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Assessing the Joint Role of Perceived Technology Integration and ICT Quality in Students' Utilization of Educational Technology in Tertiary Institutions

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ABSTRACT

Despite extensive investment in hardware for digital transformation, ICT adoption remains inconsistent across universities in South-West Nigeria, with student engagement outcomes varying widely. This study examined how the quality of ICT infrastructure and students' perceptions of their lecturers' technology integration are jointly associated with students' usage of educational technology at nine universities in South-West Nigeria (N = 1,648). A cross-sectional descriptive-correlational design was used. Confirmatory factor analysis and structural path modelling were conducted in AMOS, with bootstrapped regression in Python. The analysis found that perceived technology integration ($B = 0.395$, $p < 0.001$) and ICT Quality ($B = 0.353$, $p < 0.001$) were each positively associated with student usage behaviour, and together accounted for 54.6% of its variance. In addition, 77.2% of students reported using smartphones as their primary learning device. These findings suggest that access alone is unlikely to be associated with effective engagement if pedagogical integration is weak. The study concludes that ICT infrastructure and perceived technology integration are complementary correlates of student usage, and that institutional strategies focused solely on hardware provision may have limited impact unless matched with professional development that strengthens lecturers' technology integration. For universities in resource-constrained settings, attending to pedagogical competence alongside infrastructure, and to mobile-first learning, appears warranted. Because the design is cross-sectional and technology integration was rated by students, the results describe associations and cannot establish causal effects.

1. INTRODUCTION

The field of higher education around the world is witnessing a massive digital transformation, wherein the use of ICTs has transformed from an additional element to a crucial one for learning innovations (Eze et al., 2018). Within today's tertiary institutions, the use of ICT helps create dynamic, collaborative, and evidence-based learning spaces to match the needs of the 21st-century knowledge economy. Nevertheless, procurement of hardware and software is by itself not enough to lead to improved quality of education. ICT requires alignment of technology, pedagogy, and people for it to be effective (Kwiek et al., 2024).

Without this synergy, the use of digital technologies could end up being peripheral distractions rather than facilitators of effective learning experiences.

In Nigerian tertiary educational institutions, the adoption of ICT encounters unique socio-technical and economic difficulties. Though there are policies that advocate for the use of digital technology in teaching and learning, challenges such as erratic power supply, expensive internet subscriptions, and unequal levels of digital literacy have led to fragmentation of educational processes (Agbatogun,



2012; Tunde-Awe, 2021).

This is indicative of the second-tier digital divide, wherein access to technology alone may not automatically imply productive use of the same in academics. Several studies suggest that ICT usage is associated with better academic output mainly where users have adequate digital skills (Oyelere et al., 2018).

The connection between ICT infrastructure and academic performance is usually not linear; rather, it involves complex interactions of how students use ICT infrastructure. The TPACK model emphasizes that effective integration of technology in the instructional process entails consistency between content, pedagogy, and technology (Mishra and Koehler, 2006; Mishra and Warr, 2024).

The use of ICT is seen as enabling, but the extent to which lecturers make use of it, and the extent to which learners become involved, depends on more than access. Scholarly research suggests that the expertise of the lecturer is associated with learners' involvement with the platform (Awofala et al., 2019). This study seeks to fill an important gap in the literature on educational technology in Nigeria by examining how the quality of ICT infrastructure and students' perceptions of their lecturers' technology integration are jointly associated with student engagement. While many studies have investigated the inadequacies in ICT infrastructure (Agbatogun, 2012) as well as digital literacy among lecturers (Tunde-Awe, 2021), very few studies have considered both factors simultaneously.

1.1 Objectives of the study

The objectives of the study are:

1. To examine the joint associations of ICT infrastructure quality and students' perceptions of lecturers' technology integration with students' engagement with educational technology in South-West Nigerian universities.
2. To determine the extent to which ICT quality and perceived technology integration jointly account for variance in students' usage behaviour, and how usage is associated with perceived learning outcomes.
3. To identify the primary digital devices used by students for learning and discuss the implications of this mobile-centric ecosystem for institutional ICT policy.

1.2 Hypotheses

The study tests the following hypotheses:

- H₁: ICT Quality is positively associated with students' usage behaviour.
- H₂: Perceived technology integration is positively associated with students' usage behaviour.
- H₃: ICT Quality and perceived technology integration jointly account for a significant proportion of variance in students' usage behaviour.

