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Mathematical Skills as a Correlate of Teachers' Performance and Secondary Students' Lesson Mastery in Electrolysis for Sustainable Development

Sarki Ibrahim Zubairu[1]*, Jonathan Salihu Mari[2], Ado Bala Inuwa[3], Aliyu Suleiman Aliyu[4], Ramatu Ematum Umahaba[2]

[1]Registry Department, Bayero University Kano, Kano State, Nigeria.

[2]Department of Science Education, Ahmadu Bello University, Zaria, Kaduna State, Nigeria.

[3]Department of Chemistry, Rabiu Musa Kwankwaso College of Advanced and Remedial Studies, Tudun Wada, Kano State, Nigeria.

[4]Division of Agricultural College, Ahmadu Bello University Zaria, Kaduna State, Nigeria.

***Corresponding author**: izsarki.reg@buk.edu.ng

Abstract

This study examined mathematical skills acquisition as a correlate of teachers' performance and secondary students' lesson mastery in electrolysis for sustainable development in Nigeria. A quantitative correlational design was used across 18 public secondary schools from 6 Local Government Areas. The population consisted of 34 chemistry teachers and 494 chemistry students out of which 18 chemistry teachers and 180 students were selected using stratified and purposive sampling techniques respectively for data collection. Three instruments were used: the Prerequisite Mathematics Skills Acquisition for Teaching Electrolysis Test (PMSATE) for teachers, Mean Performance in Teaching Electrolysis (MPTE) observation checklist, and Students' Lesson Mastery (SLM) test. Instrument reliability was established at 0.83 using Cronbach's Alpha. Data were analyzed using Pearson Product Moment Correlation (PPMC) and Multiple Linear Regression at $p < .05$. Findings show that teachers' prerequisite mathematical skills significantly correlate with and predict teaching performance and student lesson mastery in electrolysis. Furthermore, teacher education programs should integrate specialized courses focused on mathematics to cater for chemistry calculations and common student misconceptions. Finally, future studies should explore whether the strategic integration of digital instructional tools can effectively compensate for environments where baseline teacher mathematics skills are low.

Keywords: mathematical skills acquisition, teachers' performance, lesson mastery, electrolysis, sustainable development, chemistry education

1 Introduction

Mathematics serves as the foundational language of quantitative reasoning and scientific inquiry, dealing fundamentally with measurement, numbers, spatial data, and abstract quantities. In science education, a student's conceptual advancement in chemistry is heavily dictated by their mathematical skills acquisition, which encompasses the cognitive capacity to manipulate algebraic variables, interpret data, and apply sequential reasoning to solve complex problems (Otunu-ogbisi & Ukpebor, 2009). This utility is particularly visible in the chemistry curriculum, where the topic of electrolysis stands out as a highly quantitative area that requires both students and instructors to seamlessly blend algebraic calculations, ratios, and electrochemical formulas. Despite the acknowledged importance of mathematical literacy in understanding chemistry, secondary school students consistently encounter severe difficulties mastering the computational demands of electrolysis. Traditional educational interventions frequently focus on student-level deficiencies, creating a noticeable research gap regarding how the prerequisite mathematical skills acquisition of the instructors themselves influences the classroom environment. Charles-Ogan et al. (2017) assert that effective instruction requires chemistry teachers to possess a robust command of mathematical principles underpinning electrochemical reactions. Instructors' mathematical proficiency directly influences teacher performance, determining how confidently they explain multi-step calculations, address student misconceptions, and break down the mathematical steps of Faraday's laws of electrolysis. According to Idris (2008), when teachers demonstrate superior instructional delivery and pedagogical competence, it directly impacts secondary students' lesson mastery, transforming abstract chemical equations into clear, understandable concepts.

