Developing a context-responsive framework for optimum information and communication technology utilisation in Tanzanian secondary schools: Multi-group structural equation modelling and Delphi evidence

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ABSTRACT

Information and communication technology (ICT) utilisation in Tanzanian secondary schools remains uneven across institutional contexts and between teachers and students. This study developed a context-responsive framework for optimum ICT utilisation through measurement validation, multi-group structural equation modelling, and a two-round Delphi assessment. The study integrates seven complementary perspectives to explain how ICT resources become meaningful educational practice. A quantitative model-development and validation design was applied within a Type 2 Design and Development Research orientation. Parallel questionnaire data from 1,334 teachers and 1,584 students across 56 schools were examined using reliability and validity assessments, confirmatory factor analysis, measurement invariance testing, and multi-group structural equation modelling. Four domains—technological readiness, organisational support, individual capacity and environmental enablers—were positively associated with utilisation, with technological readiness generally producing the strongest effects. The models explained 60.82% of the teacher-utilisation variance and 52.49% of the student-utilisation variance, while explanatory power varied across school categories. Teacher and student pathways were integrated into a common empirical framework. Two Delphi rounds involving 28 education experts assessed the framework's clarity, relevance, feasibility, applicability and expected effectiveness, informing its refinement. The final framework combines a shared four-domain architecture with differentiated priorities for African Digital Schools Initiative, private, piloted and government schools. It is ready for controlled pilot implementation, followed by longitudinal evaluation of effectiveness and sustainability.

Keywords: Delphi technique; framework development; ICT utilisation; multi-group structural equation modelling; secondary education; Tanzania.

I. INTRODUCTION

Information and communication technology (ICT) can broaden access to educational resources, support communication, assessment and feedback, and create opportunities for interactive and learner-centred teaching and learning. International evidence nevertheless shows that its educational value depends on the conditions under which it is introduced and used. The provision of technology requires appropriate governance, equitable access, and teacher preparation to support meaningful educational practice (United Nations Educational, Scientific and Cultural Organisation [UNESCO], 2023). Reviews of secondary education similarly identify curriculum alignment, professional capability, reliable infrastructure and institutional support as interconnected conditions for effective ICT integration (Msafiri et al., 2023; Msambwa et al., 2024).

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These findings distinguish technology availability from optimum utilisation. In this study, optimum ICT utilisation refers to effective, efficient, equitable, purposeful, and pedagogically meaningful use across teaching and learning activities. Device ownership or occasional use provides an incomplete indication of whether ICT supports educational tasks or reaches learners directly (Bendera, 2024; Msafiri et al., 2023; UNESCO, 2023). Teachers may use technology for preparation and presentation while students have fewer opportunities for independent inquiry, collaboration, assessment or digital production. Examining teacher and student utilisation separately therefore helps distinguish institutional provision and instructional use from learners' direct participation.

In Tanzania, studies report ongoing constraints related to functional equipment, electricity, connectivity, technical support, teacher competence, and opportunities for classroom integration (Bendera, 2024; Minga & Ghosh, 2024; Ngodu et al., 2024; Swai, 2024). Research on teachers' computer use and classroom practice also demonstrates the importance of examining how available resources are employed in everyday teaching and learning (Mchalo et al., 2021; Peter, 2022). These conditions make utilisation a technological, organisational and educational concern: additional equipment may have limited practical value where maintenance, access arrangements, professional development or user confidence remain inadequate.

School context is consequently important. African Digital Schools Initiative (ADSI), private, piloted and government schools provide contrasting settings in which to examine ICT utilisation. Their inclusion allows the study to investigate whether a shared framework can accommodate differences in institutional conditions and implementation priorities. A context-responsive approach should identify common enabling domains while allowing individual schools to diagnose their needs and determine appropriate intervention sequences.

Policy and research initiatives provide a foundation for this work. Tanzania's National Digital Education Strategy seeks to strengthen digital education through coordinated attention to infrastructure, access, capacity development, technical support, governance and monitoring (Ministry of Education, Science and Technology [MoEST], 2025). Tanzanian research has also developed frameworks for ICT-supported assessment and for monitoring ICT integration (Mfoi et al., 2024a, 2024b). Building on these contributions, the present study focuses on developing and validating a framework for optimum utilisation across the wider teaching-and-learning process.

1.1 Statement of the Problem

A broader gap concerns the limited integration of technological readiness, organisational support, individual capacity, and environmental enablers within a common empirically tested framework. Comparatively limited evidence establishes measurement comparability across relevant groups, examines teachers and students through parallel measures, tests whether structural relationships vary across contrasting school contexts, and translates those results into differentiated implementation pathways. These limitations are important because schools differ substantially in resources, institutional support, user capability, and previous exposure to ICT initiatives.

1.2 Research Objectives

The study aimed to develop a context-responsive framework for optimum ICT utilisation in Tanzanian secondary schools. Specifically, it sought to:

i. Develop an empirical framework by validating the measurement models, estimating relationships between technological readiness, organisational support, individual capacity, environmental enablers and ICT utilisation, and integrating teacher, student and school-category evidence into differentiated framework pathways.
ii. Refine and validate the integrated empirical framework through two Delphi rounds assessing its clarity, relevance, feasibility, applicability and expected effectiveness.

II. LITERATURE REVIEW

2.1 Theoretical Review

The study integrates seven complementary perspectives to explain how ICT resources become meaningful educational practice. They address technological functionality, organisational arrangements, user acceptance and capability, pedagogical purpose, system quality and environmental conditions. Together, these perspectives guide the development of the empirical framework under the first objective and inform expert refinement and validation under the second.

The Technology–Organisation–Environment (TOE) framework locates technology utilisation within technological, organisational and environmental conditions (Tornatzky & Fleischer, 1990). For Objective One, it guides the specification of contextual domains and their relationships with ICT utilisation; for Objective Two, it informs expert assessment of contextual relevance and feasibility. The Unified Theory of Acceptance and Use of Technology (UTAUT) explains performance expectancy, effort expectancy, social influence and facilitating conditions (Venkatesh et al.,

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2003). It informs Objective One's treatment of user expectations and support conditions, while guiding Objective Two's assessment of whether the framework adequately represents users' willingness and opportunities to employ ICT.

The Capability Approach distinguishes resource possession from substantive opportunities to undertake valued activities (Nussbaum, 2011; Sen, 1985, 1999). For Objective One, it supports distinguishing teachers' instructional utilisation from students' direct participation, recognising that device access does not ensure competence, agency or opportunity. Objective Two directs expert attention to whether the framework's operational provisions adequately address equitable access and users' practical ability to convert ICT resources into meaningful educational activities.

Task–Technology Fit (TTF) refers to the correspondence between technological functionality and task requirements (Goodhue & Thompson, 1995). It informs Objective One's specification of task-appropriate technological readiness and Objective Two's assessment of operational suitability for teaching, assessment and learning. The Substitution–Augmentation–Modification–Redefinition (SAMR) model distinguishes substitution from progressively redesigned learning activities (Puentedura, 2013). For Objective One, SAMR informs the interpretation of pedagogical depth without treating utilisation frequency as evidence of transformation. Objective Two guides expert consideration of whether proposed activities support meaningful pedagogical application.

The DeLone and McLean Information Systems Success Model highlights system, information and service quality (Petter et al., 2008, 2013). It informs Objective One's attention to reliability, usability and technical support, and Objective Two's assessment of their operational coverage. Ecological Systems Theory situates educational activity within interacting environments (Bronfenbrenner, 1977). It guides Objective One's treatment of school-context differences and environmental enablers, while informing Objective Two's appraisal of stakeholder responsibilities and applicability across school settings.

These perspectives inform four interrelated domains rather than seven separately tested predictors. Technological readiness incorporates functionality, task fit, and system quality; organisational support concerns institutional arrangements and facilitating conditions; individual capacity encompasses competence, expectations, and agency; and environmental enablers address policy, infrastructure, and stakeholder support. Their overlapping contributions guide Objective One's integration of teacher, student and school-category evidence into differentiated pathways. For Objective Two, they provide a conceptual basis for assessing clarity, relevance, feasibility, applicability and expected effectiveness. Expert validation, therefore, examines the framework informed by these theories; it does not independently validate each theory or demonstrate its effectiveness after implementation.

2.2 Empirical Review

The first objective concerns the development of an empirical framework that integrates technological readiness, organisational support, individual capacity, and environmental enablers while preserving differences among teachers, students, and school contexts. Reviews indicate that meaningful ICT integration depends on reliable infrastructure, curriculum alignment, professional capability, learner access and institutional support (Msafiri et al., 2023; Msambwa & Daniel, 2024; Msambwa et al., 2024). These findings support a multidimensional framework, although identifying recurring conditions does not establish their simultaneous structural relationships with utilisation.

Tanzanian evidence reinforces the relevance of these domains. Studies report uneven utilisation and constraints related to connectivity, electricity, financing, technical support, competence, and classroom access (Bendera, 2024; Minga & Ghosh, 2024; Mkude et al., 2023; Ngodu et al., 2024; Warioba et al., 2022). Kalinga (2024) highlights the distinction between policy awareness and pedagogical integration, while Nzilano (2025) identifies infrastructural and support constraints. Mubofu and Adoph (2026) further indicate that access to digital resources may remain weakly integrated into curriculum practice when professional development and institutional guidance are insufficient. Together, this evidence supports examining resources, institutional arrangements, user capability and environmental conditions jointly.

Existing frameworks provide complementary guidance. International policy evidence emphasises coordination across infrastructure, educator capacity, governance, curriculum and sustainability (Boeskens & Meyer, 2025; UNESCO, 2023). Tanzania's National Digital Education Strategy similarly identifies interconnected implementation priorities (MoEST, 2025). Research-based frameworks synthesise enabling conditions or address specific processes, including assessment integration and monitoring in Tanzanian secondary schools (Mfoi et al., 2024a, 2024b; Msambwa & Daniel, 2024). The present study extends these contributions by examining structural relationships within a common framework across respondent groups and school categories.

Measurement comparability is central to this objective. Consoli et al. (2023) identify inconsistent operationalisation and a predominance of teacher-focused technology-integration instruments. This raises questions about whether measures adequately represent students' direct participation and whether group differences can be interpreted on a comparable basis. Parallel teacher and student instruments, measurement-invariance assessment and multi-group structural analysis therefore provide a basis for developing differentiated pathways within a shared architecture.

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The second objective concerns refining and validating the integrated empirical framework through expert assessment of clarity, relevance, feasibility, applicability and expected effectiveness. Child and Shaw (2023) emphasise that framework-validation evidence should correspond to its intended purpose, users and context. Structural evidence alone does not establish whether a framework's components and implementation requirements are sufficiently clear or practically appropriate for its intended setting.

