

The Moderating Role of School ICT Infrastructure On Adaptive Digital Storytelling and Digital Information Literacy in Rural Primary Schools

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Abstract

The integration of Information and Communication Technology (ICT) into primary education has become a strategic priority for improving teaching and learning outcomes. In Kenya, initiatives such as the Digital Literacy Programme, the Competency-Based Curriculum, and the National EdTech Strategy have expanded access to digital technologies. However, disparities in ICT infrastructure persist in rural primary schools, raising concerns about whether infrastructure enhances the effectiveness of technology-supported pedagogies. This study examined the moderating influence of School ICT Infrastructure on the relationship between Adaptive Digital Storytelling (ADS) and Digital Information Literacy Skills Development (DILSD) among learners in selected rural public primary schools in Nyeri County, Kenya. Guided by Constructivist Learning Theory, Experiential Learning Theory, and the Technological Pedagogical Content Knowledge (TPACK) framework, the study adopted a positivist philosophy and a quantitative cross-sectional survey design. Data were collected from 2,894 learners across 39 rural public primary schools using structured questionnaires. School ICT Infrastructure was measured through the availability of digital devices, internet connectivity, electricity reliability, educational software, technical support, and accessibility of ICT facilities. Data were analysed using Covariance-Based Structural Equation Modelling (CB-SEM) following assessment of reliability and validity. The findings revealed that the measurement and structural models exhibited acceptable psychometric properties and model fit. School ICT Infrastructure demonstrated a positive but weak moderating influence on the relationship between Adaptive Digital Storytelling and Digital Information Literacy Skills Development, indicating that infrastructure alone is insufficient to maximize learning outcomes. The study concludes that effective digital education requires integrating adequate ICT infrastructure with learner-centred pedagogies, adaptive digital learning environments, and teacher professional development. The findings provide valuable insights for policymakers, curriculum developers, and educators seeking to strengthen digital learning in resource-constrained rural schools.

Keywords

Adaptive Digital Storytelling; School ICT Infrastructure; Digital Information Literacy Skills Development; CB-SEM; Rural Primary Schools; Kenya.

Introduction

The rapid advancement of Information and Communication Technology (ICT) has transformed education globally by creating opportunities for innovative teaching and learning approaches that promote learner engagement, collaboration, critical thinking, creativity, and digital competence. Educational systems are increasingly shifting from traditional teacher-centred instruction toward learner-centred pedagogies that encourage active participation, problem-solving, and knowledge construction through digital technologies. International organizations such as UNESCO and the World Bank recognize digital technologies as essential enablers of quality, equitable, and inclusive education, emphasizing that digital competence is now a fundamental requirement for participation in the knowledge economy and the Fourth Industrial Revolution (UNESCO, 2023; World Bank, 2024). Consequently, governments worldwide continue to invest in digital infrastructure and technology-enhanced learning initiatives to improve educational quality and prepare learners with twenty-first-century skills.

Among the emerging technology-supported pedagogies, digital storytelling has gained considerable attention because of its ability to combine traditional storytelling with multimedia elements such as text, images, audio, video, animation, and interactive content to create meaningful learning experiences. Unlike conventional teaching methods, digital storytelling encourages learners to become active creators of knowledge through inquiry, reflection, collaboration, and communication. Recent studies have demonstrated that digital storytelling enhances learner motivation, engagement, creativity, communication skills, academic achievement, and digital competence across different educational contexts (Ginting et al., 2024; Isaacs et al., 2024; Kaptan & Cakir, 2025). Its learner-centred nature aligns well with competency-based education, where learners are expected to demonstrate practical knowledge, critical thinking, and problem-solving skills rather than merely recalling factual information.

