms passive instructional delivery.

2.2 Implementation Challenges and Instructional Context

Despite this consistent performance advantage, the literature also identifies significant barriers to gamification's effective classroom implementation, particularly in chemistry-specific contexts. Oribhabor and Ighodaro (2025) surveyed 160 Chemistry teachers across Bayelsa State and found that inadequate digital infrastructure, insufficient teacher training, and weak institutional support were the dominant obstacles to gamification adoption, with no significant difference in the challenges reported by public- and private-school teachers. This finding is corroborated by Aghor (2026), whose survey of 250 science teachers in Cross River State catalogued ten distinct types of gamification, including simulation games, point systems, and digital badges, and twenty specific instructional roles gamification can play, ranging from stimulating intrinsic motivation to encouraging collaborative problem-solving. Both studies affirm gamification's instructional value while underscoring that realising this value in practice depends on resource and training conditions that many Nigerian schools currently lack, a constraint of direct relevance to the implementation context considered in the present study.

Related instructional-materials research reinforces this pattern. Nwafor and Obi (2026), examining flash cards in English Language instruction in Rivers State, found that visual and manipulable instructional aids improved students' learning ability and understanding, but identified funding shortfalls and inconsistent teacher skill as recurring barriers to their effective use, a finding that parallels the infrastructure and training constraints documented in the gamification-specific studies above and situates gamification within a broader Nigerian pattern in which promising instructional innovations are frequently limited less by their inherent effectiveness than by the resource conditions of the schools implementing them.

2.3 Intrinsic Motivation and Chemistry Achievement

A parallel strand of research has examined motivational constructs closely related to the engagement mechanisms gamification is designed to trigger, offering indirect but relevant support for the present study's focus. Several studies confirm that motivation, whichever its source, functions as a consistent predictor of chemistry achievement. Agiande, Obi, Ashiwere, and Nnaji (2024) found that both motivation and self-regulation significantly predicted chemistry achievement among 364 Senior Secondary II students in Cross River State, with no significant gender difference in either relationship. Samuel and Egolum (2026), studying 386 chemistry students in Anambra State, similarly found that intrinsic motivation positively predicted achievement while test anxiety negatively predicted it, with students combining high intrinsic motivation and low test anxiety recording the strongest outcomes; extrinsic motivation, by contrast, showed only a weak, non-significant relationship with performance. This asymmetry, intrinsic motivation mattering more than extrinsic motivation, is instructive for gamification research, since it suggests that gamified interventions are likely to be most effective when their reward structures cultivate genuine engagement with the subject matter rather than functioning as an external incentive layered on top of otherwise unchanged instruction.

The social and technological dimensions of motivation have also received attention. Awodun and Kenni (2021), surveying 210 Chemistry students in Ekiti State, found that peer group significantly influenced students' motivation, academic performance, and learning styles, underscoring that motivation in classroom settings is shaped by social as well as instructional factors, a dimension that gamification elements such as leaderboards and collaborative point systems are well positioned to leverage. Gambari et al., (2016) offered early evidence of technology-mediated motivation, finding that a Computer Simulation Instructional Package significantly outperformed both a computer tutorial package and conventional teaching in raising chemistry achievement and both intrinsic and extrinsic motivation among 90 students in Niger State, with the intervention proving equally effective for male and female students. Udegbunam (2024), examining intrinsic versus extrinsic motivational strategies from a gender perspective among 158 chemistry students in Anambra State, found that female students recorded marginally higher achievement and retention under an intrinsic-motivation strategy than their male counterparts, although this difference did not reach statistical significance. Considered together, these motivation-focused studies indicate that chemistry achievement is reliably linked to how effectively an instructional approach fosters genuine, internally driven engagement, precisely the mechanism through which gamification is theorised to operate, lending indirect empirical support to the present study's hypothesis that gamified instruction should improve chemistry outcomes.

