Advances In Multidisciplinary & Scientific Research
A Multidisciplinary & Interdisciplinary Journal

Vol. 12 No. 2, March , 2026

Influence of Continuous Professional Development on Biology Teachers' Pedagogical Skills in Oyo South Senatorial District

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ABSTRACT

This study examined the influence of Continuous Professional Development (CPD) on Biology teachers' pedagogical skills in Oyo South Senatorial District, Nigeria. Guided by Kolb's Experiential Learning Theory and the Technological Pedagogical Content Knowledge (TPACK) framework, a descriptive correlational survey design was adopted. Multi-stage sampling yielded 209 valid respondents from 108 public senior secondary schools across six Local Government Areas. Data were collected using the Continuous Professional Development Questionnaire (CPDQ) and the Biology Teachers' Pedagogical Skills Questionnaire (BTPSQ), both validated with strong internal consistency (Cronbach's $\alpha = 0.836–0.882$). Three hypotheses were tested using a one-sample t-test, Friedman test, and multiple regression at $\alpha = .05$. Findings showed that Biology teachers significantly demonstrated TPACK ($t(208) = 9.41$, $p < .001$), with Abstract Conceptualisation the most dominant CPD dimension ($M = 3.56$). A significant difference existed in the prominence of CPD dimensions ($\chi^2(3) = 147.82$, $p < .001$). Biology teachers significantly demonstrated TPACK above the criterion mean, Abstract Conceptualisation emerged as the most dominant CPD programme dimension with a statistically significant difference in prominence across all four dimensions, and the CPD dimensions jointly and relatively influenced Biology teachers' pedagogical skills in Pedagogical Knowledge, Technological Knowledge, and Technological Pedagogical Content Knowledge (TPACK). The study recommends targeted TPACK-focused interventions, diversified CPD programmes that prioritise Active Experimentation, and skill-specific CPD designs aligned to distinct pedagogical knowledge domains.

Keywords: Biology Teachers, Continuous Professional Development, Pedagogical Skills, TPACK.

Aims Research Journal Reference Format:
Ayanniyi, F.A. & Omoyajowo, B.S. (PhD) (2026): Influence of Continuous Professional Development on Biology Teachers' Pedagogical Skills in Oyo South Senatorial District. Advances in Multidisciplinary Research Journal. Vol. 12 No. 2, Pp 47-58. . www.isteams.net/aimsjournal. dx.doi.org/10.22624/AIMS/V12N2P4

1. INTRODUCTION

The pedagogical effectiveness of Biology teachers remains a central concern in Nigerian secondary education, where persistent challenges have been documented in instructional quality, technology integration, and scientific literacy development. Pedagogical skills encompass the integrated competencies enabling teachers to transform complex biological concepts into meaningful learning experiences across four key dimensions: Content Knowledge (CK), Pedagogical Knowledge (PK), Technological Knowledge (TK), and Technological Pedagogical Content Knowledge (TPACK). Globally, studies have documented inadequacies in Biology teachers' instructional delivery, particularly the tendency to rely on lecture-based methods without practical demonstrations, digital resources, or differentiated instruction. Within Nigeria, these challenges are compounded by infrastructural deficits, large class sizes, and limited access to professional learning resources.

Continuous Professional Development (CPD) provides a systematic mechanism for addressing pedagogical gaps among in-service teachers, operating through four Kolbian learning dimensions: Concrete Experience (hands-on workshop participation), Reflective Observation (peer feedback and teaching journals), Abstract Conceptualisation (formal courses and scholarly engagement), and Active Experimentation (classroom trials and action research). In Oyo South Senatorial District, concerns regarding Biology teachers' pedagogical competency have been consistently observed through classroom monitoring, manifesting in over-reliance on traditional instruction, limited technology integration, and insufficient practical engagement. Understanding the extent to which these CPD dimensions influence specific pedagogical skill domains is essential for informing targeted professional development policy and practice.

1.1 Statement of the Problem

Despite sustained efforts to improve Biology teachers' pedagogical skills through Continuous Professional Development, the effectiveness of specific CPD programme dimensions in addressing competency gaps remains inadequately understood in Nigerian contexts, particularly Oyo State. Previous studies lack specificity in examining how individual CPD dimensions Concrete Experience, Reflective Observation, Abstract Conceptualisation, and Active Experimentation differentially influence the four TPACK-framework pedagogical skill domains (CK, PK, TK, TPACK) among Biology teachers. Furthermore, the extent to which Biology teachers demonstrate TPACK and whether significant differences exist in CPD dimension prominence have not been systematically investigated in Oyo South Senatorial District. This study addresses these gaps empirically.