Advances in educational technology have further extended digital storytelling into Adaptive Digital Storytelling (ADS), which personalizes learning experiences according to learners' prior knowledge, learning pace, preferences, and performance. Adaptive Digital Storytelling integrates intelligent feedback mechanisms, branching narratives, learner analytics, and adaptive instructional pathways to accommodate individual learning needs while improving learner engagement and achievement. Unlike static digital learning resources, adaptive systems continuously adjust instructional content based on learner responses, thereby providing personalized support and enhancing learning effectiveness. Recent evidence indicates that adaptive learning environments significantly improve learner engagement, self-regulated learning, higher-order thinking, and academic performance compared with conventional instructional approaches (Albishi, 2022; Hariyanto et al., 2025). Consequently, Adaptive Digital Storytelling represents an important pedagogical innovation capable of supporting meaningful learning experiences within technology-enhanced educational environments.

One of the most significant educational outcomes associated with Adaptive Digital Storytelling is Digital Information Literacy Skills Development (DILSD). Digital information literacy extends beyond basic digital skills and encompasses learners' ability to recognize information needs, locate relevant information, critically evaluate digital sources, analyse and synthesize information, communicate findings effectively, and use information ethically within digital environments. As education increasingly relies on digital information resources, these competencies have become essential for academic success, lifelong learning, informed

decision-making, and responsible digital citizenship (UNESCO, 2023). Consequently, educational institutions are expected to adopt instructional approaches that develop learners' digital information literacy alongside technological competence. Adaptive Digital Storytelling provides opportunities for learners to interact with diverse digital resources, solve authentic problems, evaluate information critically, and construct new knowledge, thereby supporting the development of these essential competencies.

Despite substantial progress in educational technology, significant inequalities continue to exist in access to digital learning opportunities, particularly between urban and rural schools in developing countries. Rural schools often experience inadequate ICT infrastructure, including limited digital devices, unreliable internet connectivity, unstable electricity supply, insufficient educational software, and inadequate technical support. These infrastructural challenges constrain the implementation of technology-enhanced learning and limit learners' opportunities to acquire essential digital competencies. Studies conducted in Sub-Saharan Africa have consistently reported that disparities in ICT infrastructure remain a major barrier to effective technology integration in schools, contributing to unequal educational outcomes and widening the digital divide (Ngugi & Goosen, 2024; Nyamboki et al., 2025).

School ICT Infrastructure has therefore emerged as a critical contextual factor influencing the success of digital learning initiatives. It comprises the technological resources available within schools, including computers, tablets, internet connectivity, electricity, educational software, technical support services, and digital learning facilities. Adequate ICT infrastructure enables teachers to implement innovative instructional approaches, facilitates learner access to digital learning resources, and supports collaborative and interactive learning experiences. Conversely, inadequate infrastructure may limit the effectiveness of educational technologies regardless of their instructional quality (Ngugi & Goosen, 2024). Consequently, understanding the role of ICT infrastructure has become increasingly important for designing effective digital education policies and interventions, particularly in resource-constrained educational settings.

However, emerging evidence suggests that ICT infrastructure alone does not guarantee improved educational outcomes. Studies indicate that pedagogical quality, teacher competence, learner characteristics, instructional design, and institutional support frequently exert greater influence on learner achievement than the mere availability of technological resources (Albishi, 2022; UNESCO, 2023). Accordingly, ICT infrastructure is increasingly viewed not simply as an independent predictor of educational performance but as a contextual factor that may enhance or constrain the effectiveness of technology-supported pedagogies (World Bank, 2024). This perspective shifts attention from technology provision alone toward understanding the conditions under which digital learning interventions are most effective.

In Kenya, digital transformation in education has accelerated through initiatives such as the Digital Literacy Programme (DLP), the Competency-Based Curriculum (CBC), and the National EdTech Strategy, all of which seek to improve learners' digital competencies and enhance educational quality through technology integration. Although these initiatives have expanded access to ICT resources, implementation challenges remain evident, particularly in rural public primary schools where shortages of digital devices, poor internet connectivity, unstable electricity supply, and limited technical support continue to constrain technology-enhanced learning (Nyamboki et al., 2025). These challenges raise important questions regarding whether investments in ICT infrastructure alone are sufficient to improve educational

outcomes or whether infrastructure primarily strengthens the effectiveness of innovative instructional approaches such as Adaptive Digital Storytelling.