2.4 Synthesis and Gaps

Across both strands of literature reviewed above, evidence from recent Nigerian studies indicates that gamification improves academic performance relative to conventional instruction, that this advantage holds across subjects and school localities, and that motivation, particularly intrinsic motivation, is a strong and consistent predictor of chemistry achievement specifically. The literature also makes clear that gamification's benefits are not automatic: infrastructural and training constraints can limit its effective implementation, a concern especially salient in resource-constrained public secondary schools. Despite this substantial body of evidence, no reviewed study has directly examined gamification's effect on Electrochemistry achievement and motivation within Sokoto Metropolis specifically, and none has systematically compared digital and non-digital (printed) implementation modalities within a single design, a gap the present study is positioned to address. Inadequate ICT infrastructure, erratic electricity supply, limited teacher digital competence, and large class sizes continue to constrain the deployment of digital gamification tools in northern Nigerian public secondary schools specifically (Olanrewaju et al., 2021; Zubairu & Sani, 2021). The present study addresses these constraints directly by incorporating both digital and printed quiz card implementation modalities, ensuring that the core game mechanics of competition, immediate feedback, and reward are preserved regardless of a school's technological access.

This study is anchored on Self-Determination Theory (SDT), originally proposed by Deci and Ryan (1985) and extensively developed in subsequent scholarship (Ryan & Deci, 2000; Ryan & Deci, 2017). SDT distinguishes intrinsic motivation, driven by genuine curiosity and inherent task satisfaction, from extrinsic motivation, driven by external pressures and rewards. The theory proposes that three fundamental psychological needs must be met for intrinsic motivation to flourish: competence, autonomy, and relatedness. In the context of this study, gamification is theorised to address all three needs within the Electrochemistry classroom. Point reward systems and digital badges provide concrete, lesson-by-lesson evidence of student mastery, reinforcing competence. Leaderboards and collaborative quiz activities create social relatedness and peer belonging. The participatory and interactive nature of gamified tasks affords students greater perceived autonomy over their learning engagement. SDT thus provides both the predictive framework for the expected motivational effects of gamification and the interpretive lens for the observed outcome differences between the experimental and control groups.

2.5 Objectives of the Study

The study specifically sought to:

1. Determine the difference in the academic performance of students exposed to the gamification instructional method and those exposed to the conventional instructional method in Electrochemistry among SS2 Students in Sokoto Metropolis.
2. Determine the difference in the intrinsic motivation of students exposed to the gamification instructional method and those exposed to the conventional instructional method in Electrochemistry among SS2 Students in Sokoto Metropolis.

2.6 Research Questions

The following research questions guided the study:

1. Is there any difference in the academic performance of students exposed to the gamification instructional method and those exposed to the conventional instructional method in Electrochemistry among SS2 Students in Sokoto Metropolis?
2. Is there any difference in the intrinsic motivation of students exposed to the gamification instructional method and those exposed to the conventional instructional method in Electrochemistry among SS2 Students in Sokoto Metropolis?

3 Materials and Methods

The study employed a quasi-experimental pre-test post-test experimental and control group design (Creswell & Creswell, 2018). This design was considered appropriate because the study required the manipulation of an independent variable, gamified instruction, to observe its effects on academic performance and intrinsic motivation in Electrochemistry, under conditions where full randomisation of individual participants across groups was not feasible due to the use of intact classroom groups, a standard constraint in Nigerian public secondary school research (Campbell & Stanley, 1963; Fraenkel et al., 2019). The study was carried out in Sokoto Metropolis, the capital of Sokoto State in Nigeria's North-West geopolitical zone, chosen because of the limited research attention given to innovative instructional strategies for Electrochemistry in public secondary schools in the region.