1.3 Perceived Technology Integration and the TPACK Framework

The TPACK framework (Mishra and Koehler, 2006; Mishra and Warr, 2024) can serve as a theory from

which to understand the types of knowledge that teachers need for the successful use of technology in the educational process. TPACK goes further than merely having a basic knowledge of computers or information and communications technologies and represents the intersections of three types of knowledge, which include Content Knowledge (CK), Pedagogical Knowledge (PK), and Technological Knowledge (TK). In this study, we measure students' perceptions of their lecturers' technology-related teaching practices, which we term perceived technology integration. We use the TPACK framework as a theoretical lens for interpreting these perceptions, while acknowledging that students cannot directly rate lecturers' content or pedagogical knowledge.

TPACK becomes crucial in the Nigerian tertiary environment, considering that a large number of lecturers have had little training on the use of technology in teaching. As noted by (Benson and Ward, 2013), despite ICT being present in the environment, lecturers tend to lack the skills needed to take ICT beyond presenting materials passively to students actively engaging with the material.

Recent work has both extended and questioned the framework. A second-order review of 21 systematic reviews and two meta-analyses of TPACK research concluded that many recurring theoretical and methodological issues remain unresolved (Schmid et al., 2024), which argues for caution in how TPACK is measured and interpreted. A study by Ifinedo et al. (2020) surveyed teacher educators using partial least squares structural equation modelling, guided by the

TPACK and SITES frameworks, and examined how knowledge constructs, ICT pedagogical practices and beliefs relate to technology integration. Most such studies, however, focus on teachers' own knowledge or intentions; comparatively little Nigerian evidence links lecturers' TPACK to how students actually use educational technology, or compares it with the quality of the infrastructure students encounter.

1.3.1 Unified Theory of Acceptance and Use of Technology (UTAUT)

UTAUT model (Venkatesh et al., 2003) provides an alternative perspective to TPACK by emphasizing the behavioral and systems factors influencing technology acceptance. UTAUT model posits that four main determinants drive user behavior: Performance expectancy (expectations about improvement in productivity through using the technology), effort expectancy (ease of use), social influence (normative pressure to use technology), and facilitating conditions (availability of the technical infrastructure). In relation to education, facilitating conditions correlate highly with ICT Quality factors such as system reliability, information availability, and technical support responsiveness.

1.3.2 Integrating TPACK and UTAUT

This study merges the TPACK and UTAUT models, and the integration is justified on three grounds. First, the two frameworks address complementary layers of technology use, UTAUT's facilitating conditions describe the technical and organisational resources available to users, which are operationalised as ICT Quality, whereas TPACK describes the knowledge

that lets instructors put those resources to pedagogical use. Second, UTAUT was not designed to capture pedagogical knowledge, and TPACK says little about infrastructure; combining TPACK with other models of technology integration has been proposed as a way forward (Schmid et al., 2024), and a recent UTAUT–TPACK model of teachers’ digital teaching behaviour found that both TPACK and facilitating conditions were positively related to it, with TPACK the largest factor (Tang et al., 2024). Third, that work and most similar studies model teachers’ own behaviour, whereas the present study asks how students’ usage is associated with both factors. As emphasized by (Agbatogun, 2012), technological acceptance alone is not enough to achieve an effective educational outcome; pedagogical skills are needed to trigger the educational effect of the digital technologies. The integration is used as a conceptual lens, the models estimated below test the joint associations of ICT Quality and perceived technology integration with student usage. Such tests, for example, an ICT Quality $\times$ TPACK interaction, are left to future research.

2 MATERIALS AND METHODS

2.1 Research Design

A descriptive correlational, cross-sectional design was used to investigate the relationships among ICT Quality, lecturers' TPACK, Student Usage Behavior and Perceived Learning Outcomes. Using this approach made it possible not only to describe the existing situation regarding ICT usage, but also to

test the strength of the associations among the constructs. Because all variables were measured at a single point in time, the design supports associational rather than causal inferences. In this paper, ‘student usage behaviour (SUB)’, ‘student engagement’ and ‘utilization of educational technology’ are used interchangeably for the construct measured by the six-item SUB scale; perceived learning outcomes (PLO) are a distinct construct.

