

Building Smart Digital Learning Environments in Resource-Constrained Universities: Evidence from Tanzania's Higher Education for Economic Transformation Initiative

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Abstract: Universities worldwide are investing in digital technologies to improve teaching and learning. However, establishing smart digital learning environments requires more than providing technological infrastructure; it depends on how universities develop, connect, and sustain digital systems. This study examined the extent to which Tanzania's Higher Education for Economic Transformation (HEET) initiative has contributed to the development of smart digital learning environments in public universities. A convergent mixed-methods design was employed, involving five public universities that implemented the initiative. Quantitative data were collected from 271 academic staff, while qualitative data were obtained through interviews with ICT and physical infrastructure leaders and supported by institutional observations. Descriptive statistics, one-way ANOVA, and thematic analysis were used to analyse the data. The findings revealed moderate progress towards smart digital learning environments, driven by improved ICT infrastructure, internet connectivity, smart classrooms, and digital learning platforms. The progress differed significantly across universities, $F(4, 264) = 7.51, p < .001$, indicating that institutions transformed at different levels. The findings further indicated that these differences were influenced by implementation progress, existing digital capacity, and institutional coordination. The study concludes that building smart universities requires not only investment in technology but also strong institutional systems that support sustainable digital transformation.

Keywords: Digital Transformation; Higher Education; ICT Infrastructure; Resource-Constrained Universities; Smart Digital Learning Environments; Tanzania.

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I. INTRODUCTION

Digital transformation has become an important priority for universities worldwide as institutions seek to improve access, quality, and flexibility in teaching and learning. Universities are investing in digital infrastructure, internet connectivity, learning management systems, digital libraries, and technology-supported classrooms to respond to changing educational needs [1], [2]. These developments show that

technology has become an important part of how universities organise and deliver education.

However, having digital technologies does not automatically mean that a university has achieved digital transformation. Recent studies argue that successful digital transformation depends on how institutions connect technological resources with teaching, learning, and institutional systems [3], [4]. A university may have modern classrooms, computers, and internet access, but these

resources create meaningful change only when they are accessible, functional, and integrated into teaching and learning.

The idea of smart digital learning environments reflects this broader understanding of transformation. Smart learning environments influence digital infrastructure, connectivity, and online systems to create learning spaces that support access to information, communication, and flexible learning opportunities [5], [3]. Therefore, building smart universities requires attention not only to the availability of technology but also to the institutional conditions that enable these technologies to support learning.

This issue is particularly important in resource-constrained higher education systems. Many universities in developing countries continue to face long-standing challenges of inadequate infrastructure, limited internet connectivity, and unequal access to digital resources [6], [7], [8]. In addition, although investments in educational technologies have increased, universities differ in how effectively they translate these investments into improved learning environments. This indicates that digital transformation is a gradual process influenced by institutional conditions and implementation capacity.

In Tanzania, the government introduced the Higher Education for Economic Transformation (HEET) project to strengthen the quality and relevance of higher education. Among its major priorities, the project supports universities by constructing and renovating learning facilities, expanding ICT infrastructure, improving connectivity, and developing digital learning systems [9], [10]. These investments represent an important effort to move public universities towards technology-supported learning environments.

Despite these investments, there is limited evidence on the extent to which such initiatives have transformed universities into smart digital learning environments. Existing studies in Tanzania have mainly focused on ICT adoption, e-learning practices, and barriers affecting technology use [7], [11]. The attention to understanding how large-scale investments contribute to broader institutional transformation through infrastructure, connectivity, and digital systems was crucial.

This study addresses this gap by examining digital transformation as a process of building functional learning environments rather than simply providing technological resources. It argues that becoming a smart university requires universities to connect infrastructure investment with digital systems and institutional support.

Therefore, this study examined the extent to which Tanzania's Higher Education for Economic Transformation initiative has contributed to the development of smart digital learning environments in public universities. Specifically, the study examined the development of smart digital learning infrastructure, the integration of digital platforms and technology-supported systems, and institutional differences affecting sustainable digital transformation.