Investigating this instructional dynamic is essential for restructuring science teacher preparation programs and improving classroom outcomes in developing educational systems. Therefore, the purpose of this study is to examine mathematical skills acquisition as a correlate of teachers' performance and secondary students' lesson mastery in electrolysis. Shifting the focus toward instructor-targeted academic readiness, the significance of this research lies in its potential to inform educational policymakers, curriculum developers, and teacher training institutions about the necessity of integrating rigorous mathematical training into science education pathways. Ultimately, enhancing teachers' performance and securing students' lesson mastery in foundational science topics like electrolysis creates a highly skilled, scientifically literate workforce necessary for achieving long-term sustainable development. While global studies have established clear links between mathematical skills, chemistry instruction, and student learning outcomes, few studies in West Africa have used validated testing instruments to evaluate all three variables together within a single model. Local studies frequently stop at identifying that students find electrolysis difficult without diagnosing root factors, such as the teachers' mathematical skills acquisition. This study directly bridges this geographic and empirical gap across selected secondary schools using the PMSATE, MPTE, and SLM instruments to map the entire instructional chain. Achieving student lesson mastery in quantitative chemistry serves as a foundational catalyst for advancing the United Nations Sustainable Development Goals (SDGs), particularly SDG 4 (Quality Education) and SDG 9 (Industry, Innovation, and Infrastructure).

To address these gaps, the primary objective of this study was to investigate mathematical skills acquisition and teachers' instructional performance as correlates of secondary students' lesson mastery in electrolysis for sustainable development. Specifically, the study sought to examine the relationship between chemistry teachers' prerequisite mathematical skills acquisition and their instructional performance in teaching electrolysis. Furthermore, it aimed to investigate the relationship between chemistry teachers' prerequisite mathematical skills acquisition and secondary students' lesson mastery in electrolysis. Finally, the investigation determined the joint relationship and predictive value of chemistry teachers' prerequisite mathematical skills acquisition and teachers' instructional performance on secondary students' lesson mastery in electrolysis. To systematically address these educational dynamics, this study was guided by three specific research questions. First, what is the relationship between chemistry teachers' prerequisite mathematical skills acquisition scores and their instructional performance scores in teaching electrolysis? Second, what is the relationship between chemistry teachers' prerequisite mathematical skills acquisition scores and secondary students' lesson mastery scores in electrolysis? Finally, to what extent do chemistry teachers' prerequisite mathematical skills acquisition and their instructional performance jointly predict secondary students' lesson mastery in electrolysis? By answering these questions, this study aims to clarify the foundational mathematical-to-chemical instructional chain.

2 Literature Review and Theoretical Framework

This study hinged primarily on two complementary theoretical frameworks: the Cognitive Load Theory (CLT) formulated by John Sweller and the Pedagogical Content Knowledge (PCK) framework developed by Lee Shulman. Sweller (1988) posits that human working memory is severely limited in both capacity and duration when processing novel information, whereas long-term memory stores massive amounts of information structured as cognitive schemas. Within this framework, learning occurs when information is successfully processed in the working memory and integrated into long-term memory schemas. If the mental effort required to process an academic task exceeds the available working memory capacity, cognitive overload occurs, and the learning process fails. This theory is directly relevant to the present investigation because electrolysis is a highly abstract and quantitative topic. When solving problems involving Faraday's laws of electrolysis ($m = zIt$), a student must simultaneously balance complex chemical concepts such as ions, valencies, and electrode products with mathematical operations, including algebraic manipulation, ratio calculations, and unit conversions. If a student has not acquired and automated basic mathematical skills, their working memory becomes overloaded by the arithmetic steps alone. This leaves zero cognitive capacity to achieve student lesson mastery of the underlying chemical processes.

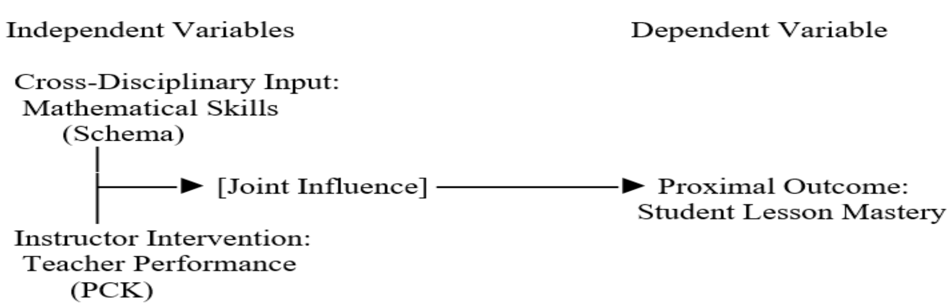
To address the instructional side of this challenge, Shulman (1986) developed the theory of Pedagogical Content Knowledge, which focuses on the unique intersection of content knowledge (deep understanding of the subject matter) and pedagogical knowledge (understanding of general teaching principles). A major assumption of this theory is that effective teaching requires more than just independent expertise in a subject. Highly competent educators must possess the capacity to transform complex, abstract domain knowledge into forms that are pedagogically powerful, adaptive, and accessible to diverse secondary school learners. Within this investigation, teachers' performance is fundamentally operationalized through the lens of PCK. An educator teaching electrolysis cannot merely state Faraday's equations; high instructional performance manifests through the ability to diagnose student mathematical deficiencies, scaffold quantitative chemistry tasks in a stepwise manner, use targeted instructional strategies, and mitigate cross-disciplinary learning friction. This framework shifts the research focus away from viewing student failure in chemistry as an isolated issue, positioning it instead as a structural failure of cross-disciplinary skill alignment and instructional execution. Together, these frameworks dictate that lesson mastery must be measured both conceptually and computationally. Cognitive Load Theory explains why automated mathematical skills free up working memory, while Pedagogical Content Knowledge explains why effective instructional scaffolding minimizes external cognitive friction.