2.2 Participants and Sampling

This study targeted an approximate number of 142,000 undergraduates from nine universities across the South West Region of Nigeria (Federal, State and Private Universities). Using the formula by Yamane (1967) at a 95 percent confidence level and 2.45 percent margin of error, the sample size is a total of 1,648 respondents across all nine universities. In this study, stratified random sampling technique was employed, whereby each of the nine universities provided about 183-184 respondents. There were 1,648 respondents who answered the questionnaires (54.2% male, 45.8% female; 51.1% aged 16-20 years) as shown in detail in Table 2.1 below.

Table 2.1. Demographic Characteristics of Respondents

Characteristic	Category	Sample(n)	Percentage (%)
Gender	Male	894	54.20
	Female	754	45.80
Age	16 -- 20 years	842	51.10
	21 -- 25 years	576	35.00
	26 -- 30 years	174	10.60
	Above 30 years	56	3.40
Primary Device	Smartphone	1,273	77.20
	Laptop	261	15.80
	Tablet	51	3.10
	Desktop	44	2.70
	Other	19	1.20

2.3 Instrumentation

The data collection instrument applied was the structured questionnaire with 24 items (see Appendix A). The measurement of the four constructs took place using six items each in ICT Quality, Lecturers' TPACK, Students' Usage Behavior, and Perceived Learning Outcomes. Answers were provided on the Likert scale with five points from strongly disagree to strongly agree.

The questionnaire was adapted from scales that have shown reliability within the literature on information system success and technology, pedagogy, and content knowledge (TPACK) (DeLone and McLean, 2003; Mishra and Warr, 2024). Content validity was ensured through three experts in computer science and education technology. The construct labelled perceived technology integration captures students' ratings of their lecturers' technology-related teaching practices. It is not a measure of lecturers' content or pedagogical knowledge, and the label is used

throughout to reflect this distinction. Implications are discussed in Section 6.1.

2.4 Procedure and Ethical Considerations

Data collection was done using the method of electronic data collection via Google Forms for eight weeks. Consent of the participants was obtained by informing them about the nature of the research, their voluntary involvement, and confidentiality using mandatory digital consent forms. Data were cleaned and no personal identifiers were retained. Although the form used required-field settings, a small proportion of item responses (0.72%) were missing in the exported dataset. These arose from partial submissions in which respondents closed the browser before final submission, and from platform-level recording gaps in the export. Median imputation was used for these items, which is appropriate given the very low proportion of missingness.

2.5 Data Analysis

Data preprocessing and regression analyses were

conducted in Python 3.11+ using pandas, NumPy, SciPy, and statsmodels. Confirmatory factor analysis and structural path modelling were conducted in IBM SPSS Amos (version 26). Internal reliability was assessed with Cronbach's α and McDonald's ω , with $\alpha \geq 0.70$ considered acceptable (Nunnally and Bernstein, 1994). Convergent validity was assessed via confirmatory factor analysis, with factor loadings ≥ 0.60 and average variance extracted ≥ 0.50 considered acceptable (Fornell and Larcker, 1981; Hu and Bentler, 1999). Structural path analysis was conducted using Structural Equation Modeling (SEM) with robust standard errors. Three hierarchical models were specified:

- i. Model 1: $SUB = \beta_0 + \beta_1(ICTQ) + \beta_2(PTI) + \varepsilon$
- ii. Model 2: $PLO = \beta_0 + \beta_1(SUB) + \varepsilon$
- iii. Model 3: $PLO = \beta_0 + \beta_1(ICTQ) + \beta_2(PTI) + \beta_3(SUB) + \varepsilon$

A bootstrapped approach was used to conduct mediation analyses (5,000 bootstrap resamples), and where 95% confidence intervals were excluded from zero, results were deemed to be significant (Preacher and Hayes, 2004). Bootstrapped indirect effects were estimated with 5,000 resamples, with significance determined by 95% confidence intervals excluding zero (Preacher and Hayes, 2004). These indirect effects are reported as exploratory statistical patterns in cross-sectional data and do not establish causal sequence. Because all constructs were self-reported by the same respondents at one time point, common method bias was assessed with Harman's single-factor test (Podsakoff et al., 2003).

3. RESULTS

3.1 Reliability, Validity and Descriptive Statistics

Based on the study results, all four constructs demonstrated acceptable to excellent internal consistency: ICT Quality ($\alpha = 0.836$, $\omega = 0.83$), Perceived Technology Integration ($\alpha = 0.886$, $\omega = 0.90$), Student Usage Behaviour ($\alpha = 0.837$, $\omega = 0.86$), and Perceived Learning Outcomes ($\alpha = 0.906$, $\omega = 0.92$). In this case, the Average variance extracted ranged from 0.552 to 0.683, above the 0.50 threshold (Fornell and Larcker, 1981). Confirmatory factor analysis in Amos showed factor loadings

between 0.686 and 0.850 ($p < 0.001$).

