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A Scalable Framework for Optimising ICT Integration in Public Secondary Schools: Evidence from Ilemela Municipal, Tanzania

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ABSTRACT: This study developed a practical and scalable framework for optimising Information and Communication Technology (ICT) integration in public secondary schools, drawing on evidence from selected schools in Ilemela Municipal, Tanzania. The study responded to the persistent gap between the physical presence of ICT resources and their systematic use in teaching, learning, assessment and administration. Guided by the Technology Acceptance Model and the Resource-Based View, the study adopted a pragmatic philosophy and an explanatory sequential mixed-methods design. Quantitative data was obtained from 150 teachers, ICT coordinators (focal teachers), and school administrators, while qualitative evidence was collected from 10 purposively selected school-level stakeholders. Descriptive statistics, multiple linear regression and thematic synthesis were used to identify the requirements, priorities and implementation conditions of the framework. The regression model demonstrated strong explanatory power ($R = .797$; $R^2 = .635$; Adjusted $R^2 = .611$; $F(9,136) = 26.264$, $p < .001$). Technical support and maintenance, funding and sustainability, teacher capacity building, and ICT infrastructure emerged as the most important statistically significant predictors of integration. Descriptive

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and qualitative findings further revealed limited student access, inadequate devices, weak maintenance capacity, insufficient recurrent funding and uneven institutional readiness. The resulting framework links foundational inputs coordinated implementation processes, technical and contextual moderating factors, immediate outputs, medium-term outcomes and long-term impacts. It also proposes a five-phase scaling pathway based on readiness assessment, minimum functionality, capacity development, operational integration, monitoring and progressive expansion. The paper argues that scalability should not be interpreted as uniform replication of equipment packages, but as context-sensitive growth in functional, pedagogically meaningful and sustainable ICT use. The framework offers an evidence-based planning, implementation and evaluation guide for schools, education authorities, policymakers and development partners seeking to strengthen digital transformation in resource-constrained secondary education systems.

Keywords: *ICT Integration, Scalable Framework, Public Secondary Schools, Teacher Digital Competence, Technical Support, Tanzania.*

1. Introduction

Information and Communication Technology has become an important component of educational reform because it can broaden access to learning materials, improve communication, support assessment and increase efficiency in school administration. Digital devices, internet-enabled resources, presentation technologies, learning platforms and electronic records can make teaching, learning and institutional management more flexible and responsive. However, the educational benefits of ICT do not arise automatically from the acquisition of related equipment or devices such as computers. They depend on the interaction between infrastructure, user competence, technical reliability, financing, leadership and the organisation of school routines. When these conditions are weak, equipment may remain underused, access may be restricted to a small number of users, and technology may be applied mainly to isolated administrative tasks rather than integrated into everyday teaching and learning (Mushi & Maharaj, 2013; Jabarkhil *et al*., 2024).

Across developing education systems, ICT initiatives have often begun through projects that supply equipment or devices such as computers, establish laboratories, provide

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connectivity or train selected teachers. Although such interventions increase the visibility of technology in schools, many struggle to move from initial provision to sustained integration. Common difficulties include unreliable electricity, inadequate bandwidth, insufficient devices, lack of appropriate digital content, weak maintenance arrangements, high recurrent costs and limited teacher confidence. In addition, a project may introduce technology without establishing clear school-level responsibilities, replacement plans, technical support procedures or indicators for monitoring actual use. As a result, the difference between having ICT resources and using them to improve education remains substantial (Nyakito *et al*., 2021; Ramafi, 2022; Wambui *et al*., 2022).

In Tanzania, the policy environment increasingly recognises ICT as a means of improving educational access, quality and efficiency. Public secondary schools have begun using digital systems for examination processing, record keeping, communication, lesson preparation and access to information. Nevertheless, implementation is uneven. Some schools have functional devices and reasonable connectivity, whereas others face shortages of equipment, limited student access and inadequate technical support. Even where computers are available, their use may be concentrated in administration, examinations or a computer studies laboratory, with less consistent application in subject teaching and learner-centred activities. This pattern suggests that the central problem is no longer simply whether ICT is present, but whether schools possess the coordinated capabilities required to translate available technology into routine educational practice (Bendera, 2024; Kiwonde, 2024).

A major weakness in many ICT initiatives is the absence of a practical pathway that recognises different school starting points. Public schools vary in electricity reliability, connectivity, number and condition of devices, teacher skills, funding capacity, leadership commitment and availability of support personnel. A uniform implementation package may therefore be unsuitable. A school that lacks secure electricity and functional devices requires a different first step from a school that already uses digital assessment and is ready to introduce a learning platform. Effective planning requires a framework that allows schools to diagnose readiness, establish minimum functional conditions, build human capacity, integrate ICT into core operations and expand only after earlier stages are sufficiently stable.

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Scalability in this context should not be understood as the rapid duplication of identical technologies across all schools. It refers to the capacity to extend the depth, breadth and sustainability of ICT use in ways that respond to local resources and evidence of performance. Depth concerns the quality of integration within teaching, learning, assessment and administration. Breadth concerns the number of teachers, learners, subjects and functions reached. Sustainability concerns whether schools can maintain devices, connectivity, support and skills after initial project assistance ends. A scalable framework must therefore be modular, readiness-based and supported by feedback mechanisms that allow schools to learn, adjust and progress over time.

This paper developsa scalable framework for optimising ICT integration in public secondary schools. The framework is built by synthesisingevidence onICT integration status, statistically significant influencing factors, challenges and enabling conditions identified in selected public secondary schools in Ilemela Municipal. The paper provides a detailed account of the theoretical foundation, empirical basis, development procedure, architecture, implementation phases and monitoring logic of the framework. Its contribution lies in translating dispersed findings into an actionable framework that can guide school leaders, education authorities, teachers, technical personnel and development partners.