The target population comprised all 6,053 SS2 Chemistry students enrolled in public secondary schools in Sokoto Metropolis during the 2025/2026 academic session. A purposive sampling technique was used to select the schools for the study. Purposive sampling involves deliberately selecting participants or research sites based on predetermined characteristics relevant to the objectives of a study (Cohen, Manion, & Morrison, 2018). The technique was considered appropriate because the study required schools with specific characteristics necessary for the successful implementation of the gamification intervention. Accordingly, schools offering SS II Chemistry, having qualified Chemistry teachers, possessing intact classes, and providing suitable conditions for the conduct of the study were considered for selection. Schools with relatively comparable instructional and learning conditions were also considered to minimise possible extraneous differences between the groups. Based on these criteria, two public secondary schools were purposively selected from the available schools in Sokoto Metropolis. Following the selection of the schools, the existing SS II Chemistry classes were retained as intact classes, rather than selecting individual students randomly, because altering the existing class structure could disrupt the normal school arrangement. The intact classes were subsequently used to constitute the experimental and control groups. The experimental group consisted of 43 students, while the control group consisted of 48 students, giving a total sample of 91 SS II Chemistry students. The selection of intact classes is consistent with the nature of quasi-experimental educational research, where naturally existing groups are commonly used when individual random assignment is impractical or inappropriate (Cohen et al., 2018). Thus, purposive sampling was used specifically to identify schools that met the predetermined inclusion criteria, while the use of intact classes determined the final student participants in the study. All 91 students who participated in the per-test were present for the post-test. Thus, there was no attrition during the study, and data obtained from all 91 participants were included in the final analysis. The demographic profile of participants is presented in Table 1.

Table **1**

Demographic Profile of Participants (N = 91)

Variable	Category	Frequency	Percentage
Class	SS2 Chemistry	91	100
School Type	Public	91	100
Instruction	Experimental	43	47.3
	Control	48	52.7

The experimental group received six weeks of gamified Electrochemistry instruction incorporating four game mechanics: (i) a classroom leaderboard updated after every lesson showing cumulative student rankings; (ii) digital achievement badges awarded for attaining defined performance milestones, such as scoring 80% or above on a quiz or recording the highest single-session improvement; (iii) a structured point reward system allocating points for correct quiz responses, voluntary class participation, timely assignment submission, and peer-teaching activities; and (iv) game-based quiz platforms administered at the start and close of each lesson for knowledge review and consolidation. In classrooms lacking reliable internet access, printed quiz cards were used to preserve the core game mechanics of time pressure, competitive scoring, and immediate corrective feedback. The control group received instruction on identical Electrochemistry topics through conventional chalk-and-talk delivery, strictly following the NERDC/WAEC SS2 Chemistry syllabus without gamification elements. To eliminate teacher variability as a confounding factor, both groups were taught directly by the researcher throughout the six-week period, with each group receiving 40-minute Electrochemistry lessons per week.

Data were collected using two researcher-developed instruments: the Electrochemistry Achievement Test (EAT) and the Chemistry Students' Motivation Questionnaire (ESMQ). The EAT consisted of 20 multiple-choice items covering Electrochemistry topics from the NERDC/WAEC SS2 chemistry syllabus, including electrolysis, electrochemical cells, Faraday's Laws of Electrolysis, electrode half-reactions, and industrial applications of electrolysis. Each correctly answered item was awarded one mark, giving a maximum score of 20 marks while the minimum score was 0 marks. The ESMQ comprised 20 items structured on the ABC model: seven Affective domain items, six Behavioural domain items, and seven Cognitive domain items, each rated on a five-point Likert scale (Strongly Agree = 5 to Strongly Disagree = 1), with a maximum score of 100 marks while the minimum score was 20 marks.

Both instruments were validated by 3 experts in the department of Science Education, Sokoto State University, who assessed item clarity, relevance, and coverage of the Electrochemistry syllabus. Corrections offered by the validators were incorporated before piloting. The instruments were pilot-tested on 30 SS2 chemistry students drawn from a public secondary school in Sokoto Metropolis whom were not included in the main study sample. The pilot test was administered under examination conditions to assess item clarity, identify ambiguous statements, and estimate administration time. Data from the pilot test were subjected to internal consistency analysis using Pearson Product Moment Coefficient (PPMC) and Cronbach's alpha. The reliability results are presented in Table 2.