Educational technology research illustrates how empirical development and expert judgement can be combined during framework refinement. Hugo et al. (2024) integrate design research with a modified Delphi approach, providing a methodological example of structured expert input. Delphi reporting guidance further emphasises transparent panel selection, questionnaire design, feedback, rounds and consensus interpretation (Niederberger et al., 2024; Spranger et al., 2022). These contributions support iterative assessment while distinguishing expert endorsement from evidence of effectiveness after implementation.

For the present study, expert validation complements empirical development by examining the operational suitability of the integrated framework. Reassessment after feedback allows experts to reconsider revised components and implementation requirements. However, favourable ratings or increased concordance support expert-assessed suitability rather than demonstrated improvements in classroom utilisation or educational outcomes. Such outcomes require subsequent implementation and evaluation.

The reviewed literature supports the four enabling domains and provides approaches to framework development and validation. Within this literature, however, limited evidence combines comparable teacher and student measurement, simultaneous structural testing across school categories, differentiated utilisation pathways and iterative expert refinement within a single development process. The study addresses the first objective through measurement validation and multi-group structural equation modelling, and the second through two-round Delphi refinement. Its contribution lies in connecting empirical explanation with context-responsive operational specification while keeping claims proportionate to the evidence collected.

Accordingly, the study specifies technological readiness, organisational support, individual capacity and environmental enablers as correlated predictors of ICT utilisation. The same architecture is examined through separate teacher and student models across the four school categories, with positive associations expected between each domain and utilisation.

III. METHODOLOGY

3.1 Research Design

The study employed a predominantly quantitative model-development and validation design within a Type 2 Design and Development Research (DDR) orientation (Richey & Klein, 2007; Richey et al., 2004). A cross-sectional survey informed measurement validation and MG-SEM, producing teacher and student empirical frameworks that were integrated into Version 2c. As part of framework development, two Delphi rounds assessed clarity, relevance, feasibility, applicability and expected effectiveness, refining Version 2c into Version 3 and subsequently Version 4. Iteration occurred through framework development and expert feedback; the survey itself was conducted once.

3.2 Study Area

The survey component covered 56 ICT-enabled secondary schools across 20 councils in 12 regions and 7 education zones of Tanzania, including mainland Tanzania and Zanzibar. The schools were classified into four mutually exclusive categories: ADSI schools, privately owned schools, government schools that had participated in ICT pilot initiatives, and government schools that had not participated in the ADSI or selected ICT pilot programmes. These categories were included because they differed in ICT investment, infrastructure, institutional support, professional development, financing, and prior exposure to digital education initiatives.

3.3 Target Population and Sampling

Teachers and students constituted the principal survey populations because they represented the primary users and beneficiaries of ICT-supported teaching and learning. The sampling frame comprised an estimated 1,902,426 students and 93,563 teachers across the four school categories. A multistage sampling procedure was employed. The sampling process progressed through geographical zones, regions, councils, schools, and respondents, while proportional allocation was used to preserve representation across school categories and school-level populations. Teacher and student respondents were subsequently selected from participating schools using probability-based procedures.

A total of 1,585 student questionnaires and 1,334 teacher questionnaires were collected. Data screening retained all 1,334 teacher records and 1,584 student records, resulting in a final analytical sample of 2,918 respondents. The

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teacher and student datasets were analysed separately to preserve differences between instructional ICT use and students' direct participation in technology-supported learning.

For the subsequent expert-validation phase, a purposively selected panel comprised 28 education professionals: seven Zonal School Quality Assurance Officers, seven Regional Academic Officers, seven Statistics and Logistics Education Officers, and seven secondary-school heads. The panel provided representation from the seven education zones and combined expertise in education quality assurance, academic administration, education data and resource management, school leadership, and ICT-supported teaching and learning. The same expert panel participated in both Delphi rounds.

3.2 Instruments and Data Collection

Parallel-structured questionnaires were developed for teachers and students, based on the theoretical framework, the empirical literature, and the study objectives. The full instruments contained demographic items and five-point Likert-scale measures of ICT utilisation, perceived impact of ICT utilisation, barriers to optimum utilisation, and critical success factors or enabling conditions. The present article reports the ICT-utilisation, barrier, and critical-success-factor measures used in the framework-development and validation analyses; the separate perceived-impact items were outside the analytical scope of this article.

ICT utilisation was measured through 12 parallel teacher indicators (BT1–BT12) and 12 student indicators (BS1–BS12), covering the use of computers, internet services, projectors, e-mail, school websites, online storage, smart boards, multimedia technologies, and reproduction facilities in teaching and learning activities. Barrier measures comprised 25 teacher indicators (DT1–DT25) and 25 parallel student indicators (DS1–DS25), organised into organisational, technological, individual, and environmental domains. Critical success factors were measured through 27 teacher indicators (ET1–ET27) and 27 student indicators (ES1–ES27), similarly organised into organisational, technological, individual, and environmental domains. Only measures that directly contributed to the analytical objectives and the framework-development sequence reported in this article were carried forward into the descriptive, measurement-invariance, structural, and framework-development analyses presented below.

The questionnaires were reviewed for face and content validity by relevant experts in academic, ICT, educational technology, and school management. They were subsequently pilot-tested using approximately 10% of the intended teacher and student samples. The pilot involved 134 teachers and 158 students drawn from the four school categories. Feedback concerning clarity, wording, interpretation, completion time, and response procedures was used to refine the instruments before the main field survey. Pilot reliability exceeded the conventional .70 threshold for both instruments. Main survey data were collected electronically using KoboCollect after obtaining the required institutional and administrative permissions. Eight trained research assistants supported field administration. Mandatory response settings, range restrictions, logical constraints, and other electronic validation features were used to reduce missing values and data-entry errors.

3.3 Data Analysis and Framework Validation

Teacher and student data were analysed using IBM SPSS Statistics and AMOS version 28. The analytical sequence progressed from data screening and descriptive analysis to measurement-model validation, measurement-invariance testing, covariance-based Multi-Group Structural Equation Modelling (MG-SEM), empirical framework construction, and Delphi validation. Measurement assessment preceded substantive group and structural comparisons so that observed differences could be interpreted against a common measurement basis.

Data exported from KoboToolbox were examined for coding accuracy, duplicate submissions, response-range errors, unusual response patterns, completeness, and consistency. The datasets were subsequently assessed for normality, univariate and multivariate outliers, and multicollinearity. Univariate normality was examined using skewness and kurtosis, while standardised z-scores and Mahalanobis distance (D^2) were used to examine univariate and multivariate outliers. Variance Inflation Factor and tolerance statistics were used to assess multicollinearity among predictor constructs. Frequencies and percentages were used to summarise respondent characteristics. Means and standard deviations were used to describe ICT utilisation, barriers, and critical success factors across teachers, students, and school categories. Mean scores were interpreted using the following bands: 1.00–1.79 = very low; 1.80–2.59 = low; 2.60–3.39 = moderate; 3.40–4.19 = high; and 4.20–5.00 = very high.

Following data screening, measurement quality was assessed before estimating structural relationships. Internal consistency was assessed using Cronbach's alpha (α) and Composite Reliability (CR), with values of .70 or above considered acceptable. Convergent validity was examined through standardised factor loadings and Average Variance Extracted (AVE), with factor loadings of at least .50 and AVE values of at least .50 indicating adequate convergence. Discriminant validity was assessed using the Fornell–Larcker criterion and Heterotrait–Monotrait ratio (HTMT), with HTMT values below .85 considered acceptable (Hair et al., 2022; Kline, 2023). Separate Confirmatory Factor Analysis models were estimated for teachers and students using Maximum Likelihood estimation. Model fit was evaluated using

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the chi-square-to-degrees-of-freedom ratio (χ^2/df), Comparative Fit Index (CFI), Tucker–Lewis Index (TLI), Root Mean Square Error of Approximation (RMSEA), and Standardised Root Mean Square Residual (SRMR). The adopted criteria were $\chi^2/df < 3$, CFI and TLI $\geq .90$, and RMSEA and SRMR $\leq .08$ (Kline, 2023; Whittaker & Schumacker, 2022).

Multi-Group Confirmatory Factor Analysis (MG-CFA) was used to determine whether the measurement structures were comparable across respondent groups and school categories. Consistent with contemporary measurement invariance practice, nested models were assessed sequentially at the configural, metric, and scalar levels (Leitgöb et al., 2023; Luong & Flake, 2023). Configural invariance assessed whether the same general factor structure operated across groups; metric invariance assessed whether factor loadings were sufficiently equivalent to support comparison of structural relationships; and scalar invariance assessed whether construct levels could be meaningfully compared. Nested models were evaluated primarily using changes in CFI and RMSEA, with $\Delta CFI \leq .01$ and $\Delta RMSEA \leq .015$ interpreted as evidence that the additional equality constraints did not materially worsen model fit (Kline, 2023; Luong & Flake, 2023).

Measurement invariance was treated as a prerequisite for multi-group comparison rather than as evidence that teachers, students, or school categories had identical construct levels. Indicator factor loadings were interpreted as evidence of how well observed indicators represented their latent constructs; they were not interpreted as measures of school performance, "best practices," or direct effects on ICT utilisation. Following establishment of acceptable and sufficiently invariant measurement models, covariance-based MG-SEM was used to estimate the structural relationships between organisational support, technological readiness, individual capacity, environmental enablers, and ICT utilisation. The structural models were estimated separately for teachers and students and compared across ADSI, private, piloted, and government schools.

Direct paths were specified from each of the four predictor constructs to ICT utilisation. Standardised path coefficients (β) were used to determine the direction and relative magnitude of the relationships. In contrast, standard errors, critical ratios, and p-values were used to assess the precision of the estimates and the statistical significance. Coefficients were interpreted broadly as small when approximately .10 to below .30, moderate from approximately .30 to below .50, and strong at .50 or above. Statistical significance was evaluated at $p < .05$. The coefficient of determination (R^2) was used to assess the proportion of variance in ICT utilisation jointly explained by the four predictor domains. R^2 was treated as a model-level statistic rather than as an attribute of an individual predictor. Structural-model fit was assessed using the chi-square statistic (χ^2) with its degrees of freedom, the Comparative Fit Index (CFI), and the Root Mean Square Error of Approximation (RMSEA). CFI values of at least .90 and RMSEA values of .08 or below were interpreted as indicating acceptable fit (Hair et al., 2022; Kline, 2023).

Cross-group structural comparisons involved unconstrained models, in which structural paths were freely estimated across school categories, and constrained models, in which corresponding paths were set equal. Model comparison was evaluated using the chi-square difference statistic ($\Delta\chi^2$), the change in degrees of freedom (Δdf), and the change in the Comparative Fit Index (ΔCFI). Because chi-square difference tests are sensitive to large sample sizes, ΔCFI was used as an additional practical criterion, with values not exceeding .01 interpreted as indicating that the equality constraints did not materially worsen model fit. This approach allowed a common four-domain architecture to be retained while permitting category-specific variation in the magnitude of individual structural relationships. The measurement and structural results then informed framework construction, which combined measurement quality, structural coefficients, explanatory power, respondent differences, school-category patterns and conceptual relevance. Operational indicators were selected for practical relevance, coverage and measurability rather than factor loadings alone. Teacher and student evidence produced Versions 2a and 2b, whose common domains and distinct utilisation pathways were integrated into Version 2c for expert validation.