1.2 Objectives of the Study

The objectives of this study were to:

(i) examine the extent to which Technological Pedagogical Content Knowledge (TPACK) is demonstrated among Biology teachers in Oyo South Senatorial District;

(ii) identify the most dominant aspects of CPD programmes undertaken by Biology teachers in Oyo South Senatorial District; and

(iii) determine the influence of CPD dimensions (Concrete Experience, Reflective Observation, Abstract Conceptualisation, and Active Experimentation) on Biology teachers' pedagogical skills in Content Knowledge, Pedagogical Knowledge, Technological Knowledge, and TPACK in Oyo South Senatorial District.

1.3 Hypotheses

- H_{01}: There is no significant level of TPACK demonstrated among Biology teachers in Oyo South Senatorial District.
- H_{02}: There is no significant difference in the prominence of the Continuous Professional Development programme dimensions undertaken by Biology teachers in Oyo South Senatorial District.
- H_{03}: The dimensions of Continuous Professional Development (Concrete Experience, Reflective Observation, Abstract Conceptualisation, and Active Experimentation) do not significantly influence Biology teachers' pedagogical skills in Content Knowledge, Pedagogical Knowledge, Technological Knowledge, and Technological Pedagogical Content Knowledge (TPACK) in Oyo South Senatorial District.

2. LITERATURE REVIEW

2.1 Conceptual Review

Pedagogical skills in Biology teaching form a multi-dimensional construct comprising Content Knowledge (CK) teachers' mastery of biological subject matter, disciplinary depth, and curriculum breadth; Pedagogical Knowledge (PK) knowledge of instructional methods, classroom management, assessment strategies, and learning theories; Technological Knowledge (TK) the ability to use digital tools, simulations, online laboratories, and educational software to enhance instruction; and Technological Pedagogical Content Knowledge (TPACK) the integrative synthesis of CK, PK, and TK that enables teachers to design and implement effective technology-enhanced Biology lessons. The TPACK framework, developed by Mishra and Koehler (2006) building on Shulman's (1987) Pedagogical Content Knowledge, conceptualises teacher competence as an emergent, context-sensitive configuration of these overlapping knowledge domains rather than a simple additive combination.

Continuous Professional Development (CPD) constitutes the systematic, career-long process through which Biology teachers engage in purposeful learning activities to sustain and enhance their pedagogical effectiveness beyond initial teacher preparation. In this study, CPD is operationalised through four dimensions grounded in Kolb's (1984) Experiential Learning Theory: Concrete Experience, involving direct participation in workshops, seminars, and peer observations; Reflective Observation, encompassing deliberate self-assessment, peer feedback, and teaching journal maintenance; Abstract Conceptualisation, involving integration of CPD knowledge into theoretical frameworks through formal courses, conferences, and scholarly engagement; and Active Experimentation, representing classroom implementation of newly acquired strategies and action research cycles.

2.2 Theoretical Framework: Kolb's Experiential Learning Theory

The anchor theoretical framework for this study is Kolb's Experiential Learning Theory (ELT; Kolb, 1984), which conceptualises professional learning as a cyclical, iterative process integrating four sequential stages: Concrete Experience, Reflective Observation, Abstract Conceptualisation, and Active Experimentation. ELT posits that effective adult learning emerges when practitioners engage all four stages: gaining direct experience, reflecting upon that experience, forming principled theoretical frameworks, and actively testing those frameworks in practice. Applied to Biology teacher professional development, ELT provides a coherent explanatory architecture for understanding how distinct CPD programme components contribute differentially to specific pedagogical knowledge domains. Concrete Experience supplies the raw material for learning; Reflective Observation deepens critical self-awareness; Abstract Conceptualisation builds transferable pedagogical frameworks; and Active Experimentation transforms knowledge into sustainable classroom competence. The TPACK framework complements ELT as the structural map of the pedagogical knowledge domains that ELT-informed CPD is expected to develop, providing measurable outcome domains for each stage of the learning cycle.