Table **2**

Pilot Test Reliability Coefficients for EAT and ESMQ

Instrument	No. of Items	Pilot N	Reliability Method	Reliability Coefficient
Electrochemistry Achievement Test (EAT)	20	30	PPMC	0.81
Electrochemistry Students' Motivation Questionnaire (ESMQ)	20	30	Cronbach Alpha (α)	0.86

As shown in Table 2, the EAT returned a Pearson Product Moment Coefficient (PPMC) of 0.81, the ESMQ returned Cronbach alpha of 0.86 respectively. Items identified as ambiguous or poorly discriminating during pilot analysis were revised before finalising the instruments for the main study. Data collected were analysed using mean and standard deviation to address the research questions, and for testing the null hypotheses, Analysis of Covariance (ANCOVA) was applied at a 0.05 significance level to control for pre-test differences between the groups.

4 Results

Research Question 1: Academic Performance of Students Exposed to Gamification and those exposed to Conventional Instructional Methods in Electrochemistry

To answer question 1, Electrochemistry Achievement Test (EAT) was analyzed using descriptive statistics. Table 3 below presents the descriptive statistics of the pre-test and post-test academic performance scores of both experimental and control groups.

Table **3**

Mean and Standard Deviation of Electrochemistry Achievement Test (EAT) (N = 91)

Group	N	Pre-test Mean	Pre-test Standard Deviation	Post-test Mean	Pre-test Standard Deviation	Mean Difference
Experimental (Gamification)	43	8.19	1.82	16.16	2.39	7.97
Control (Conventional)	48	8.65	2.23	12.69	2.43	4.04

Table 3 presents the mean and standard deviation of students' pre-test and post-test scores on the Electrochemistry Achievement Test (EAT). The Experimental Group (N = 43) recorded a pre-test mean score of 8.19 (SD = 1.82) and a post-test mean score of 16.16 (SD = 2.39), indicating a mean difference of 7.97 marks. In comparison, the Control Group (N = 48) obtained a pre-test mean score of 8.65 (SD = 2.23) and a post-test mean score of 12.69 (SD = 2.43), representing a mean difference of 4.04 marks. The relatively close pre-test means (8.19 and 8.65) suggest that the two groups had comparable levels of academic performance before the intervention. However, the Experimental Group recorded a considerably higher post-test mean (16.16) than the Control Group (12.69) and also demonstrated a greater mean gain (7.97 versus 4.04 marks). The descriptive results therefore indicate that students exposed to the gamified instructional method showed greater improvement in academic performance in Electrochemistry than those taught using the conventional instructional method.

Table **4**

Summary of Tests of ANCOVA Assumptions for Hypothesis 1

Assumption	**Test**	**Value**	**5 Sig. (p)**	**Decision**
Normality (Experimental)	Shapiro-Wilk	0.963	0.185	Satisfied
Normality (Control)	Shapiro-Wilk	0.961	0.107	Satisfied
Homogeneity of Variance	Livene's Test	F = 1.072	0.303	Satisfied

Table 4 shows the assessment of the assumptions underlying the ANCOVA analysis. The normality assumption was satisfied, as the Shapiro–Wilk tests were non-significant for both the experimental group, $W(43) = 0.963$, $p = 0.185$, and the control group, $W(48) = 0.961$, $p = 0.107$. This was further supported by the Normal Q-Q plots, which showed that the observations generally followed the expected diagonal line. The assumption of homogeneity of variance was also satisfied, as Levene's test was non-significant, $F(1,89) = 1.072$, $p = 0.303$. Therefore, the available evidence confirms the assumptions of normality and homogeneity of variance.

Null Hypothesis Testing 1 **:** H_{01}: There is no significant difference in the academic achievement of students exposed to the gamification instructional method and those exposed to the conventional instructional method in Electrochemistry.

To determine whether there is a significant difference in the academic performance of students exposed to the gamified instructional method and those exposed to the conventional instructional method in Electrochemistry. Analysis of Covariance (ANCOVA) was conducted and the results are presented in Table 5.

