



Beyond Infrastructure: A Multivariate Regression Analysis of ICT Impact Factors on Academic Performance of NTA-Level 4-5 Certificate Students at Arusha Technical College

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Abstract: This study investigates the relationship between Information and Communication Technology (ICT) factors and academic performance among NTA-Level 4-5 Certificate students specializing in ICT at Arusha Technical College, Tanzania. While substantial investments have been made in ICT infrastructure across Tanzanian technical colleges, empirical evidence regarding their specific impact on student outcomes remains limited, particularly within the competency-based National Technical Award (NTA) framework. Employing a multivariate regression analysis, this research examines five key ICT dimensions: access to digital resources, frequency and type of ICT use, quality of institutional ICT support, digital literacy skills, and pedagogical integration by instructors. Data were collected through a structured questionnaire administered to 210 certificate students, combined with their actual module scores from four core ICT courses. Results from an Ordinary Least Squares (OLS) regression model indicate that pedagogical integration by instructors ($\beta = 0.382, p < 0.001$) and student digital literacy ($\beta = 0.291, p < 0.01$) are the strongest positive predictors of academic performance. Interestingly, frequency of non-academic ICT use showed a significant negative relationship ($\beta = -0.164, p < 0.05$), while basic access to infrastructure was not a significant predictor when other factors were controlled. The model explains 47% of the variance in academic performance (Adjusted $R^2 = 0.47$). The findings suggest that for NTA-Level 4-5 certificate programs, strategic focus should shift from mere infrastructural provision toward enhancing instructional practices and developing higher-order digital competencies that align with Tanzania's technical and vocational education objectives.

Keywords: ICT in TVET, Student Performance, Regression Analysis, NTA Framework, Technical Education, Tanzania, Digital Competence

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1. Introduction

The integration of Information and Communication Technology (ICT) in Technical and Vocational Education

and Training (TVET) has become a strategic priority in Tanzania (Manyengo & Renatus Manyengo, 2021), aligned with national development frameworks including Tanzania Development Vision 2025 (Tandari, 2004) and

the National ICT Policy (Tanzania, 2016). Within this context, Arusha Technical College (ATC) has implemented various ICT initiatives to support the delivery of National Technical Award (NTA) programs, particularly at the Certificate (Level 4-5) level where foundational ICT competencies are critical.

Despite these investments, academic performance among NTA-Level 4-5 ICT students has shown considerable variability, prompting questions about which specific ICT factors most significantly influence learning outcomes. The NTA framework emphasizes competency-based education where practical skills and applied knowledge are paramount, making the effective integration of ICT potentially more impactful than in general education settings.

Previous research on ICT in education has often focused on general secondary or university contexts, with limited attention to the unique dynamics of technical certificate programs (Sangrà & González-Sanmamed, 2010). Moreover, studies have frequently treated ICT as a uniform variable rather than examining its constituent dimensions. This study addresses these gaps by conducting analysis of specific ICT factors affecting certificate students at a Arusha Technical College.

The research questions guiding this study are:

1. Which specific ICT-related factors significantly predict academic performance among NTA-Level 4-5 ICT certificate students?
2. What is the relative strength and direction of these predictors?
3. How do these findings inform ICT integration strategies within Tanzania's TVET sector?

2. Literature Review

2.1 Theoretical Framework

This study is developed in two complementary theoretical foundations that collectively explain how ICT factors influence learning outcomes in technical education environments. The *Technology Acceptance Model (TAM)* developed by (Davis, 1989) provides the first conceptual lens. TAM posits that users' behavioural intention to adopt technology is primarily shaped by *perceived usefulness* and *perceived ease of use*. In the context of NTA Level 4-5 ICT programs, these constructs are especially pertinent because students interact with technology not only as a learning tool but also as an object of professional competence. Thus, students' motivation to effectively engage with digital tools ranging from programming environments to network simulators is likely influenced by their perceptions of how these technologies support task performance and how

effortless they are to operate. This makes TAM a suitable model for examining student level ICT factors such as digital literacy, frequency of ICT use, and academic-oriented technology behaviours.