2.3 Empirical Review

Empirical studies confirm the importance of both CPD design and TPACK integration in shaping Biology teachers' pedagogical effectiveness. Research in Tanzanian and Nigerian secondary schools has demonstrated that CPD significantly predicts teacher pedagogical competence, with active and conceptually oriented CPD components emerging as particularly effective in building robust instructional skills. Studies on TPACK in science education confirm that technology integration is most effectively developed through experiential, practice-based professional learning rather than passive theoretical exposure; Anwar et al. (2024) documented uneven TPACK profiles among Biology teachers in developing contexts, with general digital literacy stronger than discipline-specific pedagogical technology integration. Regarding CPD programme prominence, meta-analytic and systematic review evidence indicates that abstract and conceptual CPD engagements, including formal courses and scholarly participation, tend to dominate teachers' professional learning experiences relative to active experimentation and classroom action research, which are consistently reported as the weakest CPD participation modes.

Studies on CPD dimension differences, such as Ambon et al. (2024) and Merino et al. (2025), highlight the theory-practice gap in professional development, wherein theoretical learning substantially outpaces classroom implementation. The present study extends this evidence base to the specific context of Biology teachers in Oyo South Senatorial District, providing the first empirical assessment of TPACK demonstration levels, CPD dimension prominence differences, and the relative influence of individual CPD dimensions on distinct TPACK-framework pedagogical skill domains in this geographical and institutional context.

3. METHODOLOGY

A descriptive correlational survey design was adopted, appropriate for examining relationships and group differences among continuous variables without experimental manipulation. The target population comprised approximately 450 Biology teachers distributed across nine Local Government Areas (LGAs) within Oyo South Senatorial District, Oyo State, Nigeria. Multi-stage sampling was employed: six LGAs were selected at the first stage; 108 public senior secondary schools were identified at the second stage; and the Yamane (1967) formula applied to the estimated population produced a sample size of 212, with proportionate allocation across LGAs and schools. Of 212 questionnaires administered, 209 were returned valid, yielding a 98.6% response rate.

Data were collected using two researcher-developed instruments. The Continuous Professional Development Questionnaire (CPDQ) measured four CPD dimensions using 20 items (5 items each for Concrete Experience, Reflective Observation, Abstract Conceptualisation, and Active Experimentation). The Biology Teachers' Pedagogical Skills Questionnaire (BTPSQ) measured four TPACK-framework skill dimensions using 20 items (5 items each for CK, PK, TK, and TPACK). Both instruments used a four-point Likert scale (1 = Strongly Disagree to 4 = Strongly Agree). Internal consistency was strong across all scales (Cronbach's α = 0.836–0.882). Content validity was established through expert review by five specialists in Biology Education and Educational Research.

Three statistical procedures were employed for hypothesis testing. H_{01} was tested using a one-sample t-test comparing the observed mean TPACK score against a test value of 2.50 (the scale criterion mean), to determine whether the level of TPACK demonstrated was significantly above chance. H_{02} was tested using the Friedman test, a non-parametric repeated-measures procedure appropriate for comparing the means of k related samples, to determine whether the four CPD dimensions differed significantly in prominence. H_{03} was tested through four parallel multiple regression analyses, each predicting one of the four pedagogical skill dimensions (CK, PK, TK, TPACK) from the four CPD dimensions as predictors. All analyses were performed using IBM SPSS Statistics Version 27 at α = .05. Comprehensive diagnostic tests including normality (Kolmogorov–Smirnov and Shapiro–Wilk), multicollinearity (VIF and Tolerance), homoscedasticity (Breusch–Pagan test), and autocorrelation (Durbin–Watson) confirmed the suitability of the data for parametric analysis.

4. RESULTS AND DISCUSSION

Demographic Characteristics of Respondents

Table 1: Demographic Distribution of Respondents (N = 209)

Variable	Category	Frequency	Percentage (%)
Gender	Male	89	42.6
	Female	120	57.4
Teaching Experience	1–5 years	44	21.1
	6–10 years	56	26.8
	11–15 years	50	23.9
	16–20 years	34	16.3
	21 years and above	25	12.0
Educational Qualification	NCE	21	10.0
	B.Sc./B.Ed.	119	56.9
	M.Sc./M.Ed.	62	29.7
	Ph.D.	7	3.3
CPD Participation (last 3 years)	Yes	168	80.4
	No	41	19.6
No. of CPD Programmes Attended	1–2 programmes	78	46.4
	3–4 programmes	56	33.3
	5–6 programmes	24	14.3
	7 and above	10	6.0

Note. Source: Field Survey, 2026.