2. Theoretical Review

2.1 Technology Acceptance Model

The Technology Acceptance Model (TAM), introduced by Davis (1989), explains technology adoption primarily through perceived usefulness and perceived ease of use. Perceived usefulness is the degree to which a user believes that a technology improves performance, while perceived ease of use is the degree to which the technology is considered understandable and manageable with limited effort. In a school environment, teachers are more likely to use ICT when they observe practical benefits such as easier lesson preparation, clearer presentation of concepts, faster assessment, improved access to resources and efficient communication. Conversely, complicated interfaces, slow networks, repeated breakdowns and insufficient support increase the perceived effort of use and can discourage adoption.

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TAM is relevant to ICT integration because user acceptance is also influenced by external conditions. Teacher training, prior experience, availability of digital content, technical assistance, device access and leadership support shape whether ICT is perceived as useful and easy to use. A teacher who receives hands-on training, subject-relevant resources and timely assistance is more likely to develop confidence and incorporate technology into regular practice. Thus, acceptance is not merely an individual attitude; it is partly produced by the institutional environment. This insight supports the inclusion of capacity building, system usability and technical support within the proposed framework (Lin *et al*., 2023; Silva *et al*., 2024).

The model also helps explain why technology may be more widely used for administrative and assessment functions than for direct classroom instruction. Teachers and administrators may quickly recognise the efficiency benefits of electronic records, result processing or communication, while pedagogical integration requires additional planning, digital content selection, classroom management and confidence. The framework therefore provides progressive opportunities for users to experience benefits, receive support and move from basic use to more complex pedagogical applications.

2.2 ResourceBased View

The Resource-Based View (RBV) explains institutional performance through the resources and capabilities that an organisation possesses and coordinates. In schools, physical resources include computers, projectors, networks, power systems and digital content and systems. Human resources include teachers with digital competence, ICT coordinators, technical personnel and school leaders. Organisational resources include policies, budgets, maintenance routines, partnerships, planning arrangements and monitoring systems. The relevance of RBV is that ICT value depends not only on resource ownership but also on the institution's capacity to organise, combine and use those resources productively.

A computer laboratory, for example, may have limited educational value when devices are faulty, access is restricted, content is unavailable, or teachers lack the competence to use it. Similarly, trained teachers may be unable to apply their skills if internet connectivity is unstable or lesson schedules do not allow access to equipment. RBV therefore encourages analysis of resource complementarity. Infrastructure, skills, support, financing and

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institutional arrangements must reinforce one another. Weaknesses in one critical resource can reduce the value of the others.

RBV further supports the framework's emphasis on sustainable internal capability. Dependence on one-off projects or external technicians can leave schools vulnerable when funding ends, or equipment fails. Sustainable integration requires schools and education authorities to build routines for budgeting, preventive maintenance, local troubleshooting, staff development, procurement and data management. These capabilities enable schools to preserve value, adapt technologies to changing needs and expand successful practices over time (Utami, 2023).

2.3 Integrated Theoretical Position

TAM and RBV provide complementary explanations of ICT integration. TAM focuses on the perceptions and behaviours of users, while RBV focuses on the resources and capabilities of institutions. A school may have resources but achieve low adoption if users do not perceive ICT as useful or manageable. Equally, teachers may be willing to use technology but remain unable to do so when devices, connectivity, technical support and time are inadequate. The proposed framework therefore combines user acceptance with institutional capability.

Within the framework, RBV informs the foundational inputs and implementation capabilities, while TAM informs the processes through which teachers and administrators gain confidence, experience usefulness and reduce the effort of use. Technical support and maintenance connect the two perspectives because they preserve resource functionality and reduce user frustration. Continuous monitoring creates a feedback loop through which schools can identify problems, adjust support and demonstrate benefits. The integrated theoretical position therefore treats ICT integration as a socio-technical and organisational process rather than a simple equipment intervention.

3. Empirical Review and Research Gap

3.1 Status and Patterns of ICT Integration

Empirical studies indicate that ICT can improve instructional preparation, learner engagement, access to information, assessment and administrative efficiency. Digital

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presentations, videos, simulations, and virtual laboratory resources may help teachers illustrate concepts and demonstrate science practicals digitally, while online and offline resources can broaden the materials available to learners (Lestari *et al*., 2023; Kefalis *et al*., 2025; Zhang *et al*., 2024). ICT can also reduce the time required for grading, attendance management, reporting and communication. However, evidence from African schools shows that these benefits are uneven because access, functionality and teacher readiness differ considerably between schools (Anastasopoulou *et al*., 2023; Bendera, 2024).

A recurring pattern is that administrative use develops more rapidly than pedagogical use. Schools may use computers for records, examinations, timetables and official communication while classroom integration remains limited. Administrative applications often involve fewer users, clearer procedures and immediate efficiency gains. Classroom use requires subject-specific content, teacher confidence, student access, pedagogical redesign and reliable technology during lessons. A framework intending to deepen integration must therefore recognise functional differences and establish targeted strategies for both administration and teaching.

Student access is another important dimension. The presence of a computer laboratory does not guarantee regular or equitable learner use. High student-to-device ratios limited opening hours, security restrictions, lack of connectivity and concentration of ICT within a certain subject can reduce access. Effective integration should consequently be assessed through the frequency and inclusiveness of use rather than the number of devices alone.

3.2 Factors Influencing ICT Integration

Previous studies identify infrastructure, electricity, internet connectivity, teacher competence, technical support, perceived usefulness, leadership and financing as major determinants of ICT integration. Wambui *et al*. (2022) emphasised the interaction between knowledge, infrastructure, affordability and user perceptions. Alestriani Sibagariang *et al*. (2023) similarly emphasised the importance of supportive educational conditions, including ICT facilities, user competence and institutional support, as important for adoption. These findings suggest that technology use is shaped by both material resources and institutional conditions.

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Teacher competence is especially important because teachers translate technology into learning activities. General computer literacy is useful but insufficient; teachers also require the ability to select appropriate tools, align digital content with curriculum objectives, manage technology-supported classrooms, design assessments and address digital safety (Ajani, 2024; Tzafilkou *et al*., 2023; UNESCO, 2018). Continuous professional development is therefore more effective than one-off introductory training. Peer mentoring, demonstration lessons and classroom-based coaching can help teachers apply knowledge in realistic settings.