The resulting Integrated Empirical Framework Version 2c underwent a two-round Delphi validation with the same 28 experts. The procedure used repeated rounds, controlled aggregate feedback, and reassessment by the same expert panel; this structure is consistent with recent Delphi methodological and reporting guidance (Niederberger et al., 2024; Spranger et al., 2022). Experts evaluated the framework using five-point Likert-scale ratings for clarity, relevance, feasibility, applicability, and expected effectiveness, and provided written recommendations for improvement. For each round, mean ratings and standard deviations were used to summarise expert endorsement and the dispersion of responses. Kendall's coefficient of concordance (W) was used as a round-level measure of panel concordance (Kendall, 1970). Kendall's W was not interpreted as an item-level agreement statistic. Written comments were thematically coded to identify recommendations concerning terminology, framework components, indicators, stakeholder responsibilities, implementation requirements, and monitoring arrangements.

Round One served as a diagnostic evaluation of Version 2c. Quantitative ratings and qualitative feedback were used to revise the framework into Version 3 without re-estimating the underlying MG-SEM structural relationships. The same panel then evaluated Version 3 in Round Two. Evidence of stronger consensus was assessed using higher mean ratings, lower rating dispersion, greater agreement, and stronger Kendall's W. Further refinements yielded the Final Expert-Validated Integrated Framework Version 4. The Delphi process established pre-implementation expert

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validation of the framework's clarity, relevance, feasibility, applicability, and expected effectiveness. It did not establish realised effects on classroom ICT utilisation, student learning, or educational outcomes; these require future pilot implementation and longitudinal or repeated-measures evaluation.

3.4 Ethical Considerations

The study complied with the requirements of the University of Dodoma research ethics. Permissions were obtained from the relevant regional, council and school authorities. Participation was voluntary; informed consent and the required student assent or guardian permission were obtained; and confidentiality and anonymity were maintained throughout data collection, analysis, and reporting.

IV. FINDINGS & DISCUSSION

4.1 Data Quality and Measurement Validation

The final analytical dataset comprised 1,334 teachers and 1,584 students from 56 secondary schools across 12 regions and seven education zones. All 1,334 teacher questionnaires collected were retained for analysis. Of the 1,585 student questionnaires collected, one record was excluded during data screening, resulting in 1,584 analytical student records and a total analytical sample of 2,918 respondents.

Preliminary screening indicated that the datasets were suitable for subsequent multivariate analysis. Standardised z-scores ranged from −2.41 to 2.76 and remained within the adopted ±3.29 criterion. Skewness values ranged from −0.71 to 0.56 and kurtosis from −0.61 to 0.46, indicating acceptable univariate distributional properties. The maximum Mahalanobis distance ($D^2 = 38.916$) remained below the applicable chi-square critical value of 51.179, and no cases were identified as problematic multivariate outliers. Multicollinearity was also not problematic: tolerance values ranged from .46 to .61 and variance inflation factors from 1.64 to 2.17, remaining within the adopted criteria. The datasets were therefore retained for measurement and structural modelling.

Reliability, convergent validity, and discriminant validity were established before group and structural comparisons were undertaken. Across all teacher and student constructs included in the study, Cronbach's alpha ranged from .86 to .93, Composite Reliability from .88 to .95, Average Variance Extracted from .57 to .68, and HTMT from .66 to .76. All values satisfied the adopted criteria of α and CR ≥ .70, AVE ≥ .50, and HTMT < .85. The Fornell–Larcker criterion was also satisfied, indicating empirical distinction among the latent constructs. For the five constructs forming the structural framework—ICT utilisation, organisational support, technological readiness, individual capacity and environmental enablers—the measurement properties were consistently satisfactory for both respondent groups, as shown in Table 1, Panel A.

Table 1

Measurement Quality and Confirmatory Factor Analysis Results

Panel A. Reliability and construct validity

Group	Construct	α	CR	AVE	HTMT
Teachers	ICT utilisation	.91	.93	.63	.74
	Organisational support	.92	.94	.66	.68
	Technological readiness	.91	.93	.65	.69
	Individual capacity	.93	.95	.68	.66
	Environmental enablers	.90	.92	.64	.67
Students	ICT utilisation	.90	.92	.61	.76
	Organisational support	.91	.93	.64	.70
	Technological readiness	.90	.92	.63	.71
	Individual capacity	.92	.94	.66	.69
	Environmental enablers	.89	.91	.62	.70

Panel B. Confirmatory factor analysis model fit

Respondent group	χ^2/df	CFI	TLI	RMSEA	SRMR	Decision
Teachers	1.94–1.97	.94–.96	.92–.94	.050–.055	.044–.048	Acceptable fit
Students	2.18–2.21	.92–.94	.90–.92	.055–.061	.050–.054	Acceptable fit

Note. *α = Cronbach's alpha; CR = Composite Reliability; AVE = Average Variance Extracted; HTMT = Heterotrait–Monotrait ratio; CFI = Comparative Fit Index; TLI = Tucker–Lewis Index; RMSEA = Root Mean Square Error of Approximation; SRMR = Standardised Root Mean Square Residual. Adopted criteria were α and CR ≥ .70, AVE ≥ .50, HTMT < .85, χ^2/df < 3, CFI and TLI ≥ .90, and RMSEA and SRMR ≤ .08. The Fornell–Larcker criterion was satisfied for all constructs.*

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The CFA results are summarised in Table 1, Panel B. The acceptable CFA solutions complemented the evidence of reliability, convergent validity, and discriminant validity reported in Panel A and supported progression to measurement-invariance testing. Following satisfactory reliability and CFA results, measurement invariance was assessed for ICT utilisation, barriers and critical success factors. The configural models demonstrated acceptable fit across all three measurement areas. Changes introduced by the metric and scalar constraints were consistently below the adopted thresholds of $\Delta CFI \leq .01$ and $\Delta RMSEA \leq .015$. Metric and scalar invariance were therefore supported for teachers and students, providing an adequate statistical basis for subsequent group-mean and structural comparisons. Table 2 summarises the configural, metric and scalar measurement-invariance results for the teacher and student models.

Table 2

Summary of Multi-Group Measurement Invariance

Measurement model	Group	Configural fit: χ^2/df	CFI/TLI	RMSEA/SRMR	Metric ΔCFI/ΔRMSEA	Scalar ΔCFI/ΔRMSEA
ICT utilisation	Teachers	1.95	.940/.930	.051/.045	.005/.002	.006/.003
ICT utilisation	Students	2.18	.920/.910	.056/.051	.005/.003	.008/.004
Barriers	Teachers	1.96	.940/.930	.052/.046	.006/.002	.007/.003
Barriers	Students	2.20	.920/.910	.055/.050	.006/.003	.008/.004
Critical success factors	Teachers	1.96	.950/.930	.052/.046	.006/.002	.008/.003
Critical success factors	Students	2.20	.930/.910	.059/.052	.006/.003	.008/.004

Note. CFI = Comparative Fit Index; TLI = Tucker–Lewis Index; RMSEA = Root Mean Square Error of Approximation; SRMR = Standardised Root Mean Square Residual. Measurement invariance was considered supported where $\Delta CFI \leq .01$ and $\Delta RMSEA \leq .015$. Scalar invariance was supported for all teacher and student measurement models.

Configural, metric, and scalar invariance supported comparisons of measurement structures, corresponding structural relationships, and construct means across the tested groups. Invariance does not imply equal utilisation, barriers, or enabling conditions; it supports the interpretation of group differences on a comparable measurement basis.

4.2 Diagnostic Findings for Framework Development

Table 3 summarises ICT utilisation, barriers and enabling conditions used to identify framework requirements. These descriptive findings informed operational priorities; structural relationships were subsequently examined using MG-SEM.

Table 3

Diagnostic Profile of ICT Utilisation, Barriers and Enabling Conditions

Panel A. ICT utilisation by school category

School category	Teachers M (SD)	Level	Students M (SD)	Level
ADSI	3.66 (0.70)	High	3.30 (0.79)	Moderate
Private	3.21 (0.80)	Moderate	3.14 (0.84)	Moderate
Piloted	2.76 (0.91)	Moderate	2.45 (0.97)	Low
Government	2.41 (0.99)	Low	2.34 (1.02)	Low

Panel B. Construct-level barriers

Barrier domain	Teachers M (SD)	Teacher level	Students M (SD)	Student level
Organisational	3.21 (0.84)	Moderate	3.46 (0.89)	High
Technological	3.18 (0.80)	Moderate	3.52 (0.92)	High
Individual	3.09 (0.77)	Moderate	3.40 (0.88)	High
Environmental	3.14 (0.81)	Moderate	3.47 (0.90)	High

Panel C. Critical success factors/enabling conditions

Enabling domain	Teachers M (SD)	Students M (SD)	Level
Organisational support	4.02 (0.63)	3.85 (0.74)	High
Technological readiness	3.97 (0.65)	3.79 (0.76)	High
Individual capacity	4.05 (0.61)	3.88 (0.72)	High
Environmental enablers	4.08 (0.60)	3.91 (0.70)	High

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Note. M = mean; SD = standard deviation. Mean-score interpretation: 1.00–1.79 = very low; 1.80–2.59 = low; 2.60–3.39 = moderate; 3.40–4.19 = high; 4.20–5.00 = very high.

Utilisation followed the same category ordering for both groups: ADSI, private, piloted and government schools. Teachers reported higher utilisation across all categories, with the largest teacher–student gaps in ADSI and piloted schools. The smaller government-school gap reflected low utilisation in both groups. Use remained concentrated in access, presentation, communication and resource management, with less interactive and multimedia activity (Supplementary Table S1). Higher utilisation frequency alone did not establish optimum ICT utilisation or pedagogically deep use.

Alongside these utilisation differences, teachers reported moderate barriers across all four domains, whereas students reported high barriers. Students' scores exceeded teachers' scores throughout, with the largest difference in technological barriers. The findings identify combined technological, institutional, capability, and environmental constraints, supporting a framework that extends beyond device provision.

Despite these constraints, both groups rated all four enabling domains highly, with teachers reporting higher means across all domains. Environmental enablers ranked highest, followed by individual capacity, organisational support and technological readiness. These ratings identified all four domains as relevant enabling conditions while distinguishing institutional provision from teachers' and students' practical opportunities to use ICT.

Together, these findings informed four framework requirements: distinct teacher and student pathways, greater curriculum-linked learner participation, coordinated attention to the four enabling domains, and implementation priorities adapted to schools' starting conditions. Detailed school-context priorities are presented in Supplementary Table S4.