The study provides evidence from a resource-constrained context by showing how universities are moving towards digital transformation and why similar investments may yield different levels of progress across institutions.

II. LITERATURE REVIEW

Digital transformation in higher education has attracted attention as universities seek to improve teaching, learning, and institutional services through technology. Earlier discussions on technology in education focused mainly on providing computers, internet access, and digital tools. However, recent studies show that digital transformation involves broader changes in how universities organise learning environments, support access to information, and integrate technology into institutional activities [1], [2]. This means that technology investment alone does not determine whether a university has become digitally transformed.

The development of smart digital learning environments has emerged as an important direction in higher education transformation. Smart learning environments are created when digital infrastructure, connectivity, learning platforms, and institutional systems work together to support teaching and learning [3], [5]. These environments may include smart classrooms, learning management systems, digital libraries, multimedia facilities, and reliable internet services. However, the presence of these facilities does not automatically make a university smart. The value of digital technologies depends on how effectively universities connect and sustain them within the learning environment [12].

Evidence from previous studies shows that digital technologies can improve higher education by increasing access to learning materials, supporting flexible learning, strengthening communication, and improving the management of educational resources [2], [13]. Universities that successfully integrate digital systems are better positioned to respond to changing educational demands. Nevertheless, researchers continue to emphasise that technology produces meaningful benefits only when institutions have the capacity to manage and sustain digital changes [4].

In many resource-constrained contexts, universities are still working to develop the basic conditions required for digital transformation. Limited ICT facilities, unreliable internet connectivity, inadequate funding, and difficulties maintaining digital systems continue to affect many higher education institutions [6], [7]. As a result, governments and development partners have increased investments to strengthen digital infrastructure and expand access to technology-supported education.

Although such investments are important, studies from developing contexts indicate that universities do not always achieve the same level of transformation after receiving technological support. Some institutions adopt digital systems more quickly, while others progress more slowly due to differences in implementation capacity, existing infrastructure, and institutional arrangements [4], [11], [14], [15]. This suggests that digital transformation should be

understood as a process that depends on both technological resources and institutional conditions.

In African higher education, research has largely focused on access to ICT resources, the adoption of online learning, and the challenges affecting technology use. These studies have provided important insights into the barriers and opportunities associated with digital education [6], [7], [8]. However, less attention has been given to examining how large-scale national investments contribute to the development of smart digital learning environments, especially by considering infrastructure, connectivity, digital platforms, and institutional differences together.

In Tanzania, previous studies have examined e-learning systems, ICT adoption, and factors influencing the use of educational technologies in universities [11]. However, many of these studies were conducted before recent national investments aimed at transforming higher education infrastructure and digital capacity. Therefore, there is limited evidence on whether these investments have enabled universities to transition from traditional to smart digital learning environments.

This study addresses this gap by examining digital transformation as an institutional development process rather than merely the availability of technology. Therefore, building smart digital learning environments requires universities to develop infrastructure, digital systems, and institutional capacity together. By examining Tanzania's higher education digital transformation initiative, this study provides evidence on how resource-constrained universities progress towards smart learning environments and why transformation may differ across institutions.

➤ *Theoretical Framework*

This study views the development of smart digital learning environments as a process through which universities convert technological investments into functional learning systems. Previous studies on digital transformation indicate that technology creates meaningful educational change when infrastructure, digital systems, and institutional processes operate together rather than as separate components [1], [3].

Based on this understanding, the study was guided by a smart digital learning environment perspective, which assumes that university transformation depends on three connected areas: digital infrastructure, digital learning systems, and institutional capacity.

Digital infrastructure represents the foundation of transformation. It includes physical and technological resources such as ICT facilities, smart classrooms, multimedia facilities, internet connectivity, and technology-supported learning spaces. These resources create the conditions needed for universities to introduce digital forms of teaching and learning.

Digital learning systems represent the movement from having technology to using technology as part of university operations. These include learning management systems,

online learning resources, digital communication platforms, and other systems that allow students and academic staff to access and share learning materials.

Institutional capacity refers to universities' ability to organise, manage, maintain, and sustain digital investments. Even when universities receive similar technological resources, differences in planning, implementation processes, technical support, and existing capacity may influence the level of transformation achieved.