Technical support influences both system functionality and willingness to use ICT (Abel *et al*., 2022; UNESCO, 2018). When faults remain unresolved, teachers may return to manual methods and lose confidence in digital systems. Maintenance arrangements should therefore include preventive checks, clear reporting channels, basic troubleshooting at school level, escalation procedures and access to specialised assistance. Sustainable funding is similarly essential because ICT requires recurrent expenditure for connectivity, repairs, replacement, licensing, power protection and training.

3.3 Challenges and Enabling Conditions

Research in Tanzania and comparable contexts documents shortages of devices, unreliable internet, limited teacher skills, inadequate localised content, weak maintenance, high costs and administrative bottlenecks (Kiwonde, 2024; Nyakito *et al*., 2021). These barriers are interdependent. Limited funding reduces procurement and maintenance, which affects availability and reliability. Poor reliability increases perceived difficulty, reduces teacher confidence and weakens use. Low use then makes it harder to justify further investment, producing a cycle of underutilisation.

Enabling conditions include stable electricity, supportive leadership, collaboration among teachers, relevant digital content, clear implementation plans and government or community support. Their value lies in reducing uncertainty and coordinating action. Leadership can allocate time for training, set expectations, mobilise resources and include ICT priorities in school plans. Teacher collaboration can spread practical knowledge, while partnerships may provide connectivity, maintenance or content. A scalable framework should therefore strengthen enabling conditions while addressing the most limiting barriers.

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3.4 Framework Studies and the Unresolved Gap

Framework-oriented studies demonstrate the importance of context and readiness. Vidanagama and Karunathilake (2021) proposed a framework incorporating infrastructure, policy, capacity development, stakeholder participation and monitoring. Kennedy and Cronjé (2024) emphasised context-aware appropriation, arguing that institutions should adapt technology to local pedagogical and organisational realities. These models show that integration is more sustainable when implementation begins with diagnosis and progresses through coordinated stages.

Despite these contributions, there remains limited context-specific guidance on how Tanzanian public secondary schools should link empirical priorities to an operational results chain. Many studies list barriers and success factors but do not specify how schools with different starting conditions can progress, what minimum functionality should be established before expansion, how moderating technical conditions should be addressed, or how outputs should be monitored. The present study addresses this gap by deriving a school-level framework from quantitative predictors, descriptive patterns and stakeholder explanations.

4. Methodology

4.1 Research Design and Study Context

The study adopted a pragmatic research philosophy because the objective required the combination of numerical evidence and contextual explanation to develop a practical solution. An explanatory sequential mixed-methods design was used. Quantitative data were first collected and analysed to establish the status of ICT integration, identify significant predictors and quantify major challenges. Qualitative interviews were then used to explain the observed patterns, identify practical implementation conditions and support framework refinement (Creswell, 2018).

The research was conducted in selected public secondary schools in Ilemela Municipal, Mwanza Region. The municipal context includes urban and peri-urban schools with differing levels of infrastructure, connectivity, staffing and institutional readiness. This variation was useful for developing a framework that accommodates different starting conditions rather than assuming uniform school capacity.

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4.2 Population, Sampling and Participants

The target population was estimated at 520 teachers, school administrators and ICT coordinators or focal teachers. These categories were selected because of their direct involvement in the use, management, and support of ICT in schools. The quantitative analysis used 150 valid questionnaires selected through simple random sampling. The minimum sampley size for the quantitative studywas determined using Yamane's (1967) formula for a finite population, expressed as $n = N / [1 + N (e)^2]$, where n is the required sample size, N is the target population, and e is the acceptable margin of error. Using a target population of (N=520) and a margin of error of (e=0.08), the required sample size was calculated as follows: With $N = 520$ and $e = 0.08$, the calculation was $n = 520 / [1 + 520(0.08)^2]$, producing a sample size appropriate for deriving a manageable sample of 120 from a finite population of 520 respondents. To increase representation and compensation for possible non- response, a total of 150questionnaires were distributed, and all 150 were returned complete and valid for quantitative analysis, resulting in a response rate of 100%. The respondents comprised 98 ICT coordinators or focal teachers (65%), 44 teachers (29%) and 8 school administrators (6%), as also indicated in Table 1. This distribution ensured strong representation of personnel directly involved in managing, supporting and using ICT while retaining instructional and managerial perspectives.

The qualitative phase involved 10 purposively selected participants who possessed direct knowledge of school ICT practices and challenges. Semi-structured interviews enabled participants to explain infrastructure conditions, training needs, technical problems, institutional arrangements and the measures required to improve integration. The use of multiple stakeholder categories supported triangulation and strengthened the practical relevance of the framework.

Table 1: Composition of Quantitative Respondents

Category	*n*	%
ICT coordinators/focal teachers	98	65
Teachers	44	29
Administrators	8	6
Total	150	100

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4.3 Data Collection, Reliability and Analysis

A structured questionnaire measured the status of ICT integration, infrastructure, teacher capacity, technical support, funding, leadership, institutional readiness and implementation challenges using five-point response scales. The instrument was reviewed for content validity and aligned with the research objectives, TAM and RBV. Reliability was assessed for the questionnaire constructs using Cronbach's alpha. The coefficients ranged from .717 to .817, exceeding the commonly accepted threshold of .70 and indicating adequate internal consistency for the scales used in the quantitative phase.

Descriptive statistics were used to summarise access, use and challenges. Multiple linear regression assessed the joint and individual influence of school-level factors on the ICT integration rate at the 5% significance level. Thematic analysis was used to organise interview evidence around infrastructure, human capacity, financing, technical support, institutional readiness and suggested interventions. Quantitative and qualitative evidence was then integrated during framework development.