Although previous studies have demonstrated positive relationships between digital storytelling, adaptive learning technologies, ICT integration, and learner achievement (Ginting et al., 2024; Hariyanto et al., 2025; Kaptan & Cakir, 2025), relatively few have investigated the moderating role of School ICT Infrastructure. Existing research has largely examined ICT infrastructure as an independent predictor of technology adoption or academic performance rather than as a contextual variable capable of strengthening or weakening the relationship between pedagogical interventions and learning outcomes. Furthermore, empirical evidence on this relationship remains limited within rural primary schools in Sub-Saharan Africa, where contextual realities and infrastructural challenges differ considerably from those of technologically advanced educational systems (Ajani et al., 2025; Ngugi & Goosen, 2024).

This gap highlights the need for empirical evidence on how School ICT Infrastructure influences the effectiveness of Adaptive Digital Storytelling in promoting Digital Information Literacy Skills Development. Understanding this moderating relationship is important for informing educational policy, guiding resource allocation, and supporting the design of sustainable digital learning environments capable of improving learner outcomes in resource-constrained settings. Such evidence is particularly relevant for Kenya as the country continues to expand investments in educational technology while striving to achieve equitable access to quality education.

The objective of the study was to examine the moderating influence of School ICT Infrastructure on the relationship between Adaptive Digital Storytelling and Digital Information Literacy Skills Development among learners in selected rural public primary schools in Nyeri County, Kenya. The research hypothesis (H₀₁) was that school ICT Infrastructure does not significantly moderate the relationship between Adaptive Digital Storytelling and Digital Information Literacy Skills Development among learners in selected rural public primary schools in Nyeri County, Kenya.

Accordingly, this study investigated the moderating influence of School ICT Infrastructure on the relationship between Adaptive Digital Storytelling and Digital Information Literacy Skills Development among learners in selected rural public primary schools in Nyeri County, Kenya. Specifically, the study sought to determine whether School ICT Infrastructure significantly moderates the relationship between Adaptive Digital Storytelling and learners' Digital Information Literacy Skills Development. The findings contribute to Information Systems and educational technology research by extending understanding of the contextual role of ICT infrastructure in technology-enhanced learning while providing evidence to support policy and practice aimed at improving digital learning outcomes in rural primary schools.

Literature Review

School ICT Infrastructure

School Information and Communication Technology (ICT) Infrastructure refers to the technological resources and support systems that enable the effective integration of digital technologies into teaching and learning. It includes the availability of digital devices, reliable internet connectivity, electricity supply, educational software, technical support, and digital

learning platforms. These components create the technological environment within which technology-enhanced pedagogies can be implemented effectively. UNESCO (2023) identifies ICT infrastructure as a fundamental requirement for digital transformation in education, emphasizing that successful technology integration depends on an enabling ecosystem comprising adequate hardware, connectivity, digital content, and institutional support. Similarly, the World Bank (2024) argues that educational technology investments are most effective when technological infrastructure is complemented by teacher preparedness, curriculum alignment, and effective school leadership.

Empirical evidence demonstrates that adequate ICT infrastructure promotes technology adoption, instructional innovation, and learner engagement. Ngugi and Goosen (2024) found that schools with reliable internet connectivity, sufficient digital devices, and stable electricity were more likely to implement learner-centred digital pedagogies than schools experiencing infrastructural deficiencies. Likewise, Nyamboki et al. (2025) reported that disparities in internet connectivity and access to digital devices continue to limit the implementation of Kenya's Digital Literacy Programme, particularly in rural public primary schools. These findings suggest that although ICT infrastructure provides the technological foundation for digital learning, unequal access remains a significant barrier to educational equity.