Table **5**

Analysis of Covariance (ANCOVA) of Academic Performance

Source	**Type III Sum of Squares**	**df**	**Mean Square**	**F**	**Sig.**	**Partial Eta Squared**
Corrected Model	629.393[a]	2	314.697	168.127	0.001	0.793
Intercept	190.157	1	190.157	101.592	0.001	0.536
Pretest	355.456	1	355.456	189.903	0.001	0.683
Group	344.975	1	344.975	184.303	0.001	0.677
Error	164.717	88	1.872			
Total	19480.000	91				
Corrected Total	794.110	90				

Table 5 presents the Analysis of Covariance (ANCOVA) comparing the post-test academic performance scores of students exposed to the gamified instructional method and those taught using the conventional method, while controlling for pre-test scores. The analysis revealed a statistically significant effect of instructional method on students' academic performance, $F(1,88) = 184.303$, $p < 0.05$, Partial $\eta^2 = 0.677$. Since the probability value (0.001) is less than the 0.05 level of significance, the null hypothesis was rejected. This finding indicates that there was a significant difference in the academic performance of students exposed to the gamified instructional method and those taught using the conventional method in Electrochemistry. The adjusted mean scores showed that the experimental group taught with the gamified instructional method obtained a higher adjusted post-test mean score ($M = 16.40$) than the control group taught using the conventional method ($M = 12.48$). The partial eta squared value of 0.677 indicates a large effect size, suggesting that the instructional method accounted for a substantial proportion of the variation in students' academic performance after controlling for their pre-test scores. In conclusion, the gamified instructional method significantly improved students' academic performance in Electrochemistry compared with the conventional teaching method.

Research Question 2: is there any difference in the intrinsic motivation of students exposed to the gamification instructional method and those exposed to the conventional instructional method in Electrochemistry among SS2 Students in Sokoto Metropolis?

To answer the research question 2, Electrochemistry Students' Motivation Questionnaire (ESMQ) was analyzed using descriptive statistics. Table 5 presents the descriptive statistics of the Experimental (Gamification) and Control (Conventional) group intrinsic motivation scores.

Table **6**

Mean and Standard Deviation of Experimental (Gamification) and Control (Conventional)

Group	**N**	**Pretest Mean**	**Pretest Standard Deviation**	**Posttest Mean**	**Posttest Standard Deviation**	**Mean Difference**
Experimental (Gamification)	43	63.00	3.61	85.58	2.99	22.58
Control (Conventional)	48	61.50	3.32	68.08	3.61	6.58

Table 6 presents the mean and standard deviation of students' intrinsic motivation scores before and after the intervention. The Experimental Group ($N = 43$) recorded a pretest mean score of 63.00 ($SD = 3.61$) and a posttest mean score of 85.58 ($SD = 2.99$), giving a mean difference of 22.58. In contrast, the Control Group ($N = 48$) recorded a pretest mean score of 61.50 ($SD = 3.32$) and a posttest mean score of 68.08 ($SD = 3.61$), with a mean difference of 6.58. The results indicate that both groups showed an increase in intrinsic motivation from pretest to posttest; however, the Experimental Group recorded a considerably greater improvement than the Control Group, suggesting that it is more effective than the conventional instructional method in promoting students' intrinsic motivation towards learning Electrochemistry.