Extensive academic literature establishes that student achievement in senior secondary sciences is heavily dependent on cognitive readiness and external pedagogical intervention. However, a major debate persists within the literature regarding the exact weighting of content knowledge versus general instructional behavior. Gess-Newsome et al. (2019) tested the consensus model of PCK and found that teachers’ content knowledge, including mathematical skills, predicted the quality of classroom explanations and representations more effectively than generic teaching experience did. This directly challenges traditional pedagogical models which argue that classroom management and instructional enthusiasm can compensate for subject-matter deficiencies. Kind and Chan (2021) expanded this discourse by revealing a systemic flaw in educational assessments: standard teacher evaluation protocols frequently confuse what teachers do with what teachers know. Their critical review affirmed that while many standard observation instruments are highly sensitive to classroom discipline and pacing, they completely fail to evaluate whether the instructor can actively diagnose and correction mathematical misconceptions in student work. This oversight explains a persistent paradox in secondary education: why schools with highly rated instructors on paper still produce students with weak objective lesson mastery. The Mean Performance in Teaching Electrolysis (MPTE) observation checklist used in this study was designed specifically to resolve this empirical tension, coding explicitly for the clarity of mathematical explanations rather than generic behavioral metrics.

The essential value of mathematical skills in teaching chemistry for sustainable development cannot be overstated, yet empirical research in West Africa reveals a fractured landscape. It is argue that a lack of prerequisite mathematical skills makes it structurally impossible to produce science graduates who can accurately apply quantitative findings to real-life industrial problems. This is because an impregnable link exists between mathematical operations and empirical science disciplines (Salau, 2000). Long-standing studies on ordinary-level science performance reveal that the logical patterns of thought used in expressing scientific concepts are frequently identical to those utilized in specific mathematical operations (Odili, 2006). In spite of various curriculum innovations introduced into secondary science teaching across Sub-Saharan Africa, the general performance of students in terminal examinations remains low, a conflict that traditional literature struggles to explain (Fatoke, 2013). This study argues that the bottleneck is not the curriculum itself, but cross-disciplinary instructional friction. While Charles-Ogan et al. (2017) demonstrated an independent disparity in performance proving that high mathematical achievers consistently outperform low achievers when dealing with quantitative calculations like Faraday’s first law of electrolysis their study treated student ability as an isolated trait. Conversely, Zubairu (2023) confirmed a strong, positive correlation between secondary school students' foundational mathematical skills and their ultimate achievement scores in terminal chemistry examinations, yet they omitted the role of the teacher entirely. This study bridges these conflicting, fragmented viewpoints. Rather than examining these concepts as isolated variables, this investigation treats mathematical skills as an essential cross-disciplinary input and teacher performance as an active environmental intervention to evaluate their joint predictive influence on students' proximal lesson mastery, as conceptualized in the structural framework given in Figure 2.1.

Figure **2.1**

The Researcher's Conceptual Model of Cross-Disciplinary Inputs and Instructor Interventions.



Note. Synthesized from Sweller (1988) and Shulman (1987) to map internal cognitive processing alongside external instructional support.

Most of the existing literature on education for sustainable development is purely theoretical or policy-oriented, a limitation that undermines its empirical utility. This study uniquely anchors sustainable development specifically in technical human capital creation. By ensuring robust secondary school lesson mastery in electrochemistry, the educational system actively prepares future chemical engineers, green technology innovators, and environmental scientists equipped to implement renewable energy initiatives. Consequently, this empirical framework moves beyond descriptive pedagogy, addressing the specific technical proficiencies required to actualize United Nations Sustainable Development Goals (SDGs) 4 and 9 within sub-Saharan classroom ecosystems.