Complementing TAM, this study employs the *Technological Pedagogical and Content Knowledge (TPACK)* framework introduced by (Mishra & Koehler, 2006a), which provides a holistic understanding of the instructor-side determinants of ICT effectiveness. TPACK emphasizes that effective technology-enhanced learning requires an integrated interplay of *technological knowledge (TK)*, *pedagogical knowledge (PK)*, and *content knowledge (CK)*. Within technical and vocational settings where instruction requires balancing theoretical principles with hands-on demonstrations, TPACK becomes particularly significant. Instructors must not only master the technical tools (such as programming IDEs, network analyzers, or virtual labs) but also know how to pedagogically embed these tools into competency-based training. This includes aligning ICT tools with curricular outcomes, structuring practical tasks, and orienting student learning in workshop-oriented environments.

Together, TAM and TPACK offer a dual level analytical framework: TAM explains *student adoption and engagement* with ICT resources, while TPACK explains *instructional design and facilitation* factors that shape the overall learning ecosystem. Integrating both models allows for a comprehensive examination of how ICT-related variables spanning infrastructure, digital competencies, teaching practices, and technology perceptions collectively influence academic performance in technical education programs such as those offered at Arusha Technical College.

2.2 ICT in Technical Education Context

Technical and Vocational Education and Training (TVET) presents distinct challenges and opportunities in ICT integration. Unlike general education, TVET programs demand technologies capable of simulating or interfacing with real industrial environments, making ICT use both skill-oriented and practice-oriented (Ibrahim et al., 2025). For students at NTA Levels 4-5, ICT therefore serves dual functions: it is both a standalone subject that builds foundational digital competencies and a pedagogical tool that supports the teaching and learning of other technical disciplines such as technical drawing, engineering science, and workshop practice.

Empirical studies across East Africa reveal mixed but insightful patterns regarding the influence of ICT on teaching and learning in technical education settings.

Evidence from Kenya, for instance, shows that computer-based instruction can significantly enhance learner engagement and improve academic performance in design-related subjects, suggesting that thoughtfully integrated digital tools may similarly benefit learning in technical drawing and related courses (Kinyua, 2017). However, research specific to the Tanzanian context paints a more nuanced picture. (Mtebe & Raisamo, 2014) report that the adoption of digital learning resources in higher education is frequently undermined by limited ICT infrastructure, unreliable Internet connectivity, and insufficient institutional support factors that restrict instructors' capacity to effectively implement open educational resources. Complementing these findings, (Mtebe, 2015) highlights that the success of learning management systems in Tanzanian universities is strongly influenced by instructors' digital readiness and the availability of adequate technical assistance, demonstrating that technological tools alone cannot guarantee improvements in student learning.

National evaluations further confirm these systemic challenges. The (GESCI, 2018) assessment of ICT initiatives in Tanzanian educational institutions reveals that despite ongoing investments, disparities in device access, inconsistent connectivity, and weak integration of ICT into everyday pedagogical practice continue to hinder the effectiveness of digital learning environments. Collectively, the literature suggests that while ICT carries significant potential to enhance learning outcomes in technical education, realizing this potential requires substantial improvements in infrastructure, consistent institutional support, and strengthened pedagogical capacity among instructors.

2.3 ICT Factors and Academic Performance

Research has identified several interrelated ICT dimensions that play a critical role in shaping academic performance within technical and vocational education settings. One of the foundational dimensions is *access and infrastructure*, which includes availability of computers, internet connectivity, laboratory facilities, and reliable power supply. While these elements are essential prerequisites for digital learning, several studies suggest that once minimum access is achieved, additional infrastructure does not automatically lead to improved learning outcomes unless accompanied by meaningful pedagogical use (Hu, 2017). Beyond access, the *type of ICT use* has emerged as an increasingly important factor, particularly in technical programs where practical engagement with technology directly influences competency development. Productive, academically oriented uses such as programming practice, engineering

simulations, or digital troubleshooting have been linked to higher performance, whereas non-academic uses such as entertainment, gaming, and social media may distract students and reduce time devoted to skill acquisition.