4.4 Framework Development Procedure

The framework development used the study findings as the primary evidence base, particularly evidence on ICT integration status, statistically significant influencing factors, challenges and enabling conditions. . The development procedure followed five analytical steps. First, the status findings identified where ICT use was established and where major access gaps remained. Second, regression analysis prioritised the factors with the strongest direct statistical relationship with integration. Third, descriptive and qualitative findings identified constraints that could affect whether these priority factors were translated into practice. Fourth, the factors were organised into a results chain comprising inputs, processes, outputs, outcomes and impacts. Fifth, the prototype was refined through stakeholder consultation and aligned with TAM and RBV.

The framework was designed around four principles: evidence-based prioritisation, readiness-based progression, modular implementation and continuous feedback. Evidence-based prioritisation ensures that technical support, financing, teacher capacity and infrastructure receive attention in accordance with their empirical importance. Readiness-based progression allows schools to begin at an appropriate stage. Modularity enables individual components to be adapted without losing the overall logic. Continuous feedback ensures that monitoring results inform corrective action and decisions about scaling.

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5. Findings

5.1 Status of ICT Integration and Readiness Informing the Framework Design

The status findings showed that ICT integration had made progress but remained uneven across school functions. Use in assessment, grading and feedback recorded the strongest positive response, with 72.6% of respondents agreeing or strongly agreeing that ICT was used in this area. Internet connectivity was reported positively by 61.7%, while ICT use in administrative processes was reported at 58.6%. These results indicate that technology has gained a meaningful presence in functions where it could improve processing speed, accuracy and communication.

Classroom-oriented integration was less developed. ICT tools used in lesson delivery and digital content used in class each recorded 52.3% agreement. Although these figures indicate emerging use, they also show that a substantial proportion of respondents experienced limited or inconsistent classroom application. Student access was the weakest status indicator: only 35.2% agreed that students accessed ICT resources, while 46.9% disagreed or strongly disagreed. This gap suggests that schools had not yet leveraged available infrastructure to achieve broad learner participation.

Technical support availability and institutional readiness were also modest, with only 44.5% of respondents positively rating technical support and 43.8% positively rating institutional readiness. These results directly informed theframework design by showing (Table 2) that schools were attempting to use ICT despite incomplete support systems. The framework therefore needed to strengthen both visible resources and the organisational capabilities required to sustain regular use.

Table 2: Status Indicators Informing Framework Design

ICT integration aspect	Agree/strongly agree (%)	Interpretation
Assessment, grading and feedback	72.6	Relatively established
Internet connectivity	61.7	Moderate but uneven
Administrative processes	58.6	Emerging institutional use
Lesson delivery	52.3	Moderate classroom use
Digital content in class	52.3	Moderate pedagogical use
Technical support availability	44.5	Insufficient support
Institutional readiness	43.8	Mixed readiness
Student access to ICT	35.2	Major access gap

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5.2 Statistical Prioritisation of Framework Factors

The regression model demonstrated a strong relationship between the selected school-level factors and ICT integration. The model correlation was R = .797, while R^2 = .635 indicated that the predictors jointly explained 63.5% of the variation in the ICT integration rate. The adjusted R^2 of .611 remained high after accounting for the number of predictors, suggesting that the model provided substantial explanatory value. The overall model was statistically significant, F (9,136) = 26.264, p < .001, with a standard error of estimate of .632.

Technical support and maintenance had the strongest positive influence reported in the model (B = .329, p < .001). This finding means that integration was strongly associated with the availability of functioning support and maintenance arrangements. Funding and sustainability also had a significant positive influence (B = .254, p = .013), confirming that recurrent financing is essential for connectivity, repairs, replacement, software and training. Teacher capacity building (B = .080, p = .029) and ICT infrastructure (B = .027, p = .033) were also significant.

Leadership and policy support, as well as monitoring and evaluation, were not statistically significant when the other predictors were controlled. Monitoring and evaluation recorded evaluation's comparatively large but non-significant coefficient (B = .175, p = .677), suggesting that its apparent contribution was not estimated precisely enough to confirm an independent effect in the multivariable model. Nevertheless, qualitative findings showed that both leadership and monitoring remained important for coordination, accountability and sustainability. The framework therefore distinguishes between direct operational predictors and enabling governance mechanisms. Statistical non-significance in a multivariable model does not mean that leadership and monitoring should be removed; rather, their contribution may operate indirectly through resource mobilisation, implementation discipline and institutionalisation of routines.

Table 3: Regression Evidence Used to Prioritize Framework Components

Factor	B	P	Framework implication
Technical support and maintenance	.329	<.001	Highest operational priority
Funding and sustainability	.254	.013	Recurrent financing required
Teacher capacity building	.080	.029	Continuous practical development

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ICT infrastructure	.027	.033	Minimum functional platform
Leadership and policy support	.123	.143	Coordination and institutionalisation
Monitoring and evaluation	.175	.677	Feedback and accountability

5.3 Challenges and Enabling Factors

The challenge findings reinforced the regression priorities. Insufficient budget was identified by 54.7% as a major barrier, while 51.5% reported that dedicated ICT funding was inadequate. Insufficient ICT devices were identified by 52.4%, demonstrating that access remained constrained by the quantity and availability of equipment. Technical support and maintenance capacity was rated inadequate by 45.4%, and 45.3% thus identifying inadequate technical support or maintenance as a practical barrier.

Teacher capacity was another important constraint. A total of 36.7% indicated that ICT skills and ongoing training were inadequate, while interview respondents emphasised the need for regular workshops, practical assistance and access to functional computers. Resistance to change and negative attitudes were also present, although their effects were intertwined with unreliable technology and limited confidence. Users who repeatedly encounter faults or lack suitable content may reasonably become reluctant to depend on ICT.

Some enabling conditions were evident. Stable electricity or power backup received 45.3% agreement, and respondents recognised that ICT could make lessons more interactive and simplify tasks such as preparing notes, recording attendance and managing examination results. These positive experiences provided an important foundation for scaling. The framework therefore builds on existing strengths while addressing critical deficits simultaneously.