3 Materials and Methods

3.1 Research Design and Participant Sampling

This study adopted a quantitative correlational research design utilizing a post-instruction testing framework to examine the relationships among the target variables without manipulating the natural classroom environment. The target population comprised all senior secondary school chemistry teachers and their respective students within six Local Government Areas (LGAs) in Kano State, Nigeria: Gwale, Kumbotso, Ungogo, Tofa, Gezawa, and Gabasawa. A multi-stage sampling procedure was employed for sample selection. First, stratified random sampling was used to select 18 public secondary schools across the region, allocating exactly three schools per LGA. From these institutions, a total sample of 18 chemistry teachers was purposively selected from a broader population of 34 available chemistry instructors. Subsequently, stratified sampling was used to select 180 secondary chemistry students from a total population of 494 students, drawing exactly 10 students from each specific classroom taught by the sampled instructors to ensure balanced data nesting.

3.2 Instrumentation

Data collection was facilitated through three specialized instruments developed and adapted to measure the independent and dependent variables. All tools were coded using matching identification keys to link each teacher's datasets directly with their respective students' achievement records for integrated statistical analysis. The first instrument, the Prerequisite Mathematical Skills Acquisition for Teaching Electrolysis Test (PMSATE), was designed as a subject-matter assessment for teachers. The content of the PMSATE focused strictly on foundational mathematical principles directly relevant to executing calculations in electrochemical units. The test comprised 25 subjective, open-ended items administered to the 18 teachers individually prior to the commencement of the instructional unit. The items explicitly evaluated instructor proficiency in direct and joint proportionality, multi-variable algebraic substitution, unit conversions, dimensional analysis, ratios, stoichiometric fractions, scientific notation, and decimal operations. To establish psychometric rigor, the instrument was validated by experts in science and mathematics education, yielding an internal consistency reliability coefficient of 0.83 using Cronbach's Alpha. The test had a maximum duration of 45 minutes and was scored over a 100% scale.

The second instrument was the Mean Performance in Teaching Electrolysis (MPTE) observation checklist, adapted from the standardized Science Teaching Observation Protocol. The MPTE was utilized by three trained research assistants to evaluate teachers’ classroom delivery and pedagogical execution during active instructions on electrolysis. The observation checklist contained 25 items rated on a 4-point Likert scale, where 1 represented Not Observed, 2 represented Poorly Observed, 3 represented Observed, and 4 represented Excellently Observed. The items explicitly assessed the clarity of mathematical explanations, the strategic deployment of worked examples related to Faraday's laws, unit conversions involving time and current, the explicit linking of mathematical operations to chemical concepts, and the active engagement of students in computational tasks. To ensure evaluation objectivity, inter-rater reliability was calculated among the three observers, yielding a Cohen’s Kappa coefficient range of 0.77 to 0.85. The observation scores were averaged across sessions to establish a composite MPTE percentage score for each teacher.

The third instrument was the Students’ Lesson Mastery (SLM) test, designed to evaluate terminal learning outcomes in quantitative chemistry. The SLM consisted of 25 items structured as 15 subjective conceptual questions and 10 calculation-based problem-solving items. The items were pilot-tested on a non-sampled group of senior secondary students, establishing an internal consistency reliability coefficient of 0.83 via Cronbach's Alpha. The test was administered to the sampled students in their respective groups of 10 immediately following the conclusion of the instructional unit on electrolysis to capture immediate lesson mastery and minimize external historical threats to validity. The testing period lasted 45 minutes, with each correct item awarded 1 point for a maximum raw score of 25, which was subsequently converted to a 100% scale.

Higher scores across these instruments operationalized greater lesson mastery, stronger teacher performance, and superior mathematical skills acquisition.