A third dimension concerns *digital literacy*, which extends far beyond basic computer operation to include task specific competencies essential in technical disciplines. For NTA-Level 4–5 students, this includes skills such as navigating specialized software, understanding digital workflow processes, applying ICT tools to technical tasks, and engaging with online technical resources. Evidence from TVET research indicates that students with stronger applied digital literacy are better able to transfer theoretical knowledge into practical contexts, thereby improving performance in competency-based assessments (Regassa & Desissa, 2025; Zhong & Juwaheer, 2024). Equally important is *pedagogical integration of ICT*, which refers to how instructors embed technology into teaching and learning activities. In competency-based education systems such as those used in Tanzanian NTA programs, effective integration involves using ICT to demonstrate procedures, simulate technical processes, provide virtual labs, and support formative assessment. Studies consistently show that well designed pedagogical use of ICT amplifies student engagement, enhances problem-solving abilities, and strengthens mastery of practical skills. Conversely, limited or superficial integration such as using ICT only for presentations has minimal impact on learning outcomes.

3. Methodology

3.1 Research Design and Context

This study employed a quantitative, cross-sectional design combining survey data with academic records. The research was conducted at Arusha Technical College, focusing specifically on NTA-Level 4-5 Certificate students in ICT-related programs (Information Technology, Computer Science, and Multimedia and Animation Technology).

The NTA-Level 4 certificate program spans two years and includes both theoretical and practical components, with ICT integrated across multiple modules. This context provides an ideal setting for examining how different ICT factors influence performance in a competency-based technical education environment.

3.2 Participants and Sampling

A stratified random sampling technique was used to select participants from three ICT-related departments. The sample consisted of 210 certificate students (Table 1), representing approximately 65% of the target population.

The sample size was determined using Cochran's formula with a 5% margin of error and 95% confidence level.

Table 1. Demographic Characteristics of the Sample

Sample Characteristics (N=210)		
Characteristic	Frequency	Percentage
Gender		
Male	138	65.7%
Female	72	34.3%
Program		
Information Technology	92	43.8%
Computer Science	68	32.4%
Multimedia and Animation Technology	50	23.8%
Year of Study		
Year 1	110	52.4%
Year 2	100	47.6%
Age Range		
18-20 years	158	75.2%
21-23 years	52	24.8%

3.3 Variables and Measures

3.3.1 Dependent Variable

Academic Performance: Academic performance was operationalized as a composite achievement index calculated from the final examination results in four core ICT modules central to the NTA Level 4–5 curriculum: Microcomputer Applications (MCA), Programming Using C (PUC), Introduction to Computer Networks (ICN), and

Web Designing (WD). These modules were selected because they represent foundational competencies in both theoretical and applied ICT skills. Raw examination scores from each module were first normalized to a uniform 100-point scale to ensure comparability across assessments with different grading structures. The standardized module scores were then aggregated using an equal-weighting approach to generate a composite performance score for each student. Internal consistency analysis indicated strong reliability of the composite index, with Cronbach's alpha

of $\alpha = 0.82$, demonstrating that the four modules collectively measure a coherent underlying construct of ICT academic competence.

3.3.2 Independent Variables (ICT Factors)

Five key ICT dimensions were measured using a 5-point Likert scale questionnaire, which demonstrated strong overall reliability (Cronbach's $\alpha = 0.86$). ICT Access and Infrastructure (AC) was assessed using six items that examined students' availability of computers, software, internet connectivity, and specialized ICT equipment ($\alpha = 0.78$). Academic ICT Use (AU) consisted of five items capturing how frequently students used ICT for coursework, programming practice, online research, and other learning-related tasks ($\alpha = 0.81$). Non-academic ICT Use (NU) was measured through four items focusing on students' engagement with social media, entertainment, and gaming activities ($\alpha = 0.79$). Digital Literacy Competence (DL) included seven items evaluating students' technical skills, information literacy, and ability to use ICT tools for problem-solving ($\alpha = 0.84$). Instructor Pedagogical Integration (PI) was assessed using six items that captured the extent to which instructors effectively incorporated ICT into teaching, aligned learning activities with technical skills, and provided digital support to learners ($\alpha = 0.87$).