Common method bias. Harman's single-factor test (Podsakoff et al., 2003) was applied to all 24 items. An unrotated principal-component analysis extracted three factors with eigenvalues above 1, and the first factor accounted for 45.6% of total variance. The extraction of three factors rather than the hypothesised four is not fully consistent with the measurement structure and, given the known insensitivity of Harman's test, common method variance cannot be ruled out. This is acknowledged as a limitation in Section 6.1. Table 3.1 and Figure 3.1 below summarise the descriptive statistics of all the

composite construct scores used in this study. As seen from the table, all the constructs obtained means higher than the theoretical scale midpoint of 3.0, indicating relatively favourable perceptions of ICT use in the classroom setting. Among the constructs, perceived learning outcomes had the highest mean of 3.724.

Table 3.1 Descriptive Statistics of Composite Construct Scores

Construct	M	SD	Median	Skewness
ICT Quality	3.282	0.973	3.333	-0.31
Lecturers' TPACK	3.423	1.010	3.500	-0.28
Student Usage Behavior	3.552	0.934	3.667	-0.35
Perceived Learning Outcomes	3.724	0.996	3.833	-0.42

Where $N = 1,648$. All constructs are measured on a 5-point Likert scale.



Figure 3.1: Mean scores of the study constructs with 95% confidence intervals ($N = 1,648$)

3.2. Correlation Analysis

The Pearson correlation analysis indicated that all variables were significantly and positively correlated with each other ($p < 0.001$). The strongest correlation was between the Student Usage Behavior variable and the Perceived Learning Outcomes variable ($r = 0.752$). There was also a strong correlation between Lecturers' TPACK and Student Usage Behavior ($r = 0.695$). ICT Quality and perceived technology integration were strongly correlated ($r = 0.727$), and VIF diagnostics were 2.1, below conventional thresholds. This strong correlation limits the precision with which their separate associations can be estimated and is acknowledged in Section 6.1.

3.3. Joint Associations of ICT Quality and Perceived Technology Integration with Student Usage Behaviour

Model 1 examined the associations of ICT Quality and lecturers' TPACK with students' usage behaviour. The regression model was statistically significant ($F(2, 1645) = 989.85$, $p < 0.001$) and accounted for 54.6% of the variance in SUB ($R^2 = 0.546$).

Table 3.2 Model 1: Student Usage Behaviour Regressed on ICT Quality and Perceived Technology Integration

Predictor	B	SE	T	p	95% CI
Intercept	0.6965	0.0487	14.31	< 0.001	[0.601, 0.792]
ICT Quality	0.3528	0.0232	15.18	< 0.001	[0.307, 0.398]
Lecturers' PTI	0.3954	0.0224	17.66	< 0.001	[0.352, 0.439]

Note. $N = 1,648$. B = unstandardised coefficient. $R^2 = 0.546$, $F(2, 1645) = 989.85$, $p < 0.001$. Standardised coefficients derived from B and the construct SDs in Table 4.1: ICT Quality $\beta \approx 0.37$; TPACK $\beta \approx 0.43$.

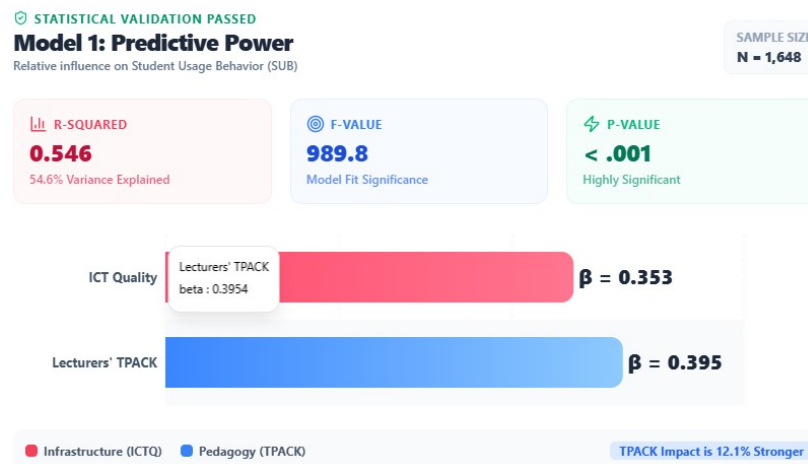


Figure 3.2 Unstandardised coefficients (B) with 95% confidence intervals for Model 1

As shown in Table 3.2 and Figure 4.2, both ICT Quality ($B = 0.353$, $p < 0.001$) and perceived technology integration ($B = 0.395$, $p < 0.001$) were significantly and positively associated with student usage behaviour. Together they accounted for a substantial proportion of variance in usage.