3.3 Validity and Reliability of Instruments

Content and face validity for the PMSATE, MPTE, and SLM instruments were established through an expert evaluation panel. The panel consisted of three science education experts from the Department of Science Education at Bayero University, Kano, alongside two Measurement and Evaluation specialists, one from Bayero University and one from the Federal University of Education, Kano. Recommendations from the experts regarding item clarity and curricular alignment were fully integrated before field administration. To establish instrument reliability, a pilot study was conducted using 15 chemistry teachers and 45 chemistry students drawn from schools within the same local government areas that were excluded from the final sample. The internal consistency of the student achievement tool was calculated using Cronbach's alpha formula, yielding a high reliability coefficient of 0.83. Concurrently, the inter-rater reliability for the observational tool yielded a Cohen's Kappa coefficient range of 0.77 to 0.85 among the observers. These sub-instrument reliabilities confirmed that the evaluation tools possessed sufficient psychometric stability and internal consistency for formal inferential research.

3.4 Ethical Considerations

Administrative approval for data collection was obtained from the Kano State Ministry of Education and the principals of participating in public secondary schools. Prior to implementation, written informed consent was acquired from all participating chemistry instructors. Parental or guardian assent, alongside student informed consent, was obtained for all participating secondary students. To ensure confidentiality and protect participant identities, all collected data records were completely kept anonymous using digital alphanumeric codes, ensuring that individual testing scores could not be traced back to specific teachers or students.

3.5 Data Analysis Procedures

Prior to conducting inferential testing, the completed data sheets were compiled into a centralized database and subjected to rigorous data screening procedures to identify missing values, entry errors, or extreme univariate outliers. Having verified the data integrity, formal diagnostic testing was conducted to evaluate the fundamental assumptions of classical linear regression. Linearity was assessed via bivariate scatterplots, and multivariate normality was confirmed using the Shapiro-Wilk test alongside normal probability plots (P-P plots). Homoscedasticity was evaluated using the Breusch-Pagan test and residual plots. Multicollinearity was guarded against by calculating Variance Inflation Factors (VIF) and tolerance thresholds across all independent predictors. To answer the three guiding research questions, descriptive statistics including mean and standard deviation scores were computed to establish baseline performance profiles across all variables. To test the corresponding null hypotheses while strictly accounting for the nested structure of the data (180 students clustered within 18 teacher groups), parametric inferential statistical analyses were executed using cluster-adjusted modeling. Pearson Product Moment Correlation (PPMC) was applied to evaluate the direct linear relationships postulated in the first two hypotheses. Finally, Multiple Linear Regression analysis utilizing Huber-White Cluster-Robust Standard Errors was executed to test the third hypothesis. This clustering correction directly adjusts the variance-covariance matrix to account for the non-independence of nested student observations within teacher units, ensuring that the calculated standard errors and p-values are mathematically conservative, robust and free from inflation. All statistical decisions and inferential models were tested at a strict alpha significance level of $p < .05$.

4 Results

4.1 Diagnostic Testing of Regression Assumptions

Before interpreting the predictive capabilities of the combined model, the diagnostic parameters of the linear regression assumptions were systematically verified. Bivariate inspections confirmed robust linear trends across all variable axes. The Shapiro-Wilk test confirmed that the standardized residuals were normally distributed ($W = .984$, $p > .05$), which was further supported by a clean, tight alignment along the diagonal axis of the normal P-P plot. The Breusch-Pagan test confirmed homoscedasticity ($chi^2 = 3.14$, $p = .208$), showing that the variance of the residuals remained constant across all levels of the independent variables. Multicollinearity was verified as non-threatening; the independent predictors yielded a Variance Inflation Factor (VIF) of 2.12 and a tolerance value of 0.471, sitting well within the conservative thresholds (VIF < 5.0); Tolerance > 0.20. Finally, to control for the structural non-independence of observations caused by the nesting of students within teachers, the regression model was executed using cluster-robust standard errors grouped by the 18 distinct instructing units.

Table **1**

Descriptive Statistics and Inter-Correlation Matrix for Teachers' PMSATE, MPTE, and Students' SLM Scores

Variable	Mean	*SD*	1	2	3
1. Mathematical Skills (PMSATE)	25.95	2.22	—	.811*	.730*
2. Teacher Performance (MPTE)	68.40	5.15	.811*	—	.545*
3. Student Lesson Mastery (SLM)	25.62	2.33	.730*	.545*	—

Note. *N* = 18 for teachers; *N* = 180 for nested student observations. *Correlation is significant at the .05 level (2-tailed).

Table **2**

Model Summary for the Joint Predictive Influence of PMSATE and MPTE on Students' SLM Scores

Model	*R*	*R* Square	Adjusted *R* Square	Std. Error of the Estimate
1	.784[a]	.615	.610	1.455

Note. [a]Predictors: (Constant), PMSATE, MPTE. Dependent Variable: SLM.