The framework assumes that smart digital learning environments are developed when infrastructure, digital systems, and institutional capacity support one another. Technology investment provides the opportunity for transformation, but universities determine the extent of change through how effectively they implement and sustain these resources.

This three-part perspective is complemented by diffusion-of-innovation theory, which explains why institutions that receive similar technological investments adopt and institutionalise them at different rates depending on their existing capacity, leadership commitment, and organisational readiness for change [16], [17]. This lens is particularly useful for interpreting the institutional differences examined under the study's third objective.

Therefore, building smart universities is not only about installing digital technologies; it is about turning these technologies into an accessible, functional, and sustainable learning environment.

III. METHODOLOGY

➤ *Research Design and Context*

This study employed a convergent design within a mixed-methods research approach to examine the extent to which Tanzania's Higher Education for Economic Transformation (HEET) initiative contributed to the development of smart digital learning environments in public universities [18]. The design was selected because understanding digital transformation required both measuring the level of progress and explaining institutional experiences behind the observed changes.

Quantitative data provided evidence on the development of digital infrastructure, connectivity, and digital learning systems, while qualitative data explained how universities implemented, managed, and sustained these digital investments. Both forms of data were collected during the same period, analysed separately, and integrated during interpretation to provide a comprehensive understanding of digital transformation.

The study was conducted across five Tanzanian public universities that are implementing the HEET initiative. The initiative represents a national investment to improve higher education through modern teaching and learning infrastructure, ICT facilities, internet connectivity, digital learning systems, and institutional development [9], [10]. In

this study, HEET was examined as an initiative supporting universities' movement towards smart digital learning environments.

➤ *Participants and Data Collection Procedures*

Participants included academic staff, ICT leaders, and physical infrastructure leaders from the five participating universities. These groups were selected because they provided different perspectives on the development and functioning of digital learning environments. Academic staff provided information on the availability and use of digital facilities, while the leaders of the ICT and physical infrastructure components provided institutional-level information on implementation progress, achievements, and challenges.

Five public universities implementing HEET were selected for the study. Academic staff were selected using proportionate stratified random sampling to ensure representation across participating institutions. A total of 271 academic staff questionnaires were returned. Key informants, including ICT and infrastructure leaders, were purposively selected for their direct involvement in planning and implementing digital transformation initiatives.

Data were collected through questionnaires, semi-structured interviews, and institutional observations. The questionnaire measured participants' perceptions regarding improvements in ICT infrastructure, internet connectivity, digital learning facilities, and technology-supported learning environments using a five-point Likert scale ranging from very low extent to very great extent.

Interviews explored how universities developed digital infrastructure, introduced learning systems, managed implementation processes, and addressed sustainability challenges. Institutional observations were used to verify the availability and functionality of facilities, including smart classrooms, ICT facilities, internet systems, and digital learning spaces.

Using these different sources enabled the study to compare reported experiences with observed institutional conditions and provide a broader understanding of digital transformation.

➤ *Data Analysis and Ethical Considerations*

Quantitative data were analysed using descriptive and inferential statistics. Means and standard deviations were used to determine the extent to which universities progressed towards smart digital learning environments. A one-way analysis of variance (ANOVA) was conducted to examine whether the level of digital transformation differed significantly among participating universities.

Qualitative data from interviews and observation guides were analysed thematically. The analysis involved identifying recurring ideas across infrastructure development, digital learning systems, implementation processes, and factors influencing sustainable transformation. The quantitative and qualitative findings were integrated during interpretation. Quantitative findings showed the extent and pattern of transformation, while qualitative findings explained the institutional conditions behind these patterns.

The study's credibility was ensured through multiple data sources, including questionnaires, interviews, and observations. Ethical approval and institutional permission were obtained before data collection. Participation was voluntary, informed consent was obtained from all respondents, and confidentiality was maintained by protecting participants' and participating institutions' identities.

IV. RESULTS

The findings were presented in accordance with the study objectives. Quantitative findings show the extent to which universities progressed towards smart digital learning environments, while qualitative evidence explains how universities developed and sustained these digital changes.