5.4 Architecture of the Scalable Framework

The framework translates the empirical findings into a connected pathway (Figure 1). It presents ICT integration as a progressive results chain rather than a one-time supply of equipment. Reading it from left to right, begins with foundational inputs and enablers such as infrastructure, teacher competence, technical support, sustainable funding, leadership and relevant digital content. These inputs are converted into practice through implementation processes that include readiness assessment, capacity building, ICT-

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supported teaching, digital assessment, administrative digitalisation, maintenance and monitoring. Technical and contextual moderating factors, such as connectivity, device availability, data quality, school resources and system reliability, influence how effectively these processes produce results. The pathway then moves from immediate outputs to medium-term outcomes and long-term impacts, while feedback loops return monitoring evidence to earlier stages so that schools can correct weaknesses, strengthen readiness and scale ICT use gradually and sustainably. The arrangement reflects the finding that ICT integration depends not only on resource availability, but also on how resources are configured, supported, used and continuously improved.

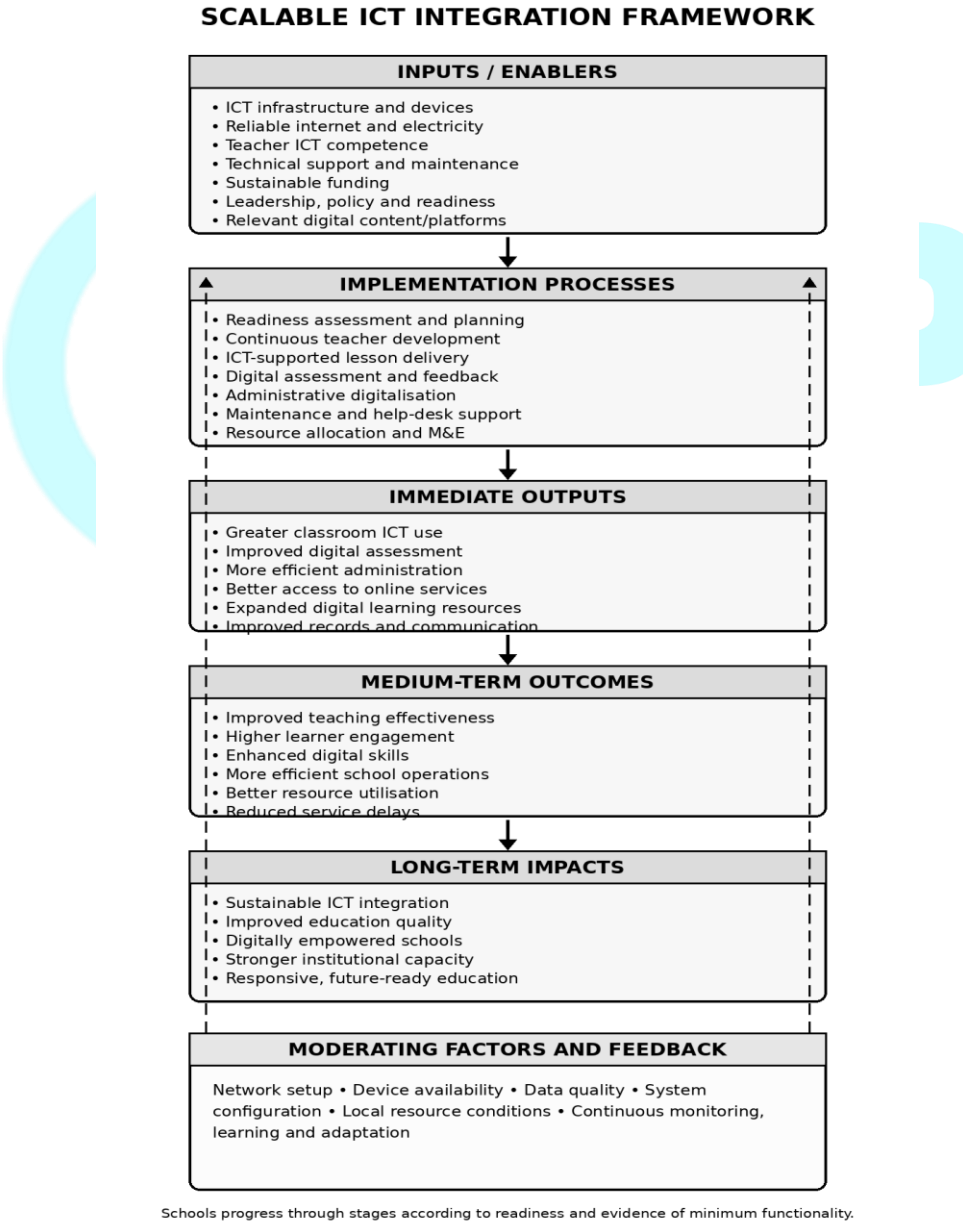

Figure 1: Scalable Framework for Optimising ICT Integration in Public Secondary Schools

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5.4.1 Inputs and Enablers

The input component defines the minimum conditions required for integration. ICT infrastructure includes functional computers, projectors, networks, power protection and secure spaces. Reliable internet and electricity enable continuity of use, while teacher ICT competence ensures that resources can be translated into learning and administrative practice. Technical support and maintenance protect functionality and reduce interruptions. Sustainable funding enables procurement, connectivity, repair and replacement. Leadership, policy and institutional readiness provide direction and clarify responsibility. Relevant digital content and platforms ensure that available technology serves curriculum and management needs.

The framework does not require every school to begin with the same quantity or type of technology. It requires each school to establish a minimum functional platform appropriate to its context. In a low-resource school, this may involve shared devices, offline resources, power protection and scheduled access. In a better-resourced school, the platform may include networked laboratories, classroom projection, learning platforms and automated administration. What matters is that the selected inputs are functional, supported and aligned with priority uses.