Table 3

Analysis of Variance (ANOVA) for the Combined Regression Model

Model	Sum of Squares	*Df*	Mean Square	*F*	*p*-value
1. Regression	595.62	2	297.81	140.48*	.000[b]
Residual	373.18	177	2.12		
Total	968.80	179			

Note. *N* = 180. [b]Predictors: (Constant), PMSATE, MPTE. Dependent Variable: SLM. *Statistically significant at the .05 level.

Table 4

Regression Coefficients and Confidence Intervals for Isolated Predictor Variables

Model	Unstandardized *B*	Robust *SE*	Standardized Beta (*β*)	*T*	*p*-value	95% Confidence Interval for *B*
1. (Constant)	3.120	1.121	—	2.78	.006	(0.908, 5.332)
Math Skills (PMSATE)	0.642	0.079	.580	8.13*	< .001	(0.486, 0.798)
Teacher Performance (MPTE)	0.114	0.031	.241	3.68*	.001	(0.053, 0.175)

Note. Dependent Variable: Students' SLM Scores. Standard errors (*SE*), *t*-statistics, and 95% Confidence Intervals are calculated using Huber-White cluster-robust adjustments to account for nested observations. *Statistically significant at the .05 level.

4.2 Testing Null Hypothesis One (H_{01})

Null hypothesis one (H_{01}) stated that there is no significant relationship between the scores of chemistry teachers in the PMSATE test and their MPTE scores. The statistical analysis presented in Table 1 reveals a strong, positive, and statistically significant linear relationship between chemistry teachers' prerequisite mathematical skills acquisition and their mean instructional performance ($r = .811$), ($N = 18$), 95% CI (.551, .928), $p < .001$). Because the exact probability value ($p < .001$) is less than the standard significance threshold, null hypothesis one (H_{01}) is rejected. Squaring the correlation coefficient yields a large effect size ($r^2 = .658$), indicating that 65.8% of the total variance observed in teachers' instructional performance is directly accounted for by variations in their foundational mathematical skills acquisition.

4.3 Testing Null Hypothesis Two (H_{02})

Null hypothesis two (H_{02}) stated that there is no significant relationship between chemistry teachers' scores in the PMSATE test and secondary students' scores in the SLM test. As illustrated in Table 1, the analysis demonstrates a strong, direct, and positive significant relationship between teachers' prerequisite mathematical skills acquisition and secondary students' lesson mastery in electrolysis [$r = .730$, $N = 180$, 95% CI (.652, .793), $p = .010$]. Since the calculated significance value ($p = .010$) sits well below the alpha threshold of .05, null hypothesis two (H_{02}) is rejected. The calculated effect size ($r^2 = .533$) confirms that 53.3% of the total variance observed in secondary students' lesson mastery of electrolysis is directly explained by the level of prerequisite mathematical skills acquired by their instructors.

4.4 Testing Null Hypothesis Three (H_{03})

The multiple regression model summary displayed in Table 2 shows a multiple correlation coefficient (R) of .784 and a coefficient of multiple determination acting as the model's global effect size, ($R^2 = .615$). This demonstrates that the joint combination of teachers' mathematical skills acquisition and their classroom instructional performance accounts for approximately 61.5% of the total variance observed in secondary students' lesson mastery of electrolysis. The analysis of variance data in Table 3 yields an F-statistic of $F(2, 177) = 140.48$, which is highly significant ($p < .001$). Because the exact probability value is less than the .05 alpha level ($p < .001$), null hypothesis three (H_{03}) is rejected. To isolate the individual contributing weights and precision parameters of each predictor variable, the regression coefficients and their respective 95% confidence intervals were evaluated, as detailed in the newly structured Table 4.