4.3 Structural Relationships and Explanatory Power

Following measurement-invariance assessment, separate teacher and student MG-SEM models were estimated to examine relationships between the four enabling domains and ICT utilisation across school categories. Table 4 presents model fit and category-specific results, while Table 5 summarises the overall respondent models. Teacher and student MG-SEM models showed acceptable fit, with CFI values of .946 and .944 and RMSEA values of .040 and .041, respectively. Equality constraints produced ΔCFI values of .004 and .005. Table 4, Panel A, reports the complete fit and comparison statistics; Panel B presents category-specific paths and explanatory power.

Table 4

MG-SEM Model Fit, Structural Relationships and Explanatory Power by School Category

Panel A. Structural model fit and cross-group comparison

Respondent model	χ^2	df	CFI	RMSEA	$\Delta\chi^2$ (Δdf)	ΔCFI
Teachers	1382.46	810	.946	.040	41.87 (20)	.004
Students	1370.81	810	.944	.041	40.95 (20)	.005

Panel B. Structural paths and explanatory power by school category

School category	Group	Technological β	Organisational β	Individual β	Environmental β	R^2
ADSI	Teachers	.46	.40	.42	.29	.72
ADSI	Students	.43	.43	.39	.31	.75
Private	Teachers	.40	.39	.36	.28	.66
Private	Students	.42	.36	.40	.24	.63
Piloted	Teachers	.35	.32	.34	.21	.51
Piloted	Students	.37	.35	.36	.24	.56
Government	Teachers	.31	.29	.26	.19	.43
Government	Students	.28	.27	.29	.18	.40

Note. β = standardised structural coefficient; R^2 = coefficient of determination. All category-specific paths were statistically significant at $p < .001$ except the environmental-enabler paths for piloted teachers ($\beta = .21$, $p = .002$), government-school teachers ($\beta = .19$, $p = .005$), and government-school students ($\beta = .18$, $p = .010$). Cross-group comparison statistics refer to constrained versus unconstrained structural models.

All four domains were positively associated with utilisation, although coefficients varied across categories and respondent groups. Category-level R^2 ranged from .40 to .75, with the highest values in ADSI schools and the lowest in government schools. Technological readiness generally showed the strongest or among the strongest relationships;

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environmental enablers showed smaller but significant relationships. These patterns supported a common architecture with differentiated operational priorities.

Across the overall respondent models, the four domains explained 60.82% of teacher-utilisation variance and 52.49% of student-utilisation variance. Technological readiness had the largest coefficient in both models, while organisational support was relatively more prominent for teachers and individual capacity for students (Table 5).

Table 5

Overall, Teacher and Student Structural Models and Framework Integration

Framework component	Teachers	Students	Framework integration
Technological readiness	β = .46	β = .42	Retain as common operational foundation
Organisational support	β = .41	β = .38	Retain in both pathways; relatively stronger institutional emphasis for teachers
Individual capacity	β = .38	β = .40	Retain in both pathways; relatively stronger learner-capability emphasis for students
Environmental enablers	β = .29	β = .21	Retain for continuity, equity, external support and sustainability
Model explanatory power	R^2 = .6082	R^2 = .5249	Preserve separate teacher and student explanatory-power estimates
Utilisation pathway	Professional and instructional ICT use	Direct learner participation	Maintain distinct outcome pathways within the common architecture

Note. β = standardised structural coefficient; R^2 = coefficient of determination. The four domains jointly explained 60.82% of the variance in teacher ICT utilisation and 52.49% of the variance in student ICT utilisation.

4.4 Framework Development and Expert Validation

These structural results informed framework development alongside measurement quality, conceptual coverage, practical relevance and measurability. The process first integrated the teacher and student evidence and then used expert feedback to refine the framework's operational specification. Empirical development of Versions 1–2c.

The literature-derived Version 1 was assessed through measurement validation and MG-SEM, producing teacher Version 2a and student Version 2b. Their shared domains and distinct pathways were integrated into Version 2c before Delphi validation. Figures 1 and 2 show the development sequence and conceptual starting framework.

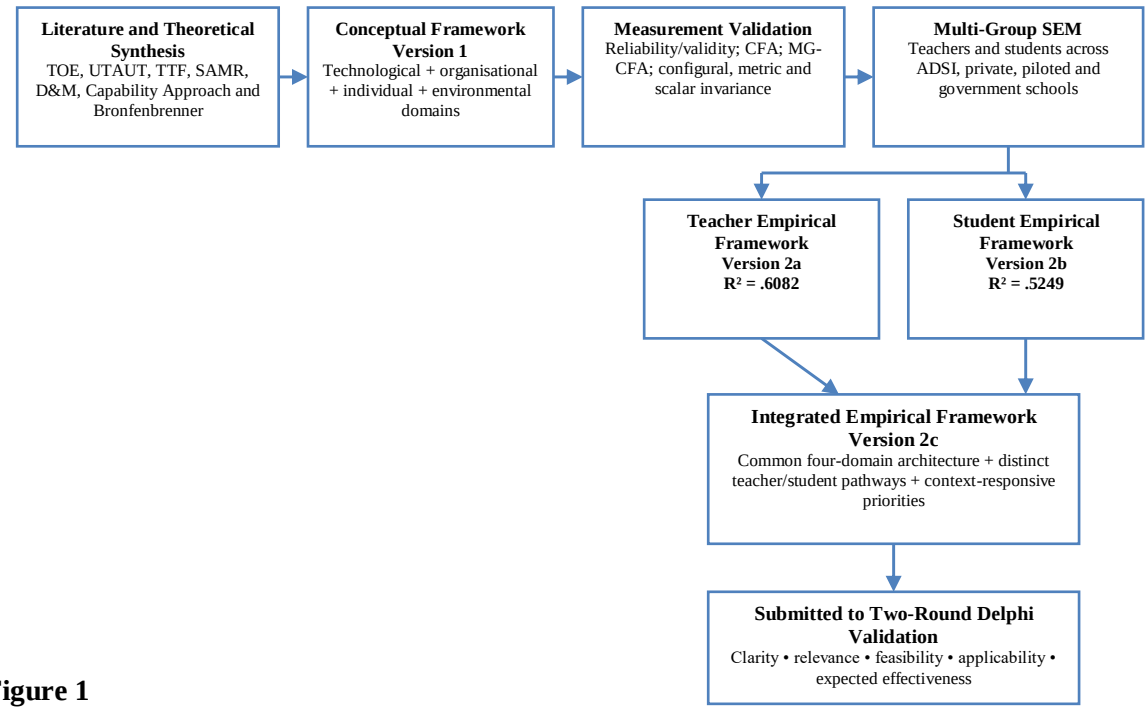


Figure 1

Empirical Framework Development Sequence

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Version 1 therefore provided the conceptual starting point rather than the final framework. The empirical stages determined whether its constructs were measurable, whether they operated comparably across groups, how strongly they were associated with ICT utilisation, and how their practical expression differed between teachers, students, and school contexts. Version 2c therefore constituted the empirically developed framework submitted for expert assessment rather than the final validated framework. Figure 2 shows the literature-derived four-domain conceptual framework that served as the starting point.

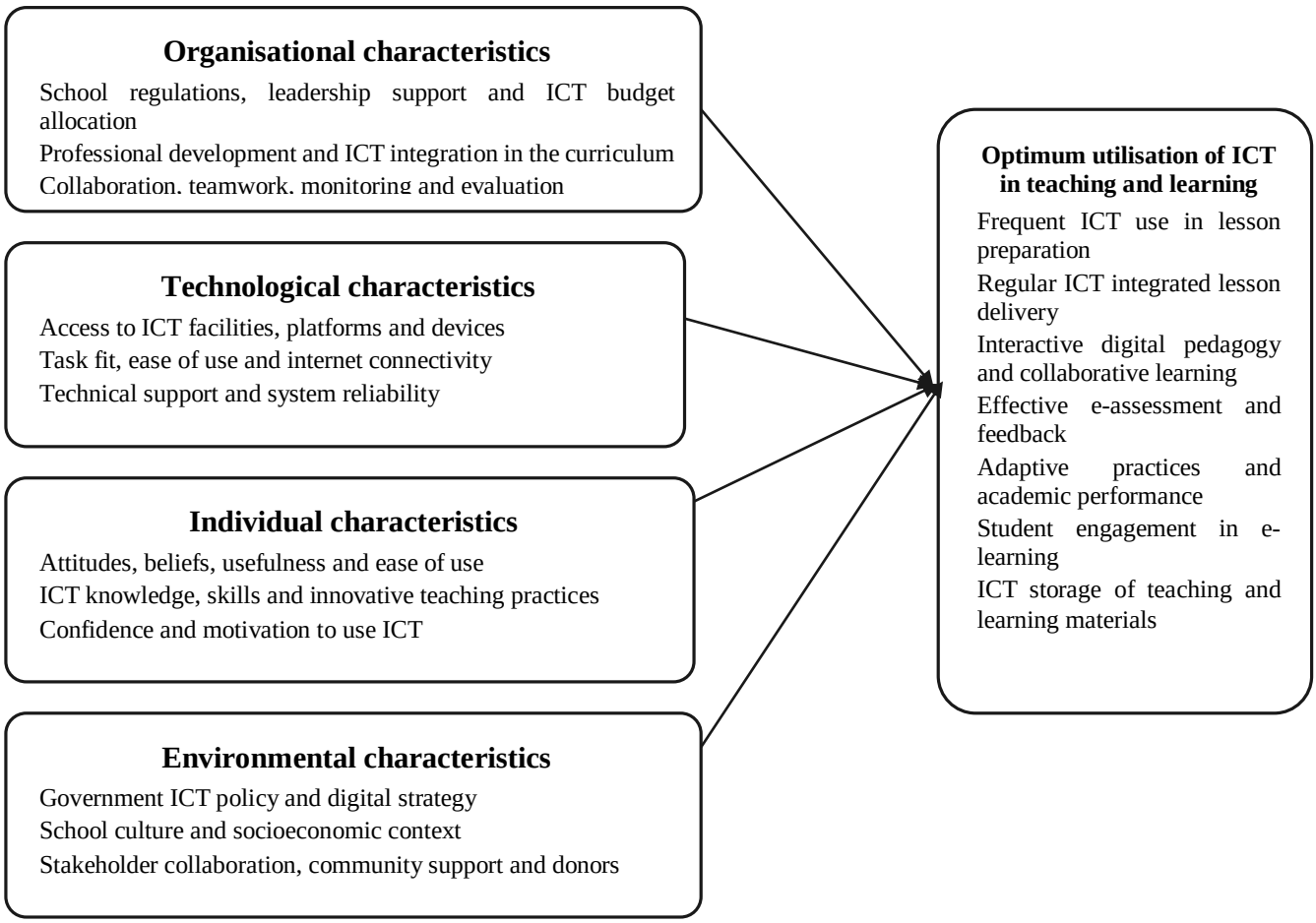


Figure 2
Literature-Derived Conceptual Framework Version 1

Version 2a represents teachers' professional and instructional ICT utilisation through the four validated domains (Figure 3). Coefficients and explanatory power are reported in Table 5; operational conditions are detailed in Supplementary Table S2.