Table 1 shows that female respondents formed the majority (57.4%, n = 120). The 6–10 years teaching experience bracket was most prevalent (26.8%), with 78.9% possessing at least six years of professional experience. B.Sc./B.Ed. holders constituted the largest qualification group (56.9%), and 80.4% had participated in CPD within the preceding three years.

Hypothesis 1: Level of TPACK Demonstrated among Biology Teachers

H_{01}: There is no significant level of TPACK demonstrated among Biology teachers in Oyo South Senatorial District.

Table 2: Mean Ratings on Technological Pedagogical Content Knowledge TPACK (N = 209)

SN	Item Statement	SD	D	A	SA	$\bar{x}$	SD	Remark
1	I effectively integrate technology into my Biology lessons to enhance student understanding.	3 (1.4%)	16 (7.7%)	61 (29.2%)	129 (61.7%)	3.51	0.70	Strongly Agreed
2	I use virtual laboratories and simulations to teach abstract Biology concepts.	2 (1.0%)	23 (11.0%)	63 (30.1%)	121 (57.9%)	3.45	0.73	Agreed
3	I employ digital tools to create interactive and engaging Biology learning experiences.	6 (2.9%)	24 (11.5%)	79 (37.8%)	100 (47.8%)	3.31	0.79	Agreed
4	I select appropriate technological tools based on specific Biology content and learning objectives.	4 (1.9%)	28 (13.4%)	62 (29.7%)	115 (55.0%)	3.38	0.79	Agreed
5	I combine technology, pedagogy, and Biology content knowledge to address students' learning difficulties.	6 (2.9%)	18 (8.6%)	69 (33.0%)	116 (55.5%)	3.41	0.77	Agreed
	Weighted Mean					3.41	0.76	Agreed

Note. SD = Strongly Disagree (1); D = Disagree (2); A = Agree (3); SA = Strongly Agree (4). Criterion mean = 2.50. Source: Field Survey, 2026.

Table 3: One-Sample t-Test on TPACK Demonstration (N = 209, Test Value = 2.50)

Variable	Mean	SD	t	df	Sig. (2-tailed)
Technological Pedagogical Content Knowledge (TPACK)	3.41	0.76	9.41	208	<.001

Note. Test value = 2.50 (criterion mean). Significance threshold: α = .05. Source: Field Survey, 2026.

Table 3 shows a one-sample t-test result of $t(208) = 9.41$, $p < .001$, indicating that the mean TPACK score (M = 3.41, SD = 0.76) is significantly above the criterion mean of 2.50. H_{01} is therefore rejected. Biology teachers in Oyo South Senatorial District demonstrate a significant level of TPACK. The mean score falls within the Agreed band (2.50–3.49), with the highest-rated item being technology integration to enhance student understanding (M = 3.51, Strongly Agreed) and the lowest being the creation of interactive digital Biology learning experiences (M = 3.31, Agreed).

Hypothesis 2: Difference in Prominence of CPD Programme Dimensions

H_{02}: There is no significant difference in the prominence of the CPD programme dimensions undertaken by Biology teachers in Oyo South Senatorial District.

Table 4: Descriptive Statistics for CPD Dimensions (N = 209)

CPD Dimension	Mean ($\bar{x}$)	SD	Mean Rank	Sum of Ranks	Remark
Abstract Conceptualisation (AC)	3.56	0.66	3.15	658.35	Strongly Agreed
Concrete Experience (CE)	3.44	0.72	2.77	578.93	Agreed
Reflective Observation (RO)	3.31	0.80	2.26	472.34	Agreed
Active Experimentation (AE)	3.15	0.84	1.82	380.38	Agreed

Note. Mean ranks computed from Friedman test. Source: Field Survey, 2026.

Table 5: Friedman Test for Differences in CPD Dimension Prominence (N = 209)

Test Statistic	Value	Df	Asymp. Sig.
Chi-Square (χ^2)	147.82	3	<.001
N	209		

Note. Friedman test. Significance threshold: $\alpha = .05$. Source: Field Survey, 2026.