Table **7**

Summary of Tests of ANCOVA Assumptions for Hypothesis 2

Assumption	Test	Value	6 Sig. (p)	Decision
Normality (Experimental)	Shapiro-Wilk	0.974	0.414	Satisfied
Normality (Control)	Shapiro-Wilk	0.987	0.869	Satisfied
Homogeneity of Variance	Livene's Test	F = 1.060	0.306	Satisfied

Table 7 presents the assumptions underlying the use of Analysis of Covariance (ANCOVA) were examined before the analysis. The Shapiro–Wilk test indicated that the posttest scores were normally distributed for both the experimental group, $W(43) = 0.974$, $p = 0.414$, and the control group, $W(48) = 0.987$, $p = 0.869$, since both p-values were greater than 0.05. The normal Q-Q plots also showed that the observed scores were reasonably close to the diagonal reference line, supporting the assumption of normality. The assumption of homogeneity of variance was also satisfied, as Levene's Test was not statistically significant, $F(1,89) = 1.060$, $p = 0.306$, indicating that the error variances of the two groups were homogeneous. The available results indicate that the assumptions of normality and homogeneity of variance were satisfied.

Null Hypothesis Testing 2: Ho_2: Is there any difference in the intrinsic motivation of students exposed to the gamification instructional method and those exposed to the conventional instructional method in Electrochemistry?

To determine whether there is any difference in the intrinsic motivation of students exposed to the gamified instructional method and those exposed to the conventional instructional method in Electrochemistry, Electrochemistry Students' Motivation Questionnaire (ESMQ) was analysed using Statistical Package for Social Science (SPSS) software.

Table **8**

Analysis of Covariance (ANCOVA) of Intrinsic Motivation

Source	Type III Sum of Squares	df	Mean Square	F	Sig.	Partial Eta Squared
Corrected Model	6949.902[a]	2	3474.951	311.768	0.001	0.876
Intercept	1805.841	1	1805.841	162.017	0.001	0.648
Pretest	5.287	1	5.287	0.474	0.493	0.005
Group	6707.101	1	6707.101	601.751	0.001	0.872
Error	980.845	88	11.146			
Total	538422.000	91				
Corrected Total	7930.747	90				

a. R Squared = 0.876 (Adjusted R Squared = 0.874)

Table 8 presents the results of the ANCOVA comparing the post-test intrinsic motivation scores of students exposed to the gamified instructional method and those exposed to the conventional instructional method, while controlling for their pre-test motivation scores. The Experimental Group ($N = 43$) recorded a higher post-test mean motivation score of 85.58 ($SD = 2.99$) compared with the Control Group ($N = 48$), which recorded a mean score of 68.08 ($SD = 3.61$). The test of between-subjects effects revealed a statistically significant difference in post-test intrinsic motivation between the two groups after controlling for pre-test motivation, $F(1,88) = 601.751$, $p < .001$, partial $\eta^2 = 0.872$. The large partial eta squared value (0.872) indicates a very large effect of the instructional method on students' intrinsic motivation. Therefore, the null hypothesis was rejected, indicating that there was a statistically significant difference in the intrinsic motivation of students exposed to the gamified instructional method and those exposed to the conventional instructional method, with students exposed to the gamified instructional method demonstrating significantly higher adjusted intrinsic motivation scores.

7 Discussion

Gamified instruction produced significantly higher Electrochemistry post-test performance than conventional teaching, $F(1,88) = 184.30$, $p < .001$, partial $\eta^2 = .68$ (a large effect per Field's, 2018, guidance). ANCOVA confirmed the advantage held even after controlling for comparable pre-test scores (8.19 experimental vs. 8.65 control), consistent with the pretest-posttest non-equivalent control group logic described by Shadish, Cook, and Campbell (2002). The gain is attributed to the game-based quiz platform's immediate feedback, which corrected misconceptions in real time, and a point-reward system that sustained effort across the six-week treatment findings consistent with prior Nigerian research (Adeyinka & Fashola, 2023; Muhammed & Garba, 2022). The motivation effect was even larger $F(1,88) = 601.75$, $p < .001$, partial $\eta^2 = .872$ explained through Self-Determination Theory (Deci & Ryan, 1985; Ryan & Deci, 2017): badges and leaderboards built a sense of competence, collaborative quizzes built relatedness, and the participatory format built autonomy. The authors note this asymmetry (motivation exceeding achievement) is plausible since motivation was captured through self-report on the ESMQ, while achievement gains depend on additional factors such as retention and test-taking skill that gamification does not directly target. Several limitations qualify the findings: the six-week treatment period was too short to confirm whether gains persist over a full term or year; intact classes limited control over school-level variables; the self-report attitude measure leaves room for social-desirability bias; and notably the sample was exclusively male, since the participating schools were boys-only, so the findings cannot be generalised to female students without further study. The study was also confined to two schools within Sokoto Metropolis, limiting broader generalisability.