5.4.2 Implementation Processes

Implementation processes convert inputs into actual practice. Readiness assessment and planning establish the baseline, priorities, responsibilities and resource requirements. Continuous teacher development builds digital and pedagogical competence through hands-on training, coaching and peer learning. ICT-supported lesson delivery integrates presentations, simulations, digital resources and collaborative activities into subject teaching. Digital assessment and feedback improve the speed and accuracy of evaluation. Administrative digitalisation strengthens records, attendance, communication and reporting.

Maintenance and help-desk support ensure that technical problems are detected and resolved. Resource allocation and monitoring link implementation to budgets, schedules and indicators. These processes should be coordinated rather than implemented as isolated activities. For example, supplying devices without training or maintenance is unlikely to

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produce sustained use. Similarly, training without access to functional tools limits opportunities for practice and reinforcement.

5.4.3 Moderating Factors and Feedback

Moderating factors affect the strength of the relationship between inputs, implementation and results. Network setup influences speed, reliability and coverage. Device availability determines whether use can reach multiple teachers and learners. Data quality affects reporting and decision-making, while system configuration influences compatibility and usability. Local resource conditions, including electricity, security, staffing and school size, shape the feasibility of different solutions.

Feedback is represented as a continuous process rather than an end-stage evaluation. Schools should monitor functionality, frequency of use, access, competence, support response time and educational value. Evidence should be reviewed by the school ICT team and leadership to identify corrective action. The framework allows schools to pause expansion when minimum conditions are unstable, strengthen weak components and proceed only when earlier stages are sufficiently functional.

5.4.4 Outputs, Outcomes and Impacts

Immediate outputs are the first observable signs that implementation is working. They include greater classroom use, improved digital assessment, more efficient administration, better access to online services, expanded digital learning resources and improved communication and records. These outputs are measurable within a relatively short period and demonstrate whether technology has moved beyond policy intention and physical availability.

Medium-term outcomes include improved teaching effectiveness, higher learner engagement, stronger digital skills, more efficient school operations, better resource utilisation and reduced service delays. These outcomes emerge when ICT use becomes regular, reliable and aligned with educational needs. They should be assessed cautiously because they depend on sustained implementation and may vary by subject, school context and learner access.

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Long-term impacts include sustainable ICT integration, improved education quality, digitally empowered schools, stronger institutional capacity and a more responsive education system. The framework treats these impacts as cumulative results of continued investment, learning and adaptation. They cannot be achieved through a single procurement cycle or short training event.

5.5 Phased Implementation and Scaling Pathway

The framework proposes five phases that enable schools to progress according to readiness (Table 4). The phases are not rigid calendar periods; they are maturity levels defined by evidence of minimum functionality. A school may work on several activities concurrently, but major expansion should be based on progress indicators. This approach reduces the risk of investing in advanced systems before basic infrastructure, competence and support are stable.

Phase One focuses on diagnosis and planning. The school assesses devices, power, connectivity, skills, student access, budgets, technical support and current uses. It then prepares a school ICT plan, assigns responsibilities and establishes baseline indicators. Phase Two establishes foundations by providing minimum functional devices, connectivity, power protection, security, relevant content and maintenance arrangements. Phase Three builds capabilities through practical teacher development, coaching, peer support and help-desk procedures.

Phase Four integrates ICT into operations. Teachers use digital resources in lesson preparation and delivery, assessment and feedback, while administrators digitalise priority functions such as attendance, records, communication and examination management. Phase Five focuses on monitoring and scaling. The school evaluates performance, resolves weaknesses, mobilises resources and expands successful uses to additional subjects, learners, classrooms or administrative functions.

Table 4: Phased Implementation Roadmap and Minimum Progress Evidence

Phase	Priority actions	Evidence for progression
1. Diagnose and plan	Baseline assessment; ICT plan; responsible team; priority uses	Documented gaps, targets, roles and budget needs
2. Establish foundations	Devices; connectivity; power protection; security; content; maintenance	Minimum infrastructure functional and accessible

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Phase	Priority actions	Evidence for progression
3. Build capabilities	Practical training; coaching; peer support; help-desk procedures	Users demonstrate basic competence and support is responsive
4. Integrate operations	Teaching; assessment; records; attendance; communication	Regular use across agreed educational and administrative functions
5. Monitor and scale	Track indicators; correct weaknesses; mobilise resources; expand	Stable functionality, wider access and evidence of value

5.6 Monitoring and Evaluation Logic

Monitoring should move beyond counting devices. Availability indicators are useful, but they do not show whether equipment works, whether teachers use it or whether learners benefit. The framework therefore proposes five categories of indicators: functionality, use, access, capacity and value. Functionality indicators include the proportion of operational devices, network uptime, power continuity and average support response time. Use indicators include the frequency of ICT-supported lessons, digital assessments and administrative transactions.

Access indicators measure the proportion of teachers and learners who can use resources, the frequency of learner access and distribution across subjects or groups. Capacity indicators include participation in training, demonstrated competence and availability of peer or technical support. Value indicators examine time saved, quality of records, user satisfaction, engagement and improvements in service delivery. Monitoring results should be interpreted in context and used for improvement rather than punitive comparison.

Evaluation should also consider recurrent cost and sustainability. Schools need to estimate connectivity, maintenance, replacement, licensing, electricity and training costs over several years. A solution that is inexpensive to acquire but impossible to maintain is not scalable. Education authorities can use aggregated school data to identify common needs, coordinate procurement, establish regional support arrangements and direct resources to the most constraining factors.

6. Discussion

6.1 ICT Integration as a Systemic Process

The findings show that ICT integration should be understood as a systemic process rather than a collection of devices. The stronger use of ICT in assessment and administration

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compared with student access and classroom teaching illustrates that different parts of the school system develop at different speeds. Technology becomes educationally meaningful when infrastructure, competence, support and routines are aligned. This interpretation is consistent with studies that distinguish technology availability from effective integration (Wambui *et al*., 2022; Kennedy & Cronjé, 2024).

The framework addresses this systemic character by connecting resources to implementation and results.. This interconnected structure reflects RBV's emphasis on resource combination and organisational capability.