3.3.3 Control Variables

Several control variables were incorporated to account for external factors that may influence student academic performance beyond the primary predictors. First, prior academic performance measured through secondary school grades was included to capture students' academic ability and learning preparedness before entering the program. Socioeconomic status, operationalized as a composite indicator of parental education and occupation, was also controlled for, as it often shapes learners' access to educational resources, study environments, and overall academic support. Gender was considered to examine and neutralize any performance variations that might arise from demographic differences. Additionally, the program of

study was included as a control variable, recognizing that different academic programs have distinct curricular demands, learning environments, and assessment structures which may affect performance outcomes. Finally, the number of hours dedicated to practical training per week was controlled for, given that increased hands on exposure can enhance skill acquisition and academic outcomes, particularly in applied and technical fields.

3.4 Data Collection and Analysis

Data were collected during the 2023/2024 academic year. The questionnaire was administered in controlled settings during scheduled class sessions. Academic performance data were obtained from college records with appropriate confidentiality protocols.

Statistical analysis was conducted using SPSS version 26. After data screening (missing values, outliers, normality assumptions), correlation analysis was performed followed by hierarchical multiple regression. The regression equation:

$$Y = \beta_0 + \beta_1(AC) + \beta_2(AU) + \beta_3(NU) + \beta_4(DL) + \beta_5(PI) + \beta_i(Controls) + \epsilon$$

Where Y represents academic performance, β_0 is the intercept, β_1 to β_5 are coefficients for ICT factors, β_i are control variable coefficients, and ϵ is the error term.

4. Results and Discussion

4.1 Descriptive Statistics and Correlations

Table 2: presents descriptive statistics and Pearson correlations for study variables. Preliminary analysis revealed significant positive correlations between academic performance and both digital literacy ($r = 0.42, p < 0.01$) and pedagogical integration ($r = 0.48, p < 0.01$). Non-academic ICT use showed a negative correlation with performance ($r = -0.21, p < 0.05$).

Table 2. Descriptive statistics and Pearson correlation coefficients for study variables

Variable	Mean	SD	1	2	3	4	5
Academic Performance	68.42	12.35	1.00	-	-	-	-
ICT Access (AC)	3.85	0.92	.18*	1.00	-	-	-
Academic Use (AU)	3.62	0.88	.31**	.24**	1.00	-	-
Non-academic Use (NU)	4.15	0.79	-.21**	.12	-.08	1.00	-
Digital Literacy (DL)	3.38	0.85	.42**	.19**	.35**	-.14	-
Pedagogical Integration (PI)	3.51	0.91	.48**	.27**	.41**	-.09	.39**

Note: * $p < 0.05$, ** $p < 0.01$

4.2 Regression Analysis

Hierarchical regression analysis was conducted in three sequential blocks to examine the unique and combined contributions of the predictor variables to academic performance. In the first block, all control variables prior to academic performance, socioeconomic status, gender, program of study and practical training hours were entered to account for baseline demographic and academic influences.

In the second block, variables representing ICT access and patterns of use (ICT access, academic ICT use, and non-academic ICT use) were added to determine whether the availability and frequency of ICT engagement explained additional variance beyond the controlled demographic factors. This stage specifically tested the assumption that mere access to ICT resources or frequency of use has a meaningful impact on student academic outcomes.

In the third and final block, competency-oriented variables digital literacy and pedagogical integration of ICT were entered to assess their incremental predictive power after accounting for both background characteristics and ICT access/use variables. This helps the evaluation of whether higher order ICT capabilities and instructional practices contribute significantly to academic performance beyond

structural or usage factors. The hierarchical structure of the model therefore enabled a clear comparison of the relative importance of each category of predictors and provided insights into the mechanisms through which ICT influences academic achievement.

4.3 Model Summary

The final model as shown in Table 3 explained 47% of the variance in academic performance (Adjusted $R^2 = 0.47$, $F(11,198) = 18.73$, $p < 0.001$). This indicates that the full combination of control variables, ICT access and use factors, and competency-based predictors provides a substantial and statistically significant contribution to understanding the determinants of student achievement. The F-statistics confirm that the overall model fits the data well and that the predictors, taken together, reliably distinguish between higher and lower-performing students. Importantly, the increase in explained variance across the three stages of the regression shows the incremental value of each block, with the competency and pedagogical integration variables contributing the largest improvement to model performance. This suggests that beyond demographic characteristics and levels of ICT access or usage, deeper cognitive and instructional dimensions play a key role in shaping academic outcomes in ICT related certificate programs.