5 Discussion

This study examined the relationships among chemistry teachers' mathematics skills acquisition, their teaching performance in electrolysis, and senior secondary school students' lesson mastery within selected Local Government Areas of Kano State, Nigeria. The findings offer new insight into why electrolysis remains challenging for students and suggest practical steps for teacher development in West African contexts. The first major finding reveals that chemistry teachers' mathematical skills acquisition is strongly and positively related to both their teaching performance in electrolysis and students' lesson mastery. This strong relationship implies that a chemistry teacher with robust mathematical foundations is structurally equipped to teach quantitative chemical concepts competently. This outcome supports the work of Kulsen and Hermann (2022), who argued that teachers possessing prerequisite math skills demonstrate higher confidence and fluency when explaining quantitative concepts like stoichiometry and Faraday's laws during electrolysis lessons. Furthermore, this aligns with Idris (2008), who affirmed that since mathematics serves as the bedrock of science instruction, systemic deficiencies in mathematical literacy directly translate to poor instructional execution in science topics. Similarly, Kampourakis and Zogza (2017) observed that a weak grasp of foundational mathematics often limits teachers to procedural, rote instructions without building conceptual bridges. In this study, teachers with superior mathematical capabilities actively utilized worked examples and seamlessly connected arithmetic steps to chemical realities, converting abstract rules into visible chemical relationships.

Regarding student outcomes, the established strong linear relationship between teacher mathematical competency and student lesson mastery reflects findings by Sevian and Talanquer (2019). They observed that students guided by instructors with strong mathematical reasoning consistently outperform their peers on conceptually demanding topics. This occurs because mathematically fluent educators can actively anticipate and resolve math-related misconceptions in real time. This capacity is highly critical for electrolysis instruction, where students routinely struggle to navigate relationships between electrical charge, mole ratios, and time-current variables. When instructors are mathematically competent, students' transition from superficial memorization toward true conceptual mastery, validating the assertion by Idris (2008) that exceptional instructional inputs are required to yield exceptional student mastery.

Particularly a compelling revelation in the structured regression model is that while teacher instructional performance (MPTE) achieved statistical significance, it exhibited only a moderate direct relationship and carried less than half the predictive weight ($\beta = .241$, $p = .001$) of baseline mathematical skills acquisition ($\beta = .580$, $p < .001$) on students' ultimate lesson mastery. This predictive imbalance uncovers a critical nuance within Shulman's (1986) Pedagogical Content Knowledge framework. Generic teacher evaluation protocols such as the Science Teaching Observation Protocol from which the MPTE checklist was adapted heavily reward macroscopic pedagogical traits. These include charisma, classroom pacing, vocal projection, generalized student engagement strategies, and efficient classroom management. The moderate nature of this relationship strongly demonstrates that these generalized pedagogical behaviors, while necessary for maintaining an orderly classroom environment, are entirely insufficient when students face highly abstract, quantitative subjects like electrolysis. An instructor can score exceptionally high on a standard evaluation by delivering a lively, well-timed lecture; however, if that instructor lacks the deep, automated mathematical schemas required to diagnose subtle computational errors, explain multi-variable algebraic substitutions, or scaffold dimensional analysis fluidly, macroscopic performance acts merely as a superficial veneer.

When dealing with Faraday's laws ($m = zIt$), student cognitive structures are highly vulnerable to immediate intrinsic cognitive overload, as conceptualized by Sweller (1988). Generic pedagogical warmth or excellent classroom management cannot structurally relieve a student's working memory if the teacher's mathematical explanations are confusing or mathematically imprecise. This finding strongly challenges conventional teacher-training assumptions in sub-Saharan Africa, which often operate under the premise that a generic "good teacher" can teach any topic within their broad discipline. Instead, these metrics empirically confirm that for highly quantitative science topics, content-specific mathematical proficiency is the non-negotiable anchor of the instructional chain, without which generalized pedagogical skill yields diminishing returns on student learning outcomes. Taken together, these findings hold strong implications for education geared toward sustainable development. Equipping students with rigorous mathematical and chemical problem-solving tools fosters the technical, analytical, and scientific literacy required to drive green technologies, sustainable engineering, and eco-innovations. True capacity-building for sustainable development relies on scientific literacy, which this study proves to be hindered by poor mathematical integration in chemistry pedagogy. Therefore, as Kind and Chan (2021) noted, targeting a teacher's mathematical proficiency yields significantly higher dividends for student learning than focusing exclusively on generic pedagogical moves during calculation-heavy units.