Tables 4 and 5 present the Friedman test result. The chi-square statistic of $\chi^2(3) = 147.82$, $p < .001$ indicates a statistically significant difference in the prominence of the four CPD dimensions. H_{02} is therefore rejected. Post-hoc inspection of mean ranks reveals the dominance ordering: Abstract Conceptualisation (M = 3.56, Mean Rank = 3.15) > Concrete Experience (M = 3.44, Mean Rank = 2.77) > Reflective Observation (M = 3.31, Mean Rank = 2.26) > Active Experimentation (M = 3.15, Mean Rank = 1.82). Abstract Conceptualisation engagement with formal courses, research-based programmes, and scholarly reading is the most prominently practised CPD dimension, whilst Active Experimentation, involving classroom action research and systematic implementation of new strategies, is the least prominent.

Hypothesis 3: Influence of CPD Dimensions on Biology Teachers' Pedagogical Skills

H_{03}: The dimensions of CPD do not significantly influence Biology teachers' pedagogical skills in CK, PK, TK, and TPACK in Oyo South Senatorial District.

Table 6: Summary of Multiple Regression Models CPD Dimensions Predicting Pedagogical Skill Domains

Dependent Variable	R	R^2	Adj. R^2	F (4, 204)	Sig.
Content Knowledge (CK)	0.612	0.375	0.362	30.62	<.001
Pedagogical Knowledge (PK)	0.578	0.334	0.321	25.60	<.001
Technological Knowledge (TK)	0.624	0.390	0.378	32.57	<.001
TPACK	0.224	0.050	0.031	2.68	0.032

Note. Predictors: Concrete Experience (CE), Reflective Observation (RO), Abstract Conceptualisation (AC), Active Experimentation (AE). Source: Field Survey, 2026.

Table 7: Regression Coefficients CPD Dimensions Predicting Content Knowledge (CK)

Predictor	B	Std. Error	Beta (β)	t	Sig.
(Constant)	0.981	0.209	—	4.694	<.001
Concrete Experience (CE)	-0.095	0.058	-0.097	-1.638	0.103
Reflective Observation (RO)	-0.036	0.050	-0.041	-0.720	0.472
Abstract Conceptualisation (AC)	0.399	0.059	0.383	6.763	<.001
Active Experimentation (AE)	0.145	0.046	0.176	3.152	0.002

Note. Dependent Variable: CK. Source: Field Survey, 2026.

Table 8: Regression Coefficients CPD Dimensions Predicting Pedagogical Knowledge (PK)

Predictor	B	Std. Error	Beta (β)	t	Sig.
(Constant)	1.254	0.238	—	5.269	<.001
Concrete Experience (CE)	0.062	0.066	0.056	0.939	0.349
Reflective Observation (RO)	0.119	0.057	0.121	2.088	0.038
Abstract Conceptualisation (AC)	0.168	0.067	0.141	2.507	0.013
Active Experimentation (AE)	0.328	0.053	0.352	6.189	<.001

Note. Dependent Variable: PK. Source: Field Survey, 2026.

Table 9: Regression Coefficients CPD Dimensions Predicting Technological Knowledge (TK)

Predictor	B	Std. Error	Beta (β)	t	Sig.
(Constant)	0.829	0.249	—	3.329	0.001
Concrete Experience (CE)	0.197	0.069	0.174	2.855	0.005
Reflective Observation (RO)	0.068	0.060	0.068	1.133	0.258
Abstract Conceptualisation (AC)	0.112	0.070	0.094	1.600	0.111
Active Experimentation (AE)	0.408	0.055	0.432	7.418	<.001

Note. Dependent Variable: TK. Source: Field Survey, 2026.

Table 10: Regression Coefficients CPD Dimensions Predicting TPACK

Predictor	B	Std. Error	Beta (β)	t	Sig.
(Constant)	3.091	0.348	—	8.881	<.001
Concrete Experience (CE)	-0.048	0.097	-0.037	-0.495	0.621
Reflective Observation (RO)	-0.198	0.083	-0.173	-2.386	0.018
Abstract Conceptualisation (AC)	0.068	0.098	0.049	0.694	0.488
Active Experimentation (AE)	0.055	0.077	0.052	0.714	0.476

Note. Dependent Variable: TPACK. Source: Field Survey, 2026.