Beyond physical resources, technical support and maintenance are essential for sustaining digital learning environments. Schools lacking qualified technical personnel often experience prolonged equipment downtime and reduced utilization of educational technologies, limiting teachers' confidence in integrating ICT into classroom instruction (Ajani et al., 2025). Furthermore, adaptive learning platforms depend on reliable infrastructure to support learner analytics, personalized feedback, and continuous access to digital resources. Consequently, deficiencies in internet connectivity, electricity, or technical support may reduce the effectiveness of technology-enhanced learning interventions.

Despite its importance, recent literature suggests that ICT infrastructure alone does not guarantee improved learning outcomes. Educational benefits are influenced by complementary factors such as pedagogical quality, teacher competence, learner characteristics, and institutional support (Albishi, 2022; UNESCO, 2023). As a result, ICT infrastructure is increasingly conceptualized as a contextual factor that enables or constrains the effectiveness of innovative instructional approaches rather than as an independent determinant of learner achievement. However, limited empirical evidence exists on its moderating role within adaptive learning environments, particularly in rural primary schools in Sub-Saharan Africa. This study therefore examines School ICT Infrastructure as a contextual moderator influencing the relationship between Adaptive Digital Storytelling and Digital Information Literacy Skills Development.

Adaptive Digital Storytelling

Adaptive Digital Storytelling (ADS) is an advancement of conventional digital storytelling that integrates adaptive learning technologies, learner analytics, and personalized instructional strategies to create interactive learning experiences tailored to individual learner needs. Unlike traditional digital storytelling, where all learners follow the same instructional pathway, ADS dynamically modifies learning content, feedback, and narrative progression based on learners' prior knowledge, performance, learning pace, and preferences. This personalization enables learners to engage with content that matches their abilities, thereby improving learning effectiveness and promoting meaningful participation (Albishi, 2022).

Digital storytelling has been widely recognized as an effective learner-centred pedagogical approach because it combines narratives with multimedia elements such as text, audio, video, images, and animations to enhance learning experiences. Through storytelling, learners actively construct knowledge, communicate ideas, and solve authentic problems rather than passively receiving information. Recent systematic reviews have shown that digital storytelling improves learner motivation, creativity, communication skills, collaboration, critical thinking, and academic achievement across different educational settings (Ginting et al., 2024; Isaacs et al., 2024; Kaptan & Cakir, 2025). These attributes make digital storytelling particularly suitable for competency-based education, which emphasizes the acquisition of practical skills and higher-order thinking.

The integration of adaptive technologies has significantly enhanced the educational potential of digital storytelling. Adaptive learning systems continuously analyse learner interactions and automatically adjust instructional content according to individual learning needs. Learners receive personalized feedback, alternative learning pathways, and differentiated instructional support, enabling them to progress at their own pace while addressing individual knowledge gaps. Hariyanto et al. (2025) found that artificial intelligence-supported adaptive learning environments significantly improve learner engagement, self-regulated learning, and academic performance by providing individualized learning experiences. Similarly, Albishi (2022) reported that adaptive learning technologies increase instructional efficiency by matching learning activities with learners' abilities and progress.

Within Adaptive Digital Storytelling, personalization is achieved through learner profiling, branching narratives, adaptive feedback, and learning analytics. These features encourage learners to make decisions, explore multiple perspectives, evaluate information, and reflect on their learning while receiving continuous instructional support. Such interactive learning environments promote deeper cognitive processing, sustained engagement, and meaningful knowledge construction, all of which contribute to improved learning outcomes.

Despite the growing adoption of Adaptive Digital Storytelling, empirical evidence regarding its effectiveness within rural primary schools remains limited, particularly in Sub-Saharan Africa. Most existing studies have focused on higher education or technologically advanced learning environments, providing little evidence on how contextual factors such as School ICT Infrastructure influence the effectiveness of Adaptive Digital Storytelling in resource-constrained schools. Addressing this gap is essential