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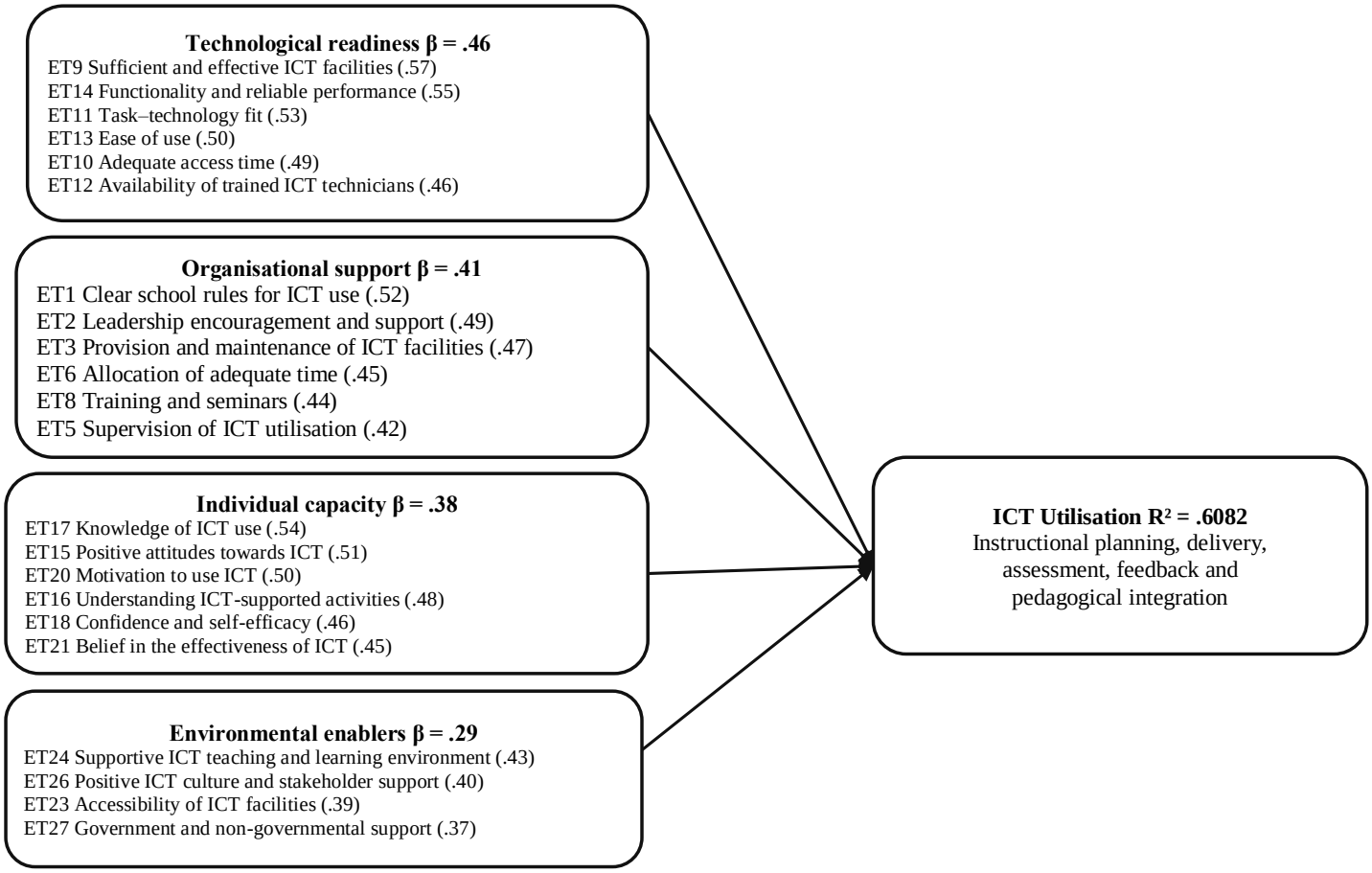


Figure 3

Teacher Empirical Framework Version 2a

Version 2b represents students' direct, curriculum-linked ICT participation through the same four domains (Figure 4). Table 5 reports its structural results, and Supplementary Table S3 details the operational conditions.

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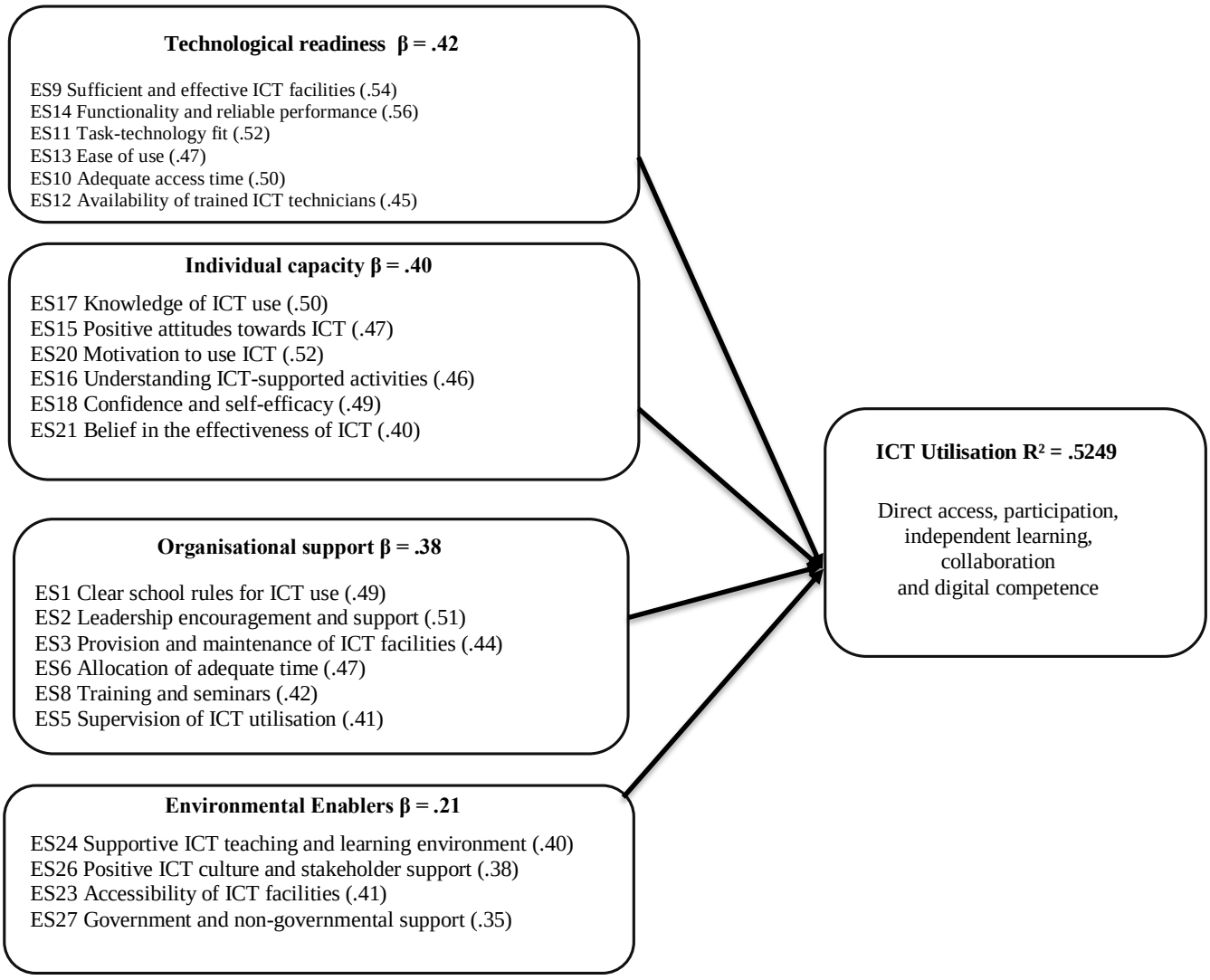


Figure 4
Student Empirical Framework Version 2b

Version 2c integrated the shared four-domain architecture while preserving separate teacher and student pathways and their structural estimates (Figure 5). It did not constitute a newly estimated combined structural model.

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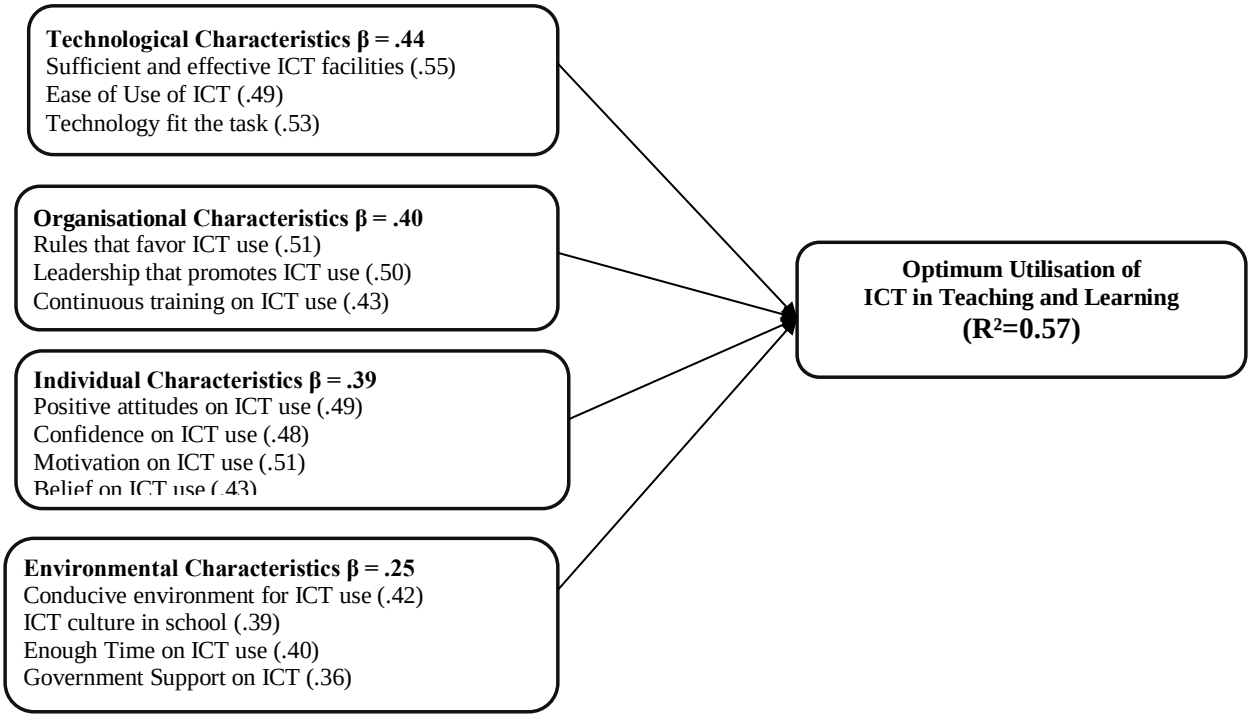


Figure 5
Integrated Teacher and Student Empirical Framework Version 2c

Version 2c incorporated differentiated school-context priorities based on observed utilisation and structural patterns (Supplementary Table S4). These priorities were diagnostic starting points rather than fixed stages or assumptions that schools within a category were identical. Version 2c was then submitted for Delphi validation.