6.2 Significance of Technical Support and Funding

Technical support and maintenance emerged as the strongest predictor, reinforcing the practical reality that technology must remain functional before it can be integrated. A broken computer, misconfigured network or unresolved software problem directly interrupts use. Repeated faults also influence TAM constructs by increasing perceived difficulty and weakening perceived usefulness. The result suggests that ICT programmes should allocate technical support resources at the same time as equipment procurement rather than treating maintenance as an afterthought.

Funding and sustainability were also strongly associated with integration. ICT generates recurrent rather than only capital expenditure. Connectivity, repairs, replacement, power protection, software and training require continuing budgets. Short-term projects may establish initial facilities, but schools need institutional financing mechanisms to sustain them. The framework therefore includes financial planning at both input and implementation stages and requires cost evidence before scaling.

6.3 Teacher Capacity and User Acceptance

Teacher capacity building was a significant predictor, supporting the argument that teachers are central agents of integration. Training should not focus only on basic computer operations. It should help teachers select tools, create and adapt content, manage student participation, assess learning and address ethical and safety considerations. Capacity development should be continuous because technologies, curriculum demands and user needs change over time. This emphasis is consistent with UNESCO's ICT Competency

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Framework for Teachers, which links effective digital integration to teachers' pedagogical, professional and technological competence (UNESCO, 2018).

TAM helps explain why practical and supported training is important. Teachers are more likely to continue using technology when training enables them to complete relevant tasks successfully and when assistance is available during early use. Demonstration of immediate benefits can strengthen perceived usefulness, while repeated practice and simplified procedures improve perceived ease of use. This reflects Davis's (1989) argument that technology acceptance is shaped by perceived usefulness and perceived ease of use and is consistent with recent evidence that educational ICT use improves when users receive adequate support and develop confidence in the technology (Lin *et al*., 2023; Silva *et al*., 2024). The framework's phased pathway creates opportunities for gradual confidence building rather than expecting instant transformation.

6.4 Meaning of Scalability in Resource-Constrained Schools

The principal conceptual contribution of the framework is its interpretation of scalability as progressive functional expansion. Scaling is not achieved merely by increasing the number of devices or extending a project to more schools. It requires preservation of functionality, user competence, access and educational value as coverage grows. This definition is particularly important in resource-constrained environments, where rapid expansion without support may multiply underused or non-functional equipment.

Readiness-based progression allows schools to follow a common logic while using different solutions. One school may rely on offline content and shared projection, while another may use cloud platforms and networked devices. Both can progress if their solutions are reliable, aligned with educational priorities and supported by monitoring. The framework therefore combines standard principles with local adaptation, which is consistent with the context-aware approach proposed by Kennedy and Cronjé (2024).

6.5 Role of Leadership and Monitoring

Leadership and monitoring were retained in the framework despite their reported non-significance in the regression model because qualitative evidence and implementation logic indicate that they coordinate other components. Leadership influences whether budgets are

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allocated, training is scheduled, responsibilities are assigned, and ICT use is incorporated into school plans. Monitoring identifies whether resources are functional and whether intended practices occur. Their influence may therefore be indirect or mediated through significant operational factors, which is consistent with framework-oriented studies that emphasise policy guidance, stakeholder participation, monitoring and contextual coordination in ICT implementation (Vidanagama & Karunathilake, 2021; Kennedy & Cronjé, 2024).

This distinction is important for interpretation. A predictor may lack independent statistical significance after controlling for correlated variables but remain necessary for implementation. The framework consequently uses leadership and monitoring as governance mechanisms rather than treating them as stand-alone inputs expected to produce integration without resources and operational capacity. This treatment also aligns with RBV, which views organisational routines, coordination and managerial capabilities as important conditions for converting resources into institutional value (Utami, 2023).

7. Implications for Policy and Practice

For policymakers and education authorities, the framework provides a basis for differentiated support. Schools should not be evaluated against identical technology packages without considering readiness and context. Authorities can establish minimum functionality standards, support baseline assessments, and allocate resources based on the most limiting factors. Aggregated monitoring data can guide regional maintenance arrangements, connectivity contracts, shared digital content and targeted professional development.

For school leaders, the framework provides a planning sequence. Schools should create multidisciplinary ICT teams, identify priority educational and administrative uses, prepare recurrent budgets and establish support procedures. Procurement decisions should consider lifecycle cost, compatibility, power requirements, security and local repair capacity. School plans should specify how teachers and learners will access resources rather than focusing only on ownership.

For teachers and ICT coordinators, the framework emphasises collaborative practice. Subject-based peer learning, demonstration lessons, shared repositories and mentoring can

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make training more relevant and sustainable. ICT coordinators should not be expected to carry all responsibilities; leadership, trained users and clear escalation arrangements should support their technical role. Teachers should also participate in selecting content and evaluating whether tools improve learning activities.

For development partners, the framework discourages isolated donation models. Support should combine infrastructure with training, maintenance, recurrent cost planning and monitoring. Pilot projects should document total cost, functionality, access and educational use before expansion. Exit strategies should define how schools or authorities will sustain services after external funding ends.

The framework can also support equity. Monitoring should identify whether access differs by subject, gender, disability, location or learner group. Offline resources, shared devices, scheduled laboratory access and inclusive content may be used where individual connectivity is not feasible. Scalability should therefore increase participation rather than concentrating benefits among a small group of users.

7.1 Stakeholder Responsibilities and Governance Arrangements

Successful implementation requires responsibilities to be distributed across school, municipal and national levels (Table 5). At school level, the head of school should provide strategic direction, approve priorities and ensure that ICT actions are incorporated into the school plan and budget. A school ICT team should coordinate the readiness assessment, maintain an asset register, schedule access, monitor functionality and review progress. ICT coordinators should manage routine technical support and user guidance, while subject teachers should identify pedagogical uses, develop or adapt content and document classroom experience.