➤ *Development of Smart Digital Learning Infrastructure*

The first objective examined the extent to which the HEET initiative contributed to the development of smart digital learning infrastructure in public universities. The analysis focused on improvements in ICT facilities, internet connectivity, networking systems, online learning infrastructure, and technology-supported learning spaces.

Table 1 Development of Smart Digital Learning Infrastructure (N = 271)

Indicator	Mean	SD
Improvement of computer laboratories	2.93	1.40
Improvement of internet services	3.10	1.35
Improvement of networking systems	3.00	1.34
Development of online learning infrastructure	3.00	1.34
ICT infrastructure supporting inclusive learning	2.93	1.35

The results in Table 1 show that universities have made moderate progress in developing the infrastructure required for smart digital learning environments. The highest-rated areas were online learning infrastructure (M = 3.12) and internet services (M = 3.10), indicating improvement in the technological foundation needed to support digital learning. The findings further show that computer laboratories and

inclusive ICT infrastructure received lower ratings. These findings suggest that infrastructure development was still ongoing.

The qualitative findings supported these results by showing that universities had improved their digital facilities,

although they started from different levels of readiness. One ICT leader explained the improvement in connectivity:

“Previously, we had a bandwidth of 230 Mbps, but we increased it to 550 Mbps for the main campus, while maintaining 100 Mbps for the remote campus. So, in total bandwidth for the university now, we have 650.” (ICT Leader, University A)

- *However, Some Universities were Still Developing Their Digital Foundation:*

“We had no improvements at first; we started many things from scratch.” (ICT Leader, University C)

- *Another Participant Explained:*

“We are expecting to have two new computer laboratories. The construction is ongoing, so we have not yet procured the ICT facility.” (ICT Leader, University D)

Together, the findings indicate that HEET strengthened the foundation for smart digital learning environments, and the universities were at different stages of development.

- *Development of Connected Digital Learning Systems*

The second objective examined whether universities moved beyond infrastructure development towards digital systems that support learning. The analysis focused on learning management systems, online learning facilities, and digital platforms.

Table 2 Development of Digital Learning Systems (N = 271)

Indicator	Mean	SD
Digital infrastructure supports learning activities	3.11	1.26
Integration of digital technologies into university systems	3.15	1.39
Development of online learning services	3.14	1.36
Grand Mean	3.13	—

The results in Table 2 show that universities had begun moving from technology availability to connected digital learning systems. However, the moderate mean score indicates that this transition was still developing.

The interview findings explained how universities were connecting digital infrastructure with learning systems. One participant explained:

“Regarding the Learning Management System, we have integrated it with Zoom. If the lecturer is physically on campus, they teach in the classroom, while students who are not present can attend remotely via Zoom.” (ICT Leader, University A)

- *Another Participant Described how Digital Platforms Expanded Learning Opportunities:*

“The teacher does not need to be physically present in the school environment all the time; they use those platforms to communicate with their students and teach.” (ICT Leader, University D)

- *Infrastructure Leaders Also Explained that New Facilities were Designed to Support Technology-Enabled Learning:*

“Our classrooms support ICT initiatives; for example, if students are far away, they can study using the ICT infrastructure that accommodates remote learning.” (Physical Infrastructure Leader, University C)

These findings show that universities were not only installing technology but were beginning to create digital systems that support flexible learning.

- *Institutional Differences in Building Smart Digital Learning Environments*

The third objective examined whether universities progressed at the same level towards smart digital transformation.

Table 3 Institutional Differences in Digital Transformation

University	Mean
University A	3.15
University B	2.60
University C	3.47
University D	3.61
University E	3.25

The results in Table 3 show that progress towards smart digital learning environments differed among universities. University D showed the highest progress ($M = 3.61$), followed by University C ($M = 3.47$), while University B recorded the lowest ($M = 2.60$). A one-way ANOVA confirmed that these differences were statistically significant: $F(4, 264) = 7.51, p < .001, \eta^2 = .10$.