Delphi refinement and validation: Version 2c was subsequently evaluated through two Delphi rounds that addressed clarity, relevance, feasibility, applicability, and expected effectiveness. Table 6 summarises the validation evidence and progression to Version 4.

Round One ratings ranged from 3.85 to 4.20, with standard deviations of 0.70–0.85. Concordance was statistically significant but modest: $W = .094$, $\chi^2(15) = 39.664$, $p < .001$. Expert feedback identified requirements concerning infrastructure reliability, technical support, competence, learner access, leadership, time allocation and ICT culture. Supplementary Table S5 links feedback to refinements.

Round One feedback produced Version 3, strengthening operational indicators, access arrangements, maintenance, continuous professional development, stakeholder responsibilities and monitoring (Figure 6). The four-domain architecture and previously estimated structural coefficients were retained.

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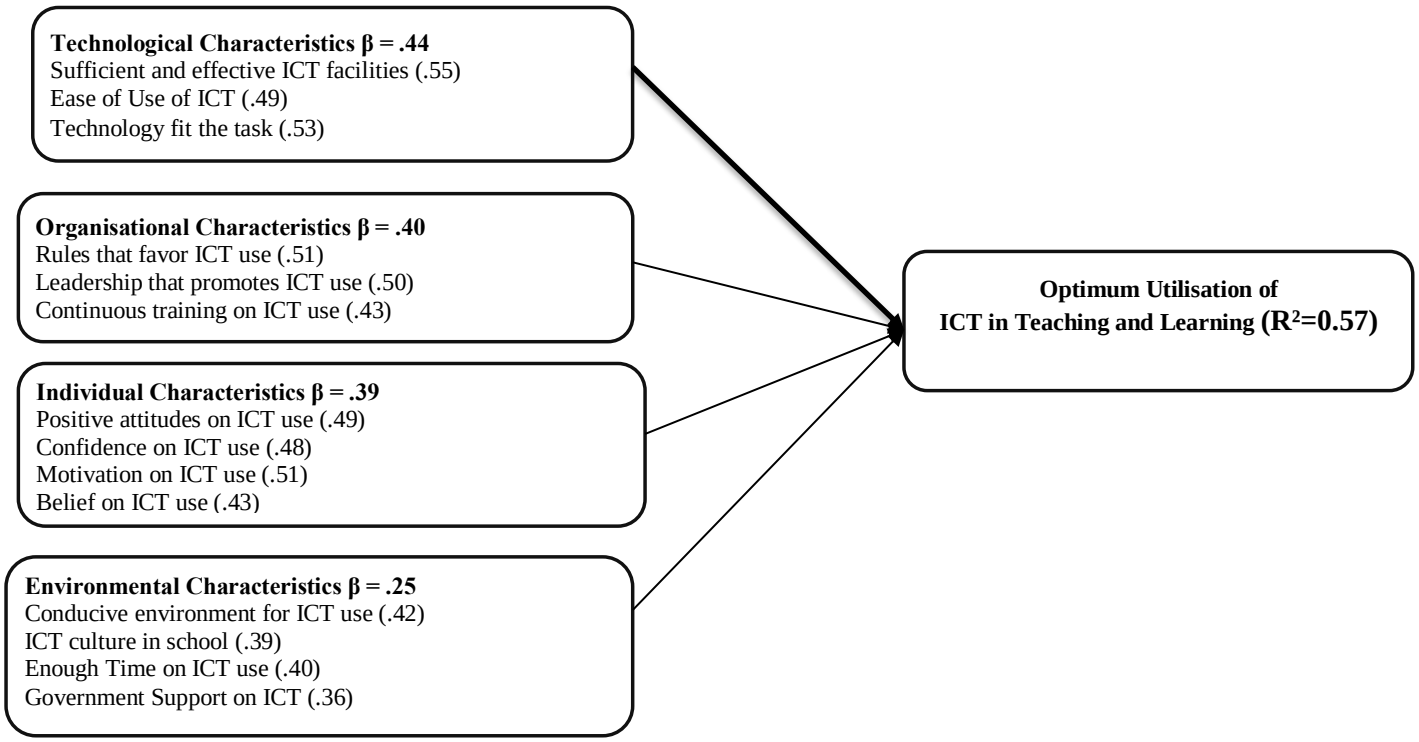


Figure 6
Expert-Refined Integrated Framework Version 3

The same 28 experts reassessed Version 3 after controlled feedback. Mean ratings increased to 4.18–4.40, standard deviations declined to 0.44–0.50, and concordance increased to W = .125, χ^2 (15) = 52.500, p < .001. Agreement remained modest despite greater convergence. Ratings and written feedback supported the finalisation of Version 4 (Table 6).

Table 6
Two-Round Delphi Validation and Framework Refinement

Validation evidence	Round One	Round Two	Interpretation/change
Framework evaluated	Version 2c	Version 3	Successive framework refinement
Expert panel	28	28	Same panel retained
Mean ratings	3.85–4.20	4.18–4.40	Increased endorsement
Standard deviations	0.70–0.85	0.44–0.50	Reduced rating dispersion
Kendall's W	.094	.125	Concordance increased
χ^2 (df = 15)	39.664, p < .001	52.500, p < .001	Agreement statistically significant in both rounds
Validation role	Diagnostic and refinement	Confirmatory validation	Progressive refinement
Resulting framework	Version 3	Version 4	Final expert-validated framework after Round Two

Note. W = Kendall's coefficient of concordance. Mean and standard-deviation ranges summarise the evaluated framework components. Kendall's W is reported at the round level; item-level W values are not interpreted. Delphi validation assessed clarity, relevance, feasibility, applicability, and expected effectiveness and did not re-estimate the MG-SEM structural coefficients.

Final framework and validation boundaries: Version 4 retains the four-domain architecture and separate teacher and student pathways, incorporating expert-refined implementation conditions, stakeholder responsibilities and monitoring requirements (Figure 7; Supplementary Table S6). School-context priorities remain adaptable to diagnosed needs.

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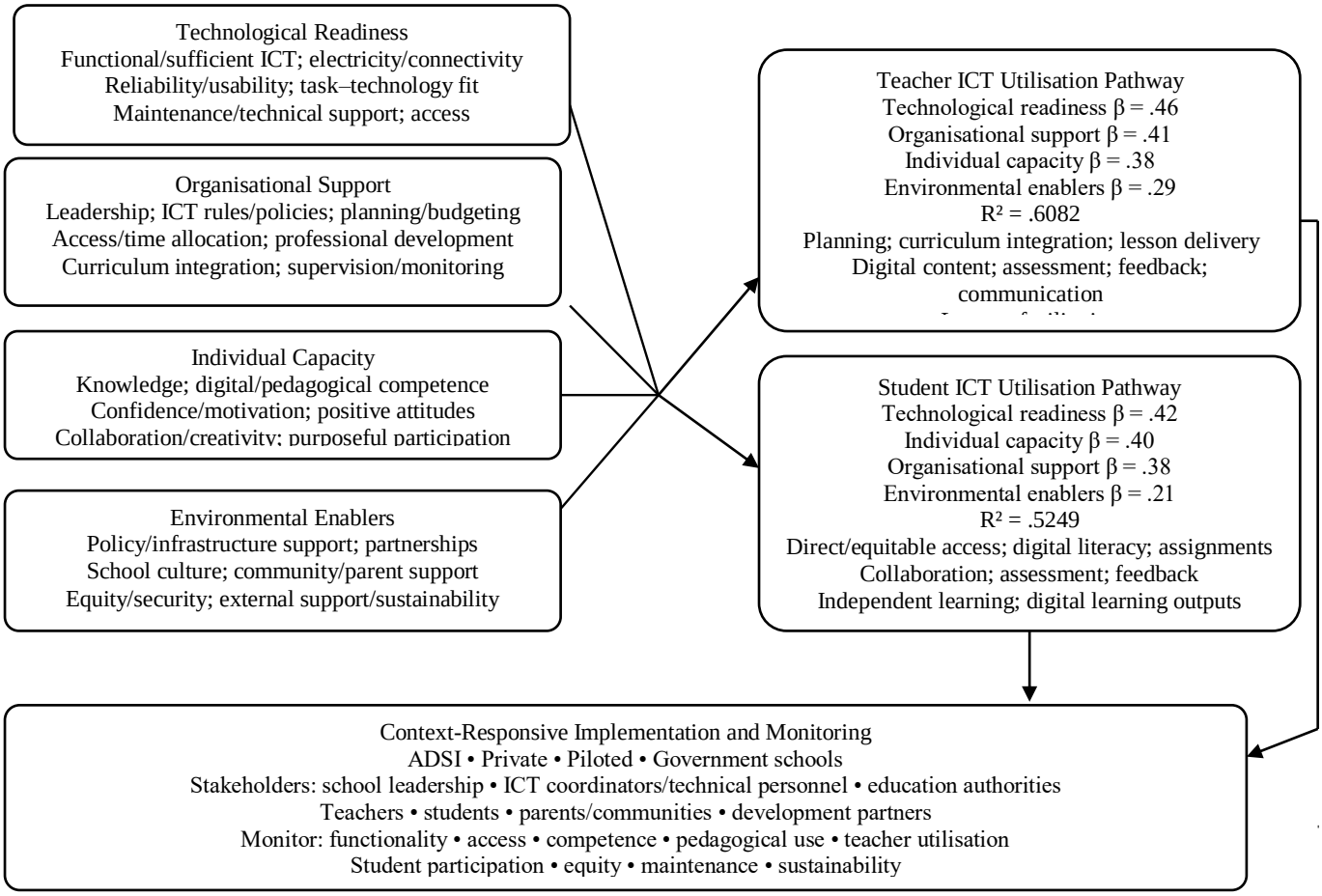


Figure 7
Final Expert-Validated Integrated Framework Version 4

Note. Structural coefficients and R^2 values were established through the MG-SEM analysis before Delphi validation. The Delphi process refined the framework's clarity, indicator coverage, implementation requirements and operational relevance but did not re-estimate the structural coefficients.

Delphi validation supports expert-assessed conceptual and operational suitability, not demonstrated effectiveness. It neither re-estimated MG-SEM coefficients nor tested changes in classroom practice, utilisation or educational outcomes.