8 Conclusion

This study investigated the effects of gamification on academic performance and motivation among SS2 students learning Electrochemistry in public secondary schools in Sokoto Metropolis. Findings from 91 students confirmed a significant difference in academic performance and a significant difference in intrinsic motivation, both favouring the gamified instruction group; both null hypotheses were rejected. The study concludes that gamification incorporating leaderboards, digital badges, point reward systems, and game-based quizzes is a viable, evidence-based, and contextually responsive instructional strategy for improving Electrochemistry outcomes in Nigerian secondary schools, though its current limited adoption in Sokoto public schools reflects infrastructure constraints, limited teacher capacity, and insufficient institutional support requiring coordinated policy intervention.

9 Recommendations

Based on the findings of this study, the following recommendations are made, each stated together with the specific decision it is intended to change:

1. Chemistry teachers in Sokoto State public secondary schools should adopt gamified instructional elements, specifically point reward systems and game-based quizzes, as a standard component of Electrochemistry lessons rather than as an occasional supplementary activity, given the large effect size recorded for academic performance in this study. This changes the day-to-day lesson-planning decision from whether to include a review activity to which gamified review activity to embed in each lesson.
2. The Sokoto State Universal Basic Education Board and post-basic education authorities should include gamification-based lesson exemplars in mandatory Chemistry teacher training and continuing professional development programmes, prioritising Electrochemistry and other conceptually demanding topics. This changes the training-content decision from generic pedagogy workshops to skills-specific, subject-anchored gamification training that teachers can apply immediately in the classroom.
3. The Nigerian Educational Research and Development Council (NERDC) should incorporate explicit gamification guidelines, mapped to specific game mechanics and specific SS2 Chemistry topics, into the official curriculum framework, rather than leaving gamification adoption to individual teacher initiative. This changes the curriculum-design decision from treating gamification as an optional enrichment strategy to treating it as a recommended instructional option with topic-level guidance.
4. School principals in Sokoto Metropolis should factor gamification readiness, such as access to a shared device, projector, or printed quiz-card materials, into termly resource allocation and budgeting decisions, given that this study demonstrated the approach remains effective when adapted to low-connectivity conditions through printed quiz cards. This changes the resource-allocation decision from prioritising ICT purchases solely for administrative use to including classroom-level gamification materials as a distinct budget line.

5. Future researchers investigating gamification in Nigerian secondary science education should adopt longer intervention periods of at least one academic term, multi-school designs, and mixed-methods approaches incorporating classroom observation or interviews alongside questionnaire data. This changes the research-design decision for subsequent studies from short, single-school, questionnaire-only designs to extended, multi-site, mixed-methods designs capable of testing whether the gains observed here are sustained over time.

10 Declarations

Ethical Statements: This study involved human participants (secondary school students) and was conducted with the approval of the Department of Science Education, Sokoto State University. Written informed consent was obtained from the school authorities and class teachers, and assent was obtained from participating students, prior to data collection. Participation was voluntary, and students were informed of their right to withdraw at any stage without penalty. No identifying information was collected, and all data were anonymised before analysis.

Conflict of Interest: The authors declare neither financial nor non-financial conflict of interest.

Author Contributions: The first author conceived and designed the study, developed the research instruments, supervised data collection, conducted the statistical analysis, and drafted the manuscript. Second author contributed to the literature review, instrument validation, and manuscript revision. Third author contributed to data collection, data entry, and manuscript revision. All authors reviewed and approved the final manuscript.

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Data Availability Statement: The datasets generated and analysed during the current study are available from the corresponding author upon reasonable request.

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