This finding indicates that universities implementing the same national initiative progressed at different levels. During the interview, the qualitative findings showed that the progress of implementation and institutional conditions influenced these differences. For example, one university was still testing its facilities as participants reported:

“We decided to test the smart class. How successful is it?” (ICT Leader, University B)

In contrast, other universities had already moved towards functioning digital systems.

“The digital infrastructure is now fully operational. Lecturers can conduct online learning, share materials

through the LMS, and communicate with students efficiently because internet access and ICT facilities have improved." (ICT Leader, University E)

In general, findings demonstrate that HEET has supported the development of smart digital learning environments in Tanzanian public universities. The findings further revealed that transformation was still developing, as universities differ in how quickly they convert infrastructure investments into functional, sustainable digital systems.

V. DISCUSSION

This study examined the extent to which Tanzania's Higher Education for Economic Transformation (HEET) initiative has contributed to the development of smart digital learning environments in public universities. The findings show that the initiative has strengthened universities' digital foundations.

The first finding showed that HEET improved the technological foundation required for smart digital learning environments. Universities reported improvements in ICT facilities, internet services, computer laboratories, smart classrooms, and online learning infrastructure. The findings confirmed these improvements by showing how universities expanded internet bandwidth, established digital facilities, and developed technology-supported learning spaces.

This finding supports previous studies, which argue that digital infrastructure is an important requirement for transforming higher education [1], [2]. Similarly, Huang et al. [3] emphasise that smart learning environments depend on the availability of digital resources that enable access to information and flexible learning.

This study shows that infrastructure alone does not represent full digital transformation. Although universities had improved facilities, some institutions were still constructing laboratories, testing smart classrooms, or expanding connectivity. This explains why the overall transformation remained moderate. Therefore, this study extends previous knowledge by showing that infrastructure investment is the beginning of digital transformation, not its final achievement. A university becomes smart when digital resources are functional, accessible, and connected to learning systems.

The second finding showed that universities were moving from infrastructure development towards digital learning systems. The introduction of learning management systems, online learning platforms, and technology-supported services demonstrated progress towards smart digital learning environments.

This finding aligns with Zhu et al. [5], who argue that smart learning environments require integrating technology, learning resources, and institutional systems. It also supports Ifenthaler and Egloffstein [4], who argue that digital transformation requires institutions to move beyond technology adoption towards sustainable digital practices.

The study findings show that Universities were not only installing ICT facilities but were also connecting these resources with teaching and learning through systems such as Moodle, Zoom integration, and online learning resources. This study adds that the difference between a university with technology and a smart university was the ability to connect technologies into a functioning learning environment. Computers, the internet, and digital platforms become valuable when they work together to support educational activities.

The third finding showed significant differences among universities implementing the same national initiative. Although all institutions received support through HEET, the level of progress towards smart digital learning environments varied.

This finding confirms previous research showing that digital transformation outcomes depend on institutional conditions, not only the availability of resources [6], [7], [14], [15]. Universities may receive similar investments but achieve different results because they differ in existing infrastructure, implementation processes, technical capacity, and sustainability arrangements.

These findings are consistent with diffusion-of-innovation theory, which frames institutions as adopting a common innovation at different rates depending on their absorptive capacity, leadership commitment, and organisational readiness [16], [17]. Viewed this way, University B's slower progress and University D's faster progress reflect differences in institutional readiness rather than differences in the resources each university received.

The findings from this study show that some universities had already developed functioning digital systems, while others were still constructing facilities or testing technologies. This explains why the transformation was uneven.

The contribution of this study is that it shows that resource-constrained universities do not follow the same path towards digital transformation. National investment creates opportunities, but institutional capacity determines how quickly universities turn those opportunities into sustainable digital learning environments.

➤ Contribution of the Findings

The findings demonstrate that HEET has moved Tanzanian public universities towards smart digital learning environments, but the transformation is still developing. The initiative has successfully addressed important digital gaps by improving infrastructure, connectivity, and digital platforms. Yet universities are at different stages of transforming these investments into fully functioning digital learning environments.