4.5 Discussion

The findings support a multidimensional explanation of ICT utilisation that involves technological readiness, organisational support, individual capacity, and environmental enablers. Technological readiness generally produced the largest structural coefficients, but all four domains were retained. This pattern aligns with reviews that identify infrastructure, professional capability, institutional support, maintenance, and curriculum alignment as interconnected conditions for meaningful ICT integration (Msafiri et al., 2023; Msambwa & Daniel, 2024; Msambwa et al., 2024). Tanzanian evidence similarly identifies competence, connectivity, financing and technical support as continuing constraints (Bendera, 2024; Kalinga, 2024; Mubofu & Adoph, 2026; Nzilano, 2025).

The teacher and student models explained 60.82% and 52.49% of utilisation variance, respectively. Although both models retained the same four-domain architecture, their estimated coefficient patterns differed descriptively, supporting separate consideration of instructional use and learner participation. This distinction addresses concerns that technology-integration measures commonly privilege teachers' perspectives (Consoli et al., 2023). It also complements evidence concerning leadership and teacher integration (Schmitz et al., 2023), unequal facilitating conditions among Tanzanian learners (Lubua, 2024), and the importance of the purpose and context of student technology use (Organisation for Economic Co-operation and Development [OECD], 2024). Teacher use should therefore be monitored alongside students' direct access and participation.

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School-category differences support differentiated implementation within a common framework. ADSI schools should emphasise pedagogical depth and learner participation; private schools should strengthen consistent ICT integration across the curriculum and equitable learner access; piloted schools should institutionalise project gains; and government schools should prioritise foundational readiness. These are evidence-informed starting points, with individual-school diagnosis determining actual priorities. This interpretation is consistent with context-relevant Tanzanian integration strategies and broader policy evidence that emphasises coordinated infrastructure, capacity development, governance, and monitoring (Boeskens & Meyer, 2025; MoEST, 2025; Ngodu et al., 2024).

The Delphi process refined the framework's operational specification without re-estimating its structural coefficients. Kendall's W increased from .094 to .125, indicating greater concordance, although both values remained modest. The validation therefore supports expert-assessed suitability and expected effectiveness rather than demonstrated classroom impact. This distinction follows guidance that validation claims should match the evidence collected and that Delphi procedures and consensus should be reported transparently (Child & Shaw, 2023; Niederberger et al., 2024; Spranger et al., 2022). The combination of empirical development and expert refinement is also consistent with research on educational technology frameworks (Hugo et al., 2024).

The study's theoretical contribution lies in integrating complementary perspectives across four empirically examined domains. Its methodological contribution is the sequence that connects measurement validation, structural modelling, separate teacher and student pathways, framework integration, and expert refinement. It extends earlier Tanzanian work on ICT-supported assessment and monitoring to wider teaching-and-learning utilisation (Mfoi et al., 2024a, 2024b).

4.6 Limitations

The cross-sectional design limits causal interpretation, while reliance on self-reported data introduces potential recall and social desirability biases. Although respondents were clustered within schools, the analysis did not separately model school-level effects, leaving some shared institutional influences unaccounted for. The inclusion of ICT-enabled schools also limits generalisability to settings with minimal or non-functional infrastructure.

Furthermore, Delphi assessment supported the framework's conceptual and operational suitability through expert judgement but did not demonstrate its effectiveness in practice. Its practical benefits and long-term sustainability therefore require evaluation through school-based implementation.

V. CONCLUSION & RECOMMENDATIONS

5.1 Conclusion

This study developed and validated a context-responsive framework for optimum ICT utilisation in teaching and learning in Tanzanian secondary schools. Technological readiness, organisational support, individual capacity and environmental enablers were positively associated with utilisation. Differences between teacher and student pathways and across school categories support differentiated implementation within a common four-domain architecture. Framework development progressed from a literature-derived conceptual model through measurement validation, multi-group structural equation modelling, teacher and student empirical frameworks, integration and two-round Delphi refinement. The resulting Framework Version 4 combines empirical structural relationships with expert-refined implementation conditions, stakeholder responsibilities and monitoring requirements. Its validation supports conceptual and operational suitability; effectiveness after implementation remains to be established.

5.2 Recommendations

Education authorities should support controlled pilot implementation of Framework Version 4 across ADSI, private, piloted and government schools before wider adoption. Evaluation should establish baseline conditions and assess implementation fidelity, costs, utilisation, equity and sustainability. School leaders should use the four domains to diagnose readiness and prepare annual ICT implementation plans that cover infrastructure functionality, recurrent financing, maintenance, technical support, professional development, and scheduled learner access. Priorities should follow each school's diagnosed needs rather than its school category alone. Teachers and ICT coordinators should strengthen the curriculum-linked use of ICT for instruction, assessment, feedback, and collaboration while ensuring opportunities for students' direct participation. Monitoring should distinguish available resources, teachers' instructional utilisation and students' hands-on engagement. Researchers should undertake longitudinal or quasi-experimental evaluation, multilevel analysis, and external validation to determine whether implementation of the framework improves sustained ICT utilisation and educational outcomes across different school contexts.

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Declaration of Interest

The authors declare that they do not have any known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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REFERENCES

Bendera, M. (2024). The adoption and usage of ICT in teaching and learning in Tanzanian secondary schools: A systematic review. *Asian Journal of Education and Social Studies, 50*(10), 315–328. https://doi.org/10.9734/ajess/2024/v50i101622

Boeskens, L., & Meyer, K. (2025). *Policies for the digital transformation of school education: Evidence from the Policy Survey on School Education in the Digital Age* (OECD Education Working Papers No. 328). OECD Publishing. https://doi.org/10.1787/464dab4d-en

Bronfenbrenner, U. (1977). Toward an experimental ecology of human development. *American Psychologist, 32*(7), 513–531. https://doi.org/10.1037/0003-066X.32.7.513

Child, S., & Shaw, S. (2023). A conceptual approach to validating competence frameworks. *Research Matters, 35*, 27–40.

Consoli, T., Désiron, J., & Cattaneo, A. A. P. (2023). What is "technology integration" and how is it measured in K–12 education? A systematic review of survey instruments from 2010 to 2021. *Computers & Education, 197*, 104742. https://doi.org/10.1016/j.compedu.2023.104742

Goodhue, D. L., & Thompson, R. L. (1995). Task–technology fit and individual performance. *MIS Quarterly, 19*(2), 213–236. https://doi.org/10.2307/249689

Hair, J. F., Black, W. C., Babin, B. J., & Anderson, R. E. (2022). *Multivariate data analysis* (9th ed.). Cengage Learning.

Hugo, J., Callaghan, R., & Cronjé, J. C. (2024). A strategy development framework for educational technology: An integrated design science research and modified Delphi approach. *Electronic Journal of e-Learning, 22*(5), 60–75. https://doi.org/10.34190/ejel.22.5.3568

Kalinga, T. (2024). Teachers' technological literacy for ICT integration to implement competence-based curriculum in public secondary schools in Tanzania. *Educational Technology Quarterly, 2024*(2), 135–151. https://doi.org/10.55056/etq.708

Kendall, M. G. (1970). *Rank correlation methods* (4th ed.). Griffin.

Kline, R. B. (2023). *Principles and practice of structural equation modeling* (5th ed.). Guilford Press.

Leitgöb, H., Seddig, D., Asparouhov, T., Behr, D., Davidov, E., De Roover, K., Jak, S., Meitinger, K., Menold, N., Muthén, B., Rudnev, M., Schmidt, P., & van de Schoot, R. (2023). Measurement invariance in the social sciences: Historical development, methodological challenges, state of the art, and future perspectives. *Social Science Research, 110*, 102805. https://doi.org/10.1016/j.ssresearch.2022.102805

Lubua, E. W. (2024). Examining digital divide in secondary and primary education online content users based in Tanzania. *University of Dar es Salaam Library Journal, 18*(2), 54–64. https://doi.org/10.4314/udslj.v18i2.5

Luong, R., & Flake, J. K. (2023). Measurement invariance testing using confirmatory factor analysis and alignment optimization: A tutorial for transparent analysis planning and reporting. *Psychological Methods, 28*(4), 905–924. https://doi.org/10.1037/met0000441

Mchalo, H., Koda, G., & Mandila, T. (2021). Teachers' use of computers in teaching and learning in public secondary schools in Arusha City Council, Tanzania. *International Journal of Innovative Research & Development, 10*(11), 37–46. https://doi.org/10.24940/ijird/2021/v10/i11/nov21014

Mfoi, D. M., Mwangakala, H. A., & Manyilizu, M. C. (2024a). Framework for full integration of ICT in assessment in secondary schools in Tanzania. *Journal of Issues and Practice in Education, 16*(2), 35–60. https://www.ajol.info/index.php/jipe/article/view/285484

Mfoi, D. M., Mwangakala, H. A., & Manyilizu, M. C. (2024b). Monitoring and evaluation of ICT integration in secondary school teaching and learning in Tanzania. *Journal of Issues and Practice in Education, 16*(2), 129–149. https://www.ajol.info/index.php/jipe/article/view/285541

Minga, C., & Ghosh, S. (2024). Student perceptions on ICT use in teaching and learning in public secondary schools in Mbeya District, Tanzania. *Journal of Education, Society and Behavioural Science, 37*(6), 26–39. https://doi.org/10.9734/jesbs/2024/v37i61325

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Ministry of Education, Science and Technology. (2025). *National digital education strategy, 2024/25–2029/30*. Government of the United Republic of Tanzania. https://www.moe.go.tz/sites/default/files/DIGITAL%20NATIONAL%20STRATEGY%202025_0.pdf

Mkude, B., Mwila, P., & Ndomba, R. M. (2023). Stakeholders' perceptions of modern technology usage in secondary schools in Mvomero District, Tanzania. *International Journal of Education and Development Using Information and Communication Technology*, *19*(3), 236–258.

Msafiri, M. M., Kangwa, D., & Cai, L. (2023). A systematic literature review of ICT integration in secondary education: What works, what does not, and what next? *Discover Education*, *2*, Article 44. https://doi.org/10.1007/s44217-023-00070-x

Msambwa, M. M., & Daniel, K. (2024). A systematic literature review on the ICT integration in teaching and learning: Lessons for an effective integration in Tanzania. *European Journal of Education, 59*(4), e12696. https://doi.org/10.1111/ejed.12696

Msambwa, M. M., Daniel, K., & Cai, L. (2024). Integration of information and communication technology in secondary education for better learning: A systematic literature review. *Social Sciences & Humanities Open, 10*, 101203. https://doi.org/10.1016/j.ssaho.2024.101203

Mubofu, C., & Adoph, E. (2026). Technology transfer practices and curriculum-integrated utilisation of Open Educational Resources by secondary school teachers. *Cogent Education, 13*(1), 2702658. https://doi.org/10.1080/2331186X.2026.2702658

Ngodu, A., Ndibalema, P. M., & William, F. (2024). Context-relevant strategies for ICT integration in teaching and learning science subjects in Tanzania secondary schools. *Educational Technology Quarterly*, *2024*(1), 20–37. https://doi.org/10.55056/etq.704

Niederberger, M., Schifano, J., Deckert, S., Hirt, J., Homberg, A., Köberich, S., Kuhn, R., Rommel, A., Sonnberger, M., & DEWISS Network. (2024). Delphi studies in social and health sciences—Recommendations for an interdisciplinary standardized reporting (DELPHISTAR): Results of a Delphi study. *PLOS ONE*, *19*(8), e0304651. https://doi.org/10.1371/journal.pone.0304651

Nussbaum, M. C. (2011). *Creating capabilities: The human development approach*. Harvard University Press.