3.4. Indirect Associations

Models 2 and 3 examined whether student usage behaviour statistically mediates the associations of ICT Quality and perceived technology integration with perceived learning outcomes. These analyses are reported as exploratory, because several predictor and outcome

items overlap conceptually, which may inflate the indirect estimates. Indirect effects were estimated with 5,000 bootstrap resamples and are reported in Table 4.4. The indirect effect of ICT Quality on PLO through SUB was 0.234 (bootstrap SE = 0.023; 95% CI [0.190, 0.282]) and that of perceived technology integration was 0.262 (SE = 0.024; 95% CI [0.215, 0.309]); both intervals exclude zero. In Model 3 ($R^2 = 0.579$), SUB was strongly associated with PLO ($B = 0.663$, $SE = 0.025$, $p < 0.001$), and the direct associations of ICT Quality ($B = 0.080$, $p = 0.002$) and perceived technology integration ($B = 0.108$, $p < 0.001$) remained significant, indicating partial mediation patterns. These are exploratory statistical patterns in cross-sectional data and do not establish a temporal or causal sequence. These are statistical mediation patterns in cross-sectional data and do not establish a temporal or causal sequence.

Table 3.4: Bootstrapped indirect effects of ICT Quality and lecturers' TPACK on perceived learning outcomes via student usage behaviour

Indirect path	Indirect effect	Boot SE	CI lower	CI upper	Direct effect (c')
ICTQ → SUB → PLO	0.234	0.023	0.190	0.282	0.080**
PTI → SUB → PLO	0.262	0.024	0.215	0.309	0.108***

Note. $N = 1,648$; 5,000 bootstrap resamples; percentile 95% confidence intervals. Direct effects (c') are from Model 3 ($R^2 = 0.579$); ** $p < 0.01$, *** $p < 0.001$. An indirect effect is significant when its interval excludes zero. Item overlap between predictors and outcomes may inflate these estimates; see Section 6.1

3.5. Item-Level Analysis

Analysis at the item level brought out some interesting trends relating to the TPACK construct. The top-scoring TPACK item was "The technology used by lecturers is highly relevant to the course objectives" ($M = 3.53$, $SD = 1.10$), while second was "My lecturers effectively integrate technology to make difficult concepts easier to understand" ($M = 3.47$, $SD = 1.12$). The bottom scoring TPACK item was "My lecturers are proficient in troubleshooting minor technical issues during online sessions" ($M = 3.33$, $SD = 1.18$). For ICT Quality, the lowest performing variables were the reliability of campus Wi-Fi ($M=3.11$, $SD=1.14$) and the availability of technical support ($M=3.18$, $SD=1.17$). This suggests that these two areas are the weakest aspects of ICT Quality as perceived by students. The variable, "Digital learning materials (e-books, lecture notes) are easily accessible 24/7" ($M=3.30$, $SD=1.18$) was close to the ICT Quality construct mean (3.28).