This study shifts the discussion from asking whether universities have technology to asking how universities transform technology into sustainable learning environments. The evidence from Tanzania shows that building smart universities requires three connected elements: digital

infrastructure, digital systems, and institutional capacity. The study therefore contributes to digital transformation literature by demonstrating that smart universities are not created by installing technologies; they are developed when universities can organise, connect, and sustain digital resources for teaching and learning.

This study contributes to the literature on digital transformation in higher education in three main ways. First, the study extends understanding of digital transformation by shifting attention from the availability of technology to the process of building functional digital learning environments. Previous studies have often focused on ICT access, technology adoption, and barriers to use. This study shows that digital transformation involves more than providing computers, internet services, or digital platforms. The findings demonstrate that smart digital learning environments develop when infrastructure, digital systems, and institutional capacity work together.

Second, the study provides evidence from resource-constrained universities, where digital transformation follows a different path than in institutions with advanced technological systems. The findings show that universities may receive similar investments but progress differently because of differences in existing infrastructure, implementation processes, and the ability to sustain new systems. This highlights that digital transformation is not only about the amount of investment provided but also how institutions convert that investment into functioning learning environments.

Third, the study provides empirical evidence from Tanzania's higher education sector, which is underrepresented in international discussions on smart universities. By examining the HEET initiative, the study demonstrates how national investment programmes can support universities in moving from traditional learning environments towards digitally supported systems. Overall, the study contributes a practical understanding that building smart universities is a continuous institutional process rather than a single technological intervention.

VI. PRACTICAL IMPLICATIONS, LIMITATIONS, AND CONCLUSION

➤ *Practical Implications*

The findings provide important lessons for policymakers, university leaders, and development partners involved in higher education transformation.

First, investment in digital infrastructure should be accompanied by strategies that ensure long-term use and sustainability. Although ICT facilities, smart classrooms, and internet systems lay the foundation for transformation, universities need clear plans to maintain and integrate these resources into daily academic activities.

Second, universities should approach digital transformation as an institutional agenda rather than only an ICT project. The findings show that infrastructure, digital

platforms, technical support, and institutional planning must operate together. Strengthening one area while ignoring others may limit the overall impact of digital investment.

Third, policymakers and funding organisations should recognise that universities transform at different speeds. Providing similar resources does not always produce similar outcomes because institutions differ in their starting points and implementation capacity. Continuous support, monitoring, and institutional learning are necessary to ensure that all universities progress towards sustainable smart digital learning environments.

➤ *Limitations and Future Research*

This study provides important insights into the development of smart digital learning environments; yet, some limitations should be considered.

First, the study involved five public universities implementing the HEET initiative. Although these institutions provide valuable evidence on digital transformation in public higher education, the findings may not represent universities operating under different contexts, including private institutions.

Second, the study examined digital transformation during the initiative's implementation period. Therefore, the findings represent universities' progress towards smart digital learning environments rather than the outcomes of transformation. Future studies could use longitudinal approaches to examine whether these improvements are sustained over time.

Third, the study relied on questionnaires, interviews, and observations to understand institutional transformation. Future research could include data from learning management systems, digital usage records, and student learning outcomes to provide additional evidence on how digital transformation affects teaching and learning experiences.

➤ *Conclusion*

This study examined the extent to which Tanzania's Higher Education for Economic Transformation initiative has contributed to the development of smart digital learning environments in public universities. The findings show that the initiative has strengthened the foundation for digital transformation through improved ICT infrastructure, connectivity, smart classrooms, and digital learning systems.

Furthermore, the study demonstrates that building smart universities requires more than providing technology. Universities progressed at different levels because transformation depended on how effectively institutions organised, connected, and sustained digital investments.

The main conclusion of this study is that technology creates the opportunity for transformation, but institutional capacity determines whether that opportunity becomes a functioning digital learning environment.

Evidence from Tanzania shows that resource-constrained universities can progress towards smart digital transformation when strong digital systems and institutional commitment support infrastructure development. Therefore, future higher education transformation initiatives should focus not only on expanding access to technology but also on helping universities build sustainable environments where technology effectively supports teaching and learning.

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