Nzilano, J. L. (2025). An investigation into the factors influencing ICT adoption and use in the administration of secondary schools in Dar es Salaam, Tanzania. *Social Sciences & Humanities Open, 11*, 101500. https://doi.org/10.1016/j.ssaho.2025.101500

OECD. (2024). *Technology use at school and students' learning outcomes: Exploring the relationship with new data from Germany* (OECD Education Spotlights No. 17). https://doi.org/10.1787/422db044-en

Peter, J. C. (2022). The use of ICT for teaching and learning among secondary schools teachers in Mtwara, Tanzania. *African Journal of Accounting and Social Science Studies, 4*(1), 364–393. https://doi.org/10.4314/ajasss.v4i1.19

Petter, S., DeLone, W., & McLean, E. R. (2008). Measuring information systems success: Models, dimensions, measures, and interrelationships. *European Journal of Information Systems, 17*(3), 236–263. https://doi.org/10.1057/ejis.2008.15

Petter, S., DeLone, W., & McLean, E. R. (2013). Information systems success: The quest for the independent variables. *Journal of Management Information Systems, 29*(4), 7–62. https://doi.org/10.2753/MIS0742-1222290401

Puentedura, R. R. (2013, May 29). *SAMR: Moving from enhancement to transformation* [Presentation slides]. Hippasus. https://www.hippasus.com/rrpweblog/archives/2013/05/29/SAMREnhancementToTransformation.pdf

Richey, R. C., & Klein, J. D. (2007). *Design and development research: Methods, strategies, and issues*. Lawrence Erlbaum Associates.

Richey, R. C., Klein, J. D., & Nelson, W. A. (2004). Developmental research: Studies of instructional design and development. In D. H. Jonassen (Ed.), *Handbook of research on educational communications and technology* (2nd ed., pp. 1099–1130). Lawrence Erlbaum Associates.

Schmitz, M.-L., Antonietti, C., Consoli, T., Cattaneo, A., Gonon, P., & Petko, D. (2023). Transformational leadership for technology integration in schools: Empowering teachers to use technology in a more demanding way. *Computers & Education, 204*, 104880. https://doi.org/10.1016/j.compedu.2023.104880

Sen, A. (1985). Well-being, agency, and freedom: The Dewey Lectures 1984. *The Journal of Philosophy, 82*(4), 169–221. https://doi.org/10.2307/2026184

Sen, A. (1999). *Development as freedom*. Oxford University Press.

Spranger, J., Homberg, A., Sonnberger, M., & Niederberger, M. (2022). Reporting guidelines for Delphi techniques in health sciences: A methodological review. *Zeitschrift für Evidenz, Fortbildung und Qualität im Gesundheitswesen, 172*, 1–11. https://doi.org/10.1016/j.zefq.2022.04.025

Swai, S. E. (2024). Utilisation of information and communication technology in teaching and assessment of secondary school students in Tanzania. *Journal of Issues and Practice in Education, 16*, 320–333. https://doi.org/10.61538/jipe.v16i.1443

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Tornatzky, L. G., & Fleischer, M. (1990). *The processes of technological innovation*. Lexington Books.

United Nations Educational, Scientific and Cultural Organization. (2023). *Global education monitoring report 2023: Technology in education: A tool on whose terms?* https://doi.org/10.54676/UZQV8501

Venkatesh, V., Morris, M. G., Davis, G. B., & Davis, F. D. (2003). User acceptance of information technology: Toward a unified view. *MIS Quarterly, 27*(3), 425–478. https://doi.org/10.2307/30036540

Warioba, M. M., Machumu, H., Kulunga, K., & Mtweve, L. (2022). Adoption of ICT as a pedagogical tool in community secondary schools in Tanzania: Possibilities and constraints. *Education and Information Technologies, 27*(2), 2835–2858. https://doi.org/10.1007/s10639-021-10715-9

Whittaker, T. A., & Schumacker, R. E. (2022). *A beginner's guide to structural equation modeling* (5th ed.). Routledge.

Supplementary Materials

Supplementary Table S1

Technology-Use Profile by School Category

Technology group	ADSI T/S	Private T/S	Piloted T/S	Government T/S
Core access and presentation	3.72 / 3.44	3.21 / 3.16	2.75 / 2.47	2.40 / 2.43
Communication and resource management	3.65 / 3.27	3.21 / 3.09	2.83 / 2.47	2.45 / 2.31
Interactive and multimedia	3.63 / 3.21	3.22 / 3.15	2.72 / 2.43	2.41 / 2.29

Note. T = teachers; S = students.

Supplementary Table S2

Operational Core of Teacher Empirical Framework Version 2a

Domain	β / R^2	Selected operational conditions
Technological readiness	.46	Sufficient functional ICT; reliable systems; task–technology fit; ease of use; access time; trained technicians
Organisational support	.41	ICT rules; leadership; provision and maintenance; time allocation; training; supervision
Individual capacity	.38	Knowledge; attitudes; motivation; understanding of ICT-supported activities; confidence; teamwork; creativity
Environmental enablers	.29	Supportive environment; ICT culture; accessibility; stakeholder support; government/partner support
Teacher ICT utilisation	R^2 = .6082	Instructional planning, delivery, assessment, feedback, communication and pedagogical integration

Note. β = standardised structural coefficient; R^2 = coefficient of determination. Operational conditions describe the empirical translation of the latent domains and should not be interpreted as independent causal effects.

Supplementary Table S3

Operational Core of Student Empirical Framework Version 2b

Domain	β / R^2	Selected operational conditions
Technological readiness	.42	Functional and sufficient ICT; task fit; access time; ease of use; reliability; technical assistance
Individual capacity	.40	Motivation; knowledge; confidence; attitudes; teamwork; creativity; belief in educational value
Organisational support	.38	Clear access rules; leadership; adequate time; maintenance; digital-literacy support; supervision
Environmental enablers	.21	Accessibility; supportive environment; ICT culture; teacher/parent/community encouragement; external support
Student ICT utilisation	R^2 = .5249	Direct access, participation, independent learning, collaboration, assessment and digital competence

Note. *β = standardised structural coefficient; R^2 = coefficient of determination. Operational conditions describe the empirical translation of the latent domains and should not be interpreted as independent causal effects.*

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Supplementary Table S4

School-Context Priorities within Integrated Empirical Framework Version 2c

School context	Empirical profile	Version 2c implementation emphasis
ADSI	Highest utilisation and explanatory power; teacher use exceeded learner use	Consolidation, pedagogical deepening, learner participation, innovation, equity and sustainability
Private	Moderate, relatively balanced utilisation with strong model explanatory power	Curriculum-wide integration, pedagogical quality, equitable access, maintenance and replacement planning
Piloted	Moderate teacher but low student use; intermediate explanatory power	Institutionalise project gains, recurrent financing, whole-school training, maintenance, technical support and learner access
Government	Low teacher and student utilisation; lowest R^2 values	Foundational power, devices, connectivity, maintenance, basic competence, leadership, scheduled access and external support

Note. The school-context priorities represent empirically informed implementation emphases rather than fixed developmental stages. Individual schools should be diagnosed according to their actual technological, organisational, individual, and environmental conditions before interventions are prioritised.

Supplementary Table S5

Principal Round One Delphi Feedback and Refinement Actions

Expert-feedback theme	Issue identified	Refinement introduced
ICT infrastructure	Reliability of internet, devices and power required clearer specification	Expanded infrastructure and functionality requirements
Technical support	Continuity of services and maintenance needed stronger treatment	Strengthened maintenance and technical-support provisions
Training and workshops	Practical and continuous capacity development insufficiently explicit	Expanded continuous training provisions
Teacher competence	Professional ICT competence required greater emphasis	Strengthened teacher digital and pedagogical competence indicators
Student digital literacy	Student skills and direct participation required clearer representation	Expanded student capability and learner-access indicators
Motivation and attitudes	Willingness and sustained use required greater attention	Strengthened motivation and attitude indicators
Policy and leadership	Administrative responsibility required clearer allocation	Clarified leadership, policy, supervision and accountability
Time allocation	Available technology did not ensure sufficient opportunities for use	Strengthened timetabling and protected access-time requirements
ICT culture and environment	Supportive institutional culture needed explicit specification	Strengthened culture, collaboration and stakeholder-support components

Note. The Round One refinements clarified the operational expression of the framework; they did not alter the four empirical domains or re-estimate the MG-SEM structural coefficients.

Supplementary Table S6

Stakeholder Responsibilities and Monitoring Evidence for Framework Version 4

Stakeholder	Principal responsibilities under Version 4	Indicative monitoring evidence
Government, education authorities and public ICT agencies	Pilot the framework; establish minimum readiness standards; coordinate power, connectivity, devices and technical support; finance professional development; promote equitable resource allocation; establish integrated monitoring	Baseline/readiness data; functionality rates; connectivity; resource allocation; teacher/student utilisation; equity and sustainability indicators
School leadership and management	Conduct readiness assessment; prepare annual ICT plans and budgets; establish access rules and timetables; supervise integration; arrange maintenance and professional development; monitor teacher and learner participation	ICT implementation plan; recurrent budget; access schedules; supervision reports; training records; maintenance logs
ICT coordinators and technical personnel	Maintain devices and systems; troubleshoot faults; manage security and backups; support users; document functionality and downtime	Maintenance records; system-availability rates; fault logs; response time; repair history
Teachers	Select technology according to curriculum and task fit; integrate ICT into instruction, assessment, feedback, collaboration and learner-centred activities; develop their digital-pedagogical competence	ICT-supported lessons; digital assessments; feedback records; curriculum coverage; learner participation and products

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Students	Participate directly and equitably in curriculum-linked ICT activities; strengthen digital literacy, confidence and responsible use; engage in research, collaboration, assessment and digital production	Access/participation records; digital outputs; assignments; assessment activities; evidence of independent and collaborative use
Parents, communities, development partners and private-sector actors	Support connectivity, technical capacity, security, inclusion and sustainability; align external projects with school/government plans; establish maintenance and exit arrangements	Partnership agreements; continuity plans; local technical-support arrangements; connectivity support; inclusion/equity evidence

Note. Stakeholder responsibilities are complementary rather than mutually exclusive. Monitoring evidence should be adapted to school context and used to support implementation, maintenance, professional development, resource allocation, equity and continuous framework refinement.

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