Table 3: Model Results Summary

Predictor	Model 1	Model 2	Model 3
Control Variables			
Prior Performance	0.228**	0.215**	0.192*
Socioeconomic Status	0.184*	0.171*	0.158*
Gender	-0.042	-0.038	-0.031
Program (IT)	0.108	0.095	0.087
Practical Hours	0.165*	0.152*	0.138
ICT Access/Use			
ICT Access (AC)	-	0.092	0.047
Academic Use (AU)	-	0.187*	0.142
Non-academic Use (NU)	-	-0.183*	-0.164*
Competency/Pedagogy			
Digital Literacy (DL)	-	-	0.291**
Pedagogical Integration (PI)	-	-	0.382***
R^2	0.18	0.29	0.49
Adjusted R^2	0.15	0.25	0.47
ΔR^2	-	0.11***	0.20***

Note: Standardized beta coefficients shown. * $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$

4.4 Key Findings

The hierarchical regression analysis revealed several important insights into how different ICT-related factors influence academic performance among NTA-Level 4 students. Pedagogical Integration (PI) emerged as the strongest predictor of student achievement ($\beta = 0.382$, $p < 0.001$). This finding underscores that the quality of ICT integration by instructors how effectively digital tools are embedded into teaching and learning activities has a more substantial impact on student performance than mere exposure to technology. Effective pedagogical use of ICT appears to transform technology from a passive resource into an active learning instrument, thereby enhancing student understanding and engagement.

Digital Literacy (DL) was the second most important predictor ($\beta = 0.291$, $p < 0.01$). This result highlights the critical role of students' higher-order digital competencies, including problem-solving, information evaluation, and task-specific ICT skills. Students who possess stronger digital literacy are better equipped to use technology effectively for academic purposes, navigate digital learning

environments, and complete practical ICT tasks all of which contribute positively to their academic performance.

Non-academic ICT Use (NU) showed a significant negative association with academic performance ($\beta = -0.164$, $p < 0.05$). This suggests that frequent engagement with technology for entertainment, social media, or gaming may displace study time or reduce cognitive focus, ultimately hindering learning outcomes. Although ICT is a central part of students' daily lives, excessive non-academic use may undermine their ability to benefit academically from technology.

In contrast, ICT Access (AC) and Academic Use (AU) demonstrated diminishing predictive power as additional variables were entered into the model. While both factors showed modest positive relationships in the intermediate stage of the analysis, their effects became statistically non-significant once Digital Literacy and Pedagogical Integration were included. This indicates that having access to ICT resources or using them for academic tasks is not sufficient, on its own, to improve academic achievement. Instead, the influence of access and usage appears to be largely mediated by *how competently students use these tools* and *how effectively instructors*

integrate them into learning. In short, access and usage provide necessary conditions for ICT-based learning, but they do not guarantee improved performance without strong pedagogical support and advanced digital skills.

Generally, the findings emphasize that the value of ICT in technical education depends more on how technology is used and understood than on how much of it is available. Pedagogical quality and digital competence are the primary drivers of academic success in ICT-based learning environments, while infrastructural access and basic usage play a supportive role.

4.5 Discussion

Interpretation of Key Findings

The strong predictive power of pedagogical integration aligns with the core premise of the Technological Pedagogical Content Knowledge (TPACK) framework, which emphasizes that meaningful technology use in education requires an integrative understanding of content, pedagogy, and technology, rather than treating them in isolation (Mishra & Koehler, 2006b). In the context of NTA-Level 4-5 certificate programs, effective ICT integration likely involves demonstrating practical applications, simulating workplace scenarios, and providing authentic technical problem-solving opportunities. This finding resonates with (Harris & Hofer, 2011) assertion that technology integration must be grounded in content-specific learning activities. It is further supported by (Graham, 2011) work on TPACK, which argues that the most effective technology integration is "content-centric," a principle that directly applies to the applied, skill-based nature of technical and vocational education and training (TVET). The integration must move beyond generic tools to those that model and scaffold specific trade practices.