At municipal or district level, education and ICT officers can aggregate school needs, provide specialised technical support, coordinate training and establish common procurement or maintenance arrangements. This level is particularly important where individual schools cannot employ specialised technicians. Regional and national authorities should provide standards, policy guidance, infrastructure programmes, content platforms, data protection requirements and sustainable financing mechanisms. Development partners

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and private providers should align assistance with school and national plans and disclose recurrent costs, support obligations and exit arrangements.

Governance should include accountability for assets, data and service quality. Schools need procedures for authorised access, password management, software installation, backup, disposal of obsolete equipment and protection of learner information. Procurement should avoid incompatible or unsupported technologies. Maintenance records should show the nature of faults, response time, cost and resolution. These records can help authorities identify common technical problems and improve future procurement decisions.

Participation is also necessary. Teachers, learners and administrators should contribute to readiness assessment and evaluation because they experience different access and usability problems. Learner feedback can reveal whether resources are available in practice, while teachers can identify curriculum and training needs. Inclusive governance reduces the risk that ICT decisions are made solely as technical purchases without attention to pedagogy, access and institutional routines.

Table 5: Suggested Stakeholder Responsibilities for Framework Implementation

Stakeholder	Core responsibility	Key accountability evidence
School leadership	Direction, budgeting, policy enforcement and coordination	Approved ICT plan, budget and review minutes
School ICT team/coordinator	Asset management, user support, maintenance and monitoring	Asset register, support log and functionality reports
Teachers and departments	Pedagogical integration, content use and learner support	ICT-supported lessons, assessments and shared resources
Municipal/district authorities	Specialised support, training, procurement coordination and supervision	Support schedule, training records and school performance summaries
National authorities/partners	Standards, platforms, financing, infrastructure and policy guidance	Service standards, programme reports and sustainability plans

7.2 Operationalising and Testing the Framework at School Level

Operationalisation should begin with a simple school ICT profile that records current resources, functionality, access, skills, support arrangements, recurrent costs and priority educational uses. The profile should distinguish between resources that are present and those that are actually functional. It should also identify who uses each resource, how

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frequently it is used and which groups remain underserved. This baseline enables the school to place itself within the phased pathway and prevents planning from relying on assumptions or equipment inventories alone.

The next step is to select a limited number of priority uses that can demonstrate value and be supported reliably. A school with basic infrastructure may prioritise digital lesson preparation, shared projection and examination processing, while a school with stronger connectivity may add online resources, learning platforms or digital attendance. Priority selection should consider curriculum relevance, expected users, technical requirements, recurrent cost, support capacity and the consequences of failure. Concentrating on a manageable set of functions allows the school to establish routines before expanding.

Minimum functionality criteria should be defined for each phase. For infrastructure, criteria may include a specified proportion of operational devices, secure storage, power protection and acceptable network availability. For teacher capacity, criteria may include demonstrated completion of basic tasks, use of ICT in an agreed number of lessons and access to coaching. For technical support, criteria may include a reporting channel, a fault log and an acceptable response period. These criteria provide evidence for deciding whether the school is ready to progress or should first strengthen existing arrangements.

Implementation should follow a recurring plan-do-review-improve cycle. During planning, the school sets targets, budgets and responsibilities. During implementation, users receive support and document practical experience. During review, the ICT team analyses functionality, use, access and value indicators, together with qualitative feedback from teachers and learners. Improvement actions may include additional training, timetable changes, repair, content adaptation, revised security procedures or redistribution of devices. The cycle reinforces learning and reduces the risk of repeating ineffective practices during expansion.

Testing the framework should include attention to risk management. Schools should assess data privacy, cyber security, equipment security, dependence on particular vendors, internet safety and continuity when electricity or connectivity fails. Backup procedures, user access controls, approved software, safe disposal of devices and alternative offline processes should be incorporated into implementation plans. A scalable framework must preserve not

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only access and functionality but also the integrity, safety and reliability of school information systems as use expands.

8. Limitations and Future Validation

The framework was developed from evidence collected in selected public secondary schools within one municipality. Although the urban and peri-urban variation supported contextual diversity, the findings should be validated in rural municipalities, regions with different connectivity conditions and schools with different resource levels. The study relied largely on respondent perceptions and did not directly measure examination performance, system logs, network uptime or long-term cost. In addition, both predictor and outcome variables were collected from the same self-reported instrument, raising the possibility of common-method variance; future studies should triangulate with objective indicators such as device logs or maintenance records.

Future validation should involve pilot implementation across schools representing low, medium and high readiness. Longitudinal data should assess changes in functionality, teacher use, student access, support response time, administrative efficiency and cost. Expert review can refine indicators and phase-transition criteria, while participatory evaluation can determine whether the framework remains understandable and usable by school stakeholders. Comparative research should also examine how policy, procurement and technical support structures affect scaling across local government authorities.

9. Conclusion and Recommendations

This study developed a detailed, evidence-based and scalable framework for optimising ICT integration in public secondary schools. The framework responds to the finding that integration was progressing but uneven, with stronger use in assessment and administration than in learner access and routine classroom practice. Regression evidence identified technical support and maintenance, funding and sustainability, teacher capacity building, and ICT infrastructure as the principal operational priorities. Descriptive and qualitative evidence further demonstrated the importance of institutional readiness, leadership, digital content, access and monitoring.

The framework links seven foundational inputs/enablers to coordinated implementation processes, technical and contextual moderators, immediate outputs, medium-term

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outcomes and long-term impacts. Its phased pathway enables schools to diagnose readiness, establish minimum functional conditions, build capabilities, integrate ICT into core operations and scale only after monitoring demonstrates stability and value. The framework therefore shifts attention from equipment provision to sustainable institutional capability and meaningful use.

Education authorities should adopt readiness assessment and lifecycle costing before or as part of ICT procurement. Recurrent budgets should cover connectivity, maintenance, replacement, software and continuous professional development. Schools should establish clear technical support and preventive maintenance procedures, while teacher development should be practical, subject-relevant and continuous. Monitoring should include functionality, actual use, equitable access, competence and educational value. Finally, the framework should be piloted and refined in diverse school contexts before wider adoption.

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