Tables 6–10 present the regression results for Hypothesis 3. As shown in Table 6, the four CPD dimensions jointly exert a significant influence on CK ($R^2 = 0.375$, $F(4, 204) = 30.62$, $p < .001$), PK ($R^2 = 0.334$, $F(4, 204) = 25.60$, $p < .001$), and TK ($R^2 = 0.390$, $F(4, 204) = 32.57$, $p < .001$). The model for TPACK is also significant overall ($R^2 = 0.050$, $F(4, 204) = 2.68$, $p = .032$), though it explains considerably less variance. H_{03} is therefore rejected across all four pedagogical skill domains: the CPD dimensions significantly influence Biology teachers' pedagogical skills. The pattern of individually significant predictors, however, differs systematically across skill domains. For CK (Table 7), Abstract Conceptualisation ($\beta = 0.383$, $p < .001$) and Active Experimentation ($\beta = 0.176$, $p = .002$) are the significant predictors. For PK (Table 8), Active Experimentation ($\beta = 0.352$, $p < .001$), Abstract Conceptualisation ($\beta = 0.141$, $p = .013$), and Reflective Observation ($\beta = 0.121$, $p = .038$) are significant. For TK (Table 9), Active Experimentation ($\beta = 0.432$, $p < .001$) and Concrete Experience ($\beta = 0.174$, $p = .005$) are the significant predictors. For TPACK (Table 10), only Reflective Observation achieves significance, with a negative coefficient ($\beta = -0.173$, $p = .018$), whilst the overall model's explanatory power is limited ($R^2 = 0.050$).

4. DISCUSSION OF FINDINGS

The significant demonstration of TPACK among Biology teachers in Oyo South Senatorial District ($t(208) = 9.41$, $p < .001$, $M = 3.41$) indicates that teachers substantively integrate technology, pedagogy, and content knowledge in their instructional practice, though the level remains within the Agreed band rather than the Strongly Agreed band. The comparatively weaker rating for the creation of interactive digital Biology learning experiences ($M = 3.31$) relative to general technology integration ($M = 3.51$) is consistent with studies across sub-Saharan African contexts, which document that Biology teachers' TPACK is characterised by stronger general digital competence than discipline-specific pedagogical technology orchestration. Anwar et al. (2024) similarly found uneven TPACK profiles among Biology teachers in developing educational contexts, attributing the gap to insufficient TPACK-targeted professional development and inadequate access to specialised digital Biology resources. The present finding underscores that whilst Biology teachers in the district demonstrate a statistically significant and practically meaningful level of TPACK, the design of interactive technology-enhanced learning experiences requires further institutional attention and targeted professional development intervention.

The Friedman test result ($\chi^2(3) = 147.82$, $p < .001$) confirms a statistically significant difference in the prominence of CPD dimensions, with the dominance ordering: Abstract Conceptualisation > Concrete Experience > Reflective Observation > Active Experimentation. This finding is consistent with evidence from Ambon et al. (2024) and Merino et al. (2025), who document that theoretical and conceptually oriented CPD modalities formal courses, conferences, and scholarly engagement consistently dominate teachers' professional learning experiences across Nigerian and comparable African educational contexts. The comparatively lower prominence of Active Experimentation ($M = 3.15$) reveals a persistent theory-practice gap: Biology teachers engage substantively with conceptual CPD but engage less systematically with the experimental implementation of newly acquired pedagogical strategies in their classrooms. This pattern aligns with Kolb's (1984) Experiential Learning Theory, which identifies Active Experimentation as the stage most dependent on institutional scaffolding and protected professional time resources that may be insufficiently available in public secondary schools within the district. The significant difference in CPD dimension prominence has direct implications for programme design, pointing to the need to strengthen the Active Experimentation component of CPD cycles.