6 Conclusion

This study successfully achieved its objectives by establishing empirical evidence regarding the critical role of mathematical literacy in secondary school chemistry education. The findings conclusively demonstrate that chemistry teachers' mathematics skills acquisition serves as a powerful predictor of both their instructional delivery performance and their students' lesson mastery in electrolysis across the studied Local Government Areas of Kano State. Furthermore, the moderate relationship observed between classroom teaching compliance and actual student mastery highlights that surface-level pedagogy cannot compensate for a lack of deep, content-specific mathematical reasoning. The major contribution of this investigation to educational practice is the realization that electrolysis proficiency cannot be achieved through rote chemical memorization alone; rather, it requires a synchronized, interdisciplinary mastery of foundational calculations. Structurally, these outcomes validate the necessity of integrating rigorous mathematical training directly into science teacher preparation frameworks and professional development programs. Ultimately, this study underscores that achieving high-quality science education is a fundamental prerequisite for sustainable development. Equipping secondary school students with precise chemical problem-solving and mathematical tools builds the necessary scientific literacy and technical capacity required to navigate future green technologies, engineering innovations, and environmental management challenges. Therefore, ensuring content-specific mathematical competence among educators is not merely an instructional advantage, but a foundational requirement for cultivating the technically skilled workforce essential for driving sustainable societal development within West African contexts.

7 Implications for Practice

The findings of this study yield critical implications for educational practice within West African secondary school systems. First, regarding teacher training, professional development programs should integrate diagnostic mathematics assessments for chemistry educators prior to conducting generic pedagogical workshops. As Kind and Chan (2021) noted, enhancing an instructor's mathematical knowledge base may yield greater dividends for student learning than solely focusing on surface-level teaching moves during calculation-heavy topics. Consequently, in-service training programs in Nigeria ought to embed modules focused on foundational logarithms and stoichiometry calculations patterned after the Pre-service Mathematics Skills Assessment for Teacher Education framework. Furthermore, quality assurance evaluation tools used by secondary school inspectors should incorporate specific criteria for assessing mathematics explanation and error diagnosis rather than focusing exclusively on general classroom management behavior. Finally, to optimize student support systems, secondary schools should establish targeted peer-mentorship networks pairing struggling instructors with mathematically proficient colleagues, alongside providing remedial quantitative modules directly tied to chemistry curriculum sessions.

8 Limitations of the Study

The structural scope of this investigation introduces certain limitations regarding the broader generalizability of the outcomes. Although a sample of eighteen chemistry teachers operating across eighteen public secondary schools is statistically appropriate for an exploratory correlational design, utilizing larger sample sizes would significantly strengthen empirical claims intended to inform national educational policy frameworks. Furthermore, student lesson mastery was evaluated immediately following instructional delivery within a post-instruction testing window; consequently, deploying longitudinal retention instruments over subsequent academic terms might reveal alternative conceptual patterns. Finally, to satisfy statistical independence assumptions required for correlational analysis, individual student performance metrics were aggregated directly to the teacher level. While methodologically necessary, this analytical choice masks localized, individual student variations. Future investigations should utilize multilevel modeling configurations paired with expanded nested sample sizes to capture nuanced teacher-level and student-level interactions simultaneously.

9 Recommendation

Based on the empirical findings of this investigation, several actionable recommendations are proposed for educational policy and future research. First, ministries of education should mandate targeted mathematics competency screenings for chemistry teachers tasked with instructing quantitative science topics. Furthermore, teacher education programs ought to actively integrate specialized courses focused on mathematics for chemistry instruction, explicitly emphasizing electrolysis calculations and common student misconceptions. For future research directions, investigators should replicate this study utilizing larger sample sizes and multilevel analysis to evaluate whether variations in institutional school resources impact the relationship between teacher mathematical proficiency and student lesson mastery. Finally, future work should explore whether the strategic integration of digital instructional tools, such as interactive software and simulations, can effectively compensate for environments where baseline teacher mathematics skills are low.

10 Declarations

Author Contributions: Zubairu I.S and Inuwa B.A designed the study, developed the data collection instruments, wrote the initial manuscript draft and coordinated the field data collection across the six Local Government Areas in Kano State and assisted with literature integration. Aliyu S. A performed the statistical analysis, structured the regression models, while Mari S.J. and Umahaba R.E reviewed the final discussion. All authors contributed to manuscript revision, read, and approved the submitted version.

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Data Availability Statement: The raw, anonymized datasets supporting the conclusions of this article including the Prerequisite Mathematics Skills Acquisition for Teaching Electrolysis Test (PMSATE) teacher scores, Mean Performance in Teaching Electrolysis (MPTE) observation metrics, and Students' Lesson Mastery (SLM) achievement data will be made available by the corresponding author upon reasonable academic request, without undue reservation.

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