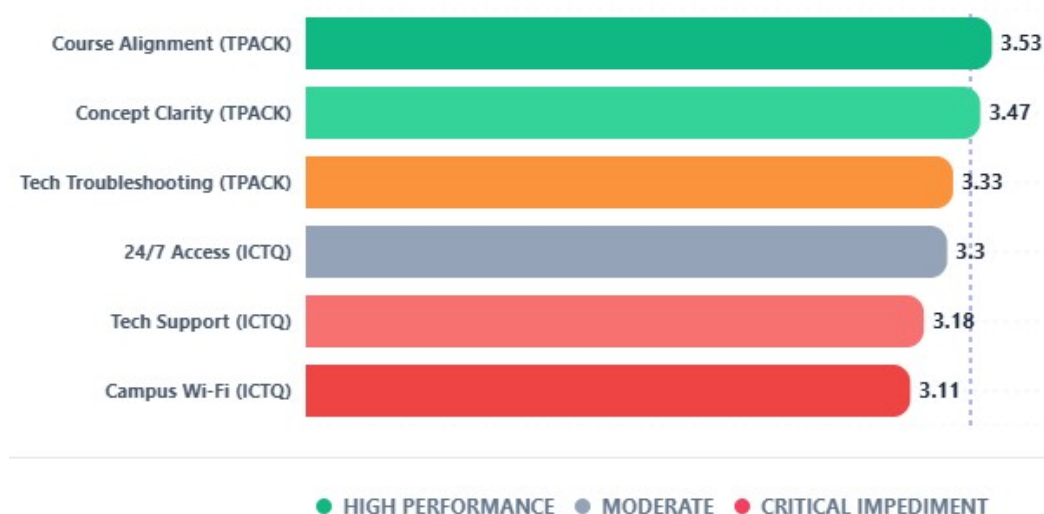


Figure 3.4 Item-level analysis

As Figure 3.4 shows, the item-level analysis suggests a possible “pedagogy–infrastructure gap”: students rated the relevance of lecturers’ technology to course objectives comparatively highly ($M = 3.53$), whereas campus Wi-Fi reliability ($M = 3.11$) and technical support ($M = 3.18$) were rated lowest among the ICT items. Item means were not formally compared.

3.6. Smartphone Dominance in Student ICT Engagement

An important observation was that 77.2% of the participants considered smartphones as their main digital learning tool, while laptops were used by only 15.8% of respondents and tablets by 3.1%. According to the cross-tab analysis, reliance on smartphones remained consistent regardless of the institution in all nine universities analyzed; however, none of the institutions showed laptop or desktops as their predominant primary device. These observations may have implications for ICT planning in institutions.

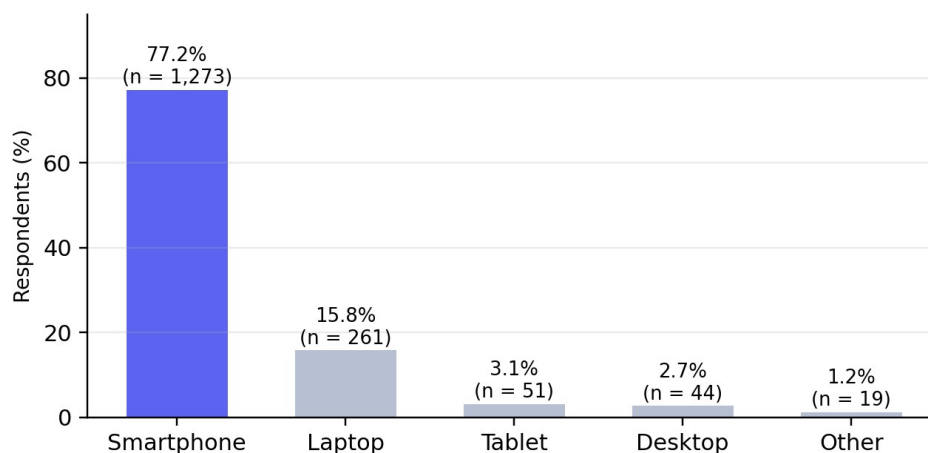


Figure 3.5 Students’ primary device for learning (N = 1,648)

Figure 3.5 shows that smartphones were the primary learning device for 77.2% of respondents, compared with 15.8% for laptops and 2.7% for desktops. Institutional device provision was not measured in this study, so whether institutional ICT provision is mismatched with students' mobile-first practice is a question for future research.

4. DISCUSSIONS

The aim of this study was to examine how the quality of ICT infrastructure and students' perceptions of their lecturers' technology integration are jointly associated with students' engagement with digital technologies in Nigerian universities. This research offers two main contributions to the education technology literature.

Firstly, both perceived technology integration ($B = 0.395$) and ICT Quality ($B = 0.353$) were significantly associated with student engagement, and together they accounted for 54.6% of the variance in usage behaviour. These findings suggest that infrastructure and pedagogical integration operate as complementary correlates rather than substitutes. They are consistent with the basic tenet of the TPACK framework that effective technology integration presupposes not only access to technology but also pedagogical knowledge (Mishra and Koehler, 2006; Mishra and Warr, 2024). One plausible interpretation, which these cross-sectional data cannot test, is that when lecturers are able to use digital tools well, students engage with them more.