The significance of digital literacy as a predictor underscores that technical students require more than basic operational computer skills (ICT literacy). They need the critical competencies encapsulated within broader digital literacy frameworks, such as information evaluation, digital problem-solving, and adaptive learning skills essential for lifelong learning in rapidly evolving technical fields. This aligns with key dimensions of the European Commission's DigComp framework, particularly "information and data literacy," "digital content creation," and "problem solving" (Carretero et al., 2017). This necessity is further emphasized by research indicating that the future workforce will require not just routine technical skills but strong digital problem-solving abilities to adapt to new technologies (OECD, 2019). For TVET students, this implies digital literacy is not a separate subject but a foundational element of professional competence.

The negative association between non-academic ICT use and academic performance warrants careful interpretation. While correlation does not imply causation, this finding is consistent with a body of research suggesting that extensive leisure-focused digital media use, particularly involving multitasking, can displace study time and fragment cognitive attention, thereby impairing academic outcomes (van der Schuur et al., 2015). This is particularly relevant for certificate students who require sustained, focused attention and substantial hands-on practice to develop procedural fluency and technical competencies. However, the relationship is nuanced. Research by (Junco, 2012) found that while certain social media activities correlate negatively with GPA, others can be neutral or even beneficial, suggesting that the *type* and *purpose* of use are critical moderating factors. Therefore, this finding may point less to a simple detriment of non-academic use and more to the critical need to develop students' self-regulation and digital time-management skills to ensure academic engagement remains prioritized.

4.6 Implications for Practice

For TVET Institutions

- a) Professional Development: Invest in sustained instructor training focused on pedagogical integration of ICT specific to technical subjects, moving beyond basic digital literacy.
- b) Curriculum Design: Integrate higher-order digital competencies explicitly into NTA-Level 4-5 curricula, aligning with industry requirements.
- c) Learning Environment Design: Create structured opportunities for academic ICT use while promoting balanced technology use among students.

For Policymakers

- a) Resource Allocation: Shift emphasis from hardware procurement toward supporting pedagogical innovation and digital competence development.
- b) Quality Assurance: Incorporate indicators of effective ICT integration and digital competence into TVET quality frameworks.
- c) Research Support: Fund further research on contextualized ICT integration models for different technical trades.

4.7 Limitations and Future Research

This study has several limitations. The cross-sectional design precludes causal inferences. The focus on a single

technical college limits generalizability, though ATC's status as a leading institution provides important insights. Self-reported measures of ICT use may be subject to social desirability bias.

Future research should:

- a) Employ longitudinal designs to examine causal relationships over time
- b) Include observational measures of actual ICT use in technical training settings
- c) Investigate discipline-specific ICT integration approaches across different technical trades
- d) Explore the interaction between digital literacy and pedagogical integration
- e) Examine similar questions in other Tanzanian technical colleges for comparative analysis

5. Conclusion and Recommendations

This study provides empirical evidence that for NTA-Level 4-5 certificate students at Arusha Technical College, the impact of ICT on academic performance is mediated primarily through pedagogical integration and digital literacy competencies. While access to ICT infrastructure remains a necessary foundation, it is insufficient alone to enhance learning outcomes in technical education. The findings challenge the assumption that increased ICT access automatically translates to improved performance and instead highlight the critical importance of human and pedagogical factors.

For Tanzania's TVET sector to effectively harness ICT for quality technical education, strategic attention must focus on developing instructors' capacity for meaningful ICT integration and cultivating students' higher-order digital competencies. These efforts should be contextualized within the specific requirements of technical trades and aligned with both national development goals and global digital transformation trends in technical education. Moreover, reflective and adaptive practices are foundational for institutional learning. (Ben Youssef et al., 2022) and (Guillén-Gámez et al., 2022) noted that higher-education institutions that institutionalize reflective cycles through data-informed teaching evaluations, regular technology audits, and participatory feedback demonstrate higher adaptability and innovation capacity. Such organizations transform digital feedback into organizational learning, positioning themselves as learning institutions in the digital age. Therefore, adaptive practice represents the iterative alignment of pedagogy, technology, and institutional policy to evolving educational realities.

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