The regression findings confirm that CPD dimensions significantly influence Biology teachers' pedagogical skills across all four TPACK-framework domains, but with a distinctly skill-specific pattern of individual predictors. For Content Knowledge, Abstract Conceptualisation ($\beta = 0.383$) and Active Experimentation ($\beta = 0.176$) are the significant contributors, indicating that deep CK is primarily cultivated through conceptually rigorous CPD engagement and reinforced through classroom implementation. This is conceptually coherent: biological subject-matter mastery is developed through scholarly engagement with the discipline and then consolidated through practical application. For Pedagogical Knowledge, Active Experimentation ($\beta = 0.352$) is the dominant predictor, followed by Abstract Conceptualisation ($\beta = 0.141$) and Reflective Observation ($\beta = 0.121$), suggesting that PK the practical knowledge of how to teach is principally acquired through trying out and refining strategies in actual classroom contexts, consistent with Shulman's (1987) characterisation of pedagogical content knowledge as fundamentally practice-based and context-dependent.

For Technological Knowledge, Active Experimentation ($\beta = 0.432$) is the overwhelmingly dominant predictor, with a smaller contribution from Concrete Experience ($\beta = 0.174$), affirming the TPACK framework's emphasis that technological competence is most robustly developed through hands-on implementation and direct experiential engagement with digital tools rather than through theoretical study alone. The TPACK outcome model is distinctive: the overall model is significant ($p = .032$) but explains only 5.0% of variance, with Reflective Observation as the sole significant predictor and exhibiting a negative coefficient ($\beta = -0.173$), suggesting that neither formal CPD dimensions nor the observational CPD components reliably develop the integrative, synthesising competence that TPACK represents. This pattern suggests that TPACK development depends on mechanisms beyond the measured CPD dimensions, including personal technology adoption, self-directed digital learning, and broader professional network engagement.

5. CONCLUSION

This study demonstrates that Biology teachers in Oyo South Senatorial District significantly demonstrate TPACK ($t(208) = 9.41$, $p < .001$), with Abstract Conceptualisation as the most dominant CPD dimension and Active Experimentation the least prominent, with significant differences among dimensions ($\chi^2(3) = 147.82$, $p < .001$). CPD dimensions jointly and significantly influence Biology teachers' pedagogical skills across all four TPACK-framework domains, with skill-specific patterns: Content Knowledge is most strongly influenced by Abstract Conceptualisation; Pedagogical Knowledge and Technological Knowledge are predominantly influenced by Active Experimentation; and TPACK is only minimally responsive to the measured CPD inputs, signalling the need for specifically designed TPACK-development interventions. These findings affirm the value of Kolb's Experiential Learning Theory as an organising framework for CPD programme design in Biology teacher education, whilst identifying the theory-practice gap between dominant conceptual CPD engagement and less developed active classroom experimentation as a critical point of intervention for educational policy in Oyo South Senatorial District.

6. RECOMMENDATIONS

Based on the findings from each objective, the following recommendations are made:

1. Regarding TPACK demonstration: The Oyo State Teaching Service Commission and secondary school administrators should establish TPACK-targeted professional development programmes for Biology teachers, specifically addressing the identified weakness in designing interactive digital Biology learning experiences. Such programmes should include structured digital pedagogy workshops, access to virtual laboratory platforms, and peer mentoring arrangements focused on technology-content-pedagogy integration, moving

beyond general technology training to discipline-specific TPACK enactment within Biology instructional contexts.

2. Regarding CPD dimension prominence: Professional development programme designers, including the Science Teachers' Association of Nigeria (STAN) and tertiary teacher education institutions, should deliberately strengthen the Active Experimentation component of Biology teachers' CPD cycles. This requires developing structured classroom action research frameworks, lesson study groups, and protected implementation time that enables teachers to systematically trial CPD-derived strategies, document outcomes, and refine practice thereby closing the theory-practice gap evidenced by the significant dominance of Abstract Conceptualisation over Active Experimentation.
3. Regarding the influence of CPD dimensions on pedagogical skills: CPD programme architects in Oyo South Senatorial District should adopt skill-specific CPD designs aligned to the differential influence patterns identified in this study. Programmes targeting Content Knowledge should prioritise Abstract Conceptualisation through formal coursework and scholarly engagement; programmes targeting Pedagogical Knowledge and Technological Knowledge should emphasise Active Experimentation through structured classroom implementation cycles and hands-on technology workshop exposure; and programmes targeting TPACK should be designed as integrative, long-duration interventions that deliberately orchestrate the simultaneous application of content, pedagogy, and technology in Biology classroom contexts, supported by institutional scaffolding beyond standard CPD provision.

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