The study contributes further to the Nigerian literature. Earlier work (Oyelere et al., 2018) noted that a positive attitude towards ICT does not necessarily translate into classroom adoption. The present findings are compatible with the interpretation that perceived technology integration

is one factor linked to this attitude–behaviour gap, but attitudes were not measured here, so this remains a hypothesis. Faculty development programmes that strengthen perceived technology integration may therefore be a worthwhile complement to hardware spending, although this study cannot show that they would yield a better return on investment than infrastructure. The results are also in line with the idea of “systemic synergy” (Kwiek et al., 2024), which holds that technological, pedagogical and organizational factors must be combined for successful implementation. It is often argued, though not tested here, that in Nigeria infrastructural resources have grown more quickly than training in digital pedagogy.

The discovery that 77.2% of students use smartphones as their main mode of learning is an important contextual issue that may not be adequately reflected in Nigeria's educational technology policies. This discovery is congruent with the observation made by (Adedoja et al., 2013) that personal mobile devices have been closing the digital divide in ways that desktop-based technologies do not. However, institutional ICT strategies may still be premised on desktop usage; this study did not collect institutional provision data, so this remains to be verified.

A possible disconnect between how students access learning systems and how those systems are structured may create obstacles. In line with the

the views of Eze et al., (2018); Abdurrazaq et al., (2026), when LMSs are not designed for mobile phones, learners may experience greater cognitive and bandwidth load, reducing the likelihood of continued use. Because most students in this sample relied on personal smartphones, institution-provided ICT infrastructure may matter less to them than would otherwise be expected, which may partly explain why ICT Quality and perceived technology integration showed comparable associations. This explanation was not tested.

The finding, "My lecturers are proficient in troubleshooting minor technical issues during online sessions," which had the lowest perceived technology integration score ($M = 3.33$), provides insight into a particular area of deficiency that needs to be addressed. This finding is consistent with the point made in (Tunde-Awe, 2021) that digital literacy gaps amongst academic staff in Nigeria go beyond simply using the tools to actually solving problems while using the technological platform for instruction. Technical problems encountered during online class sessions that cannot be resolved may lead to a loss of instructional momentum.

By contrast, the high score for "The technology used by lecturers is highly relevant to the course objectives" ($M = 3.53$) suggests that, from the students' perspective, lecturers choose appropriate tools when technology is applied. The priority may therefore lie less in selecting the right technology than in strengthening the technical skills needed when systems fail.

These findings offer preliminary empirical support for the integrated UTAUT–PTI perspective adopted in this paper. ICT Quality, as a proxy for the facilitating conditions of UTAUT, was significantly associated with usage behaviour, which implies that infrastructure counts. Lecturers' PTI was also significantly associated with usage behaviour after accounting for ICT Quality, so it seems necessary to consider pedagogical ability when applying models of technology acceptance in educational settings. Student usage behaviour was associated with perceived learning outcomes, and exploratory indirect effects were observed for both ICT Quality (0.234) and perceived technology integration (0.262; Table 3.4). Because several predictor and outcome items overlap in content, these estimates should be treated as exploratory and may be inflated by shared method and item variance. They describe statistical patterns in cross-sectional data rather than causal processes.

The finding that both ICT Quality and perceived technology integration are strongly associated with student engagement can guide institutional decision makers as they rethink ICT investment strategies. Institutions with limited financial capacity may consider pairing hardware purchases with faculty development that builds technology integration skills, rather than investing in hardware alone. Institutions with limited financial capacity may consider pairing hardware purchases with development initiatives for faculty that build TPACK skills, rather than investing in hardware alone.

Based on this study, policymakers may consider that

that ICT in education policies should take mobile learning into account.

Suggestions may include:

- i. Require all learning management systems implemented in public institutions to be optimized for mobile devices,
- ii. Arrange zero-rating deals with telecom operators for learning materials,
- iii. Create open educational resources optimized for mobile devices, and revise existing computer literacy curricula accordingly.

5. CONCLUSION

This study found that perceived technology integration and ICT infrastructure quality were each significantly associated with student engagement in educational technology in Nigerian universities, and that together they accounted for 54.6% of variance in usage behaviour. The study concludes that while ICT infrastructure is a necessary foundation, it is likely to remain underutilized without parallel attention to lecturers' technology integration competence. In addition, 77.2% of students reported that they depend on smartphones as their main learning tool, suggesting a mobile-centric environment that institutional policies should take into account. Combining TPACK theory with UTAUT helps in understanding how pedagogical skills and facilitating conditions are jointly associated with learner behavior. In the context of limited ICT resources in Nigeria, investing in lecturers' PTI and in mobile-friendly provision appears advisable for universities,

although causal effects remain to be tested.

The linkage between technology integration and ICT infrastructure is therefore one of complementarity: infrastructure provides the conditions for use, while lecturers' pedagogical and technical integration converts those conditions into student engagement. For Nigerian institutions, advancing technological input in teaching and learning requires attention to both, not either alone.

Limitations and Future Research

There are several limitations that need to be considered. Firstly, the study adopted a cross-sectional design, so causality cannot be established and all findings should be read as associations; longitudinal or experimental designs are needed to test whether strengthening TPACK or infrastructure changes student usage.

Secondly, the study was done among students from South-West Nigeria alone; thus, the findings may not be generalizable to other geopolitical zones that have varying infrastructures. Third, the construct labelled *perceived technology integration* captures students' ratings of their lecturers' technology-related teaching, not lecturers' own technology integration competence. Students cannot directly rate lecturers' content or pedagogical knowledge, and ratings of lecturers and of student usage come from the same respondents. Future studies should combine validated lecturer self-assessment, classroom observation, and multilevel designs.

Future studies should combine validated lecturer self-assessment instruments, classroom observation and multilevel designs in which students are nested within lecturers or courses. Fourth, several predictor and outcome items overlap conceptually (for example, lecturer encouragement of discussion forums and student participation in discussion threads; lecturer technology integration and perceived understanding). This overlap may inflate the observed associations and the exploratory indirect effects. Future work should refine item wording to reduce conceptual overlap. Fifth, all constructs came from a single self-report questionnaire. Although Harman's test did not indicate a dominant single factor, it extracted three factors rather than the hypothesised four, and common method variance cannot be ruled out.

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APPENDIX A: QUESTIONNAIRE INSTRUMENT

Section A (demographics): gender; age range; level of study; institution; faculty/college; length of active use of the institution's digital learning platform; primary digital tool used (smartphone, laptop, tablet, desktop, others). Sections B–E (24 items, six per construct) were rated on a five-point scale: 1 = strongly disagree, 2 = disagree, 3 = neutral, 4 = agree, 5 = strongly agree. Participation was voluntary and responses were confidential.

Construct	Code	Item statement	Source
ICT Quality	ICTQ1	The campus Wi-Fi/Internet connectivity is stable and fast enough for academic work.	(5)
	ICTQ2	The institution's Learning Management System (LMS) or Portal is easy to navigate.	
	ICTQ3	Digital learning materials (e-books, lecture notes) are easily accessible 24/7.	
	ICTQ4	Technical support and assistance are readily available when I encounter ICT issues.	
	ICTQ5	The institution provides adequate computer laboratories and charging points.	
	ICTQ6	The digital platforms provide prompt feedback (e.g., automated quiz results).	
Lecturers' PTI	PTI 1	My lecturers use a variety of digital tools (videos, simulations, etc.) to explain course content.	(9, 10)
	PTI 2	My lecturers effectively integrate technology to make difficult concepts easier to understand.	
	PTI 3	My lecturers are proficient in troubleshooting minor technical issues during online sessions.	
	PTI 4	The technology used by lecturers is highly relevant to the course objectives.	
	PTI 5	My lecturers encourage active interaction through digital discussion boards or forums.	
	PTI 6	My lecturers adapt their teaching style to suit the digital environment.	
Student Usage Behaviour	SUB1	I frequently log into the school portal/LMS to check for updates and study materials.	
	SUB2	I use digital tools to collaborate with my peers on group assignments and projects.	
	SUB3	I spend significant time exploring online library resources provided by the institution.	
	SUB4	I use ICT tools to organize my study schedule and manage my academic notes.	
	SUB5	I actively participate in online quizzes, polls, and discussion threads.	
	SUB6	I use the internet to research further into topics discussed during lectures.	
Perceived Learning Outcomes	PLO1	The use of ICT has significantly improved my understanding of course materials.	
	PLO2	Digital tools have helped me become more organized and efficient in my studies.	
	PLO3	I feel more confident in my ability to solve academic problems using ICT resources.	
	PLO4	My overall academic performance (grades) has improved due to ICT integration.	
	PLO5	ICT has made learning more flexible and convenient for me.	
	PLO6	I have developed valuable digital skills that are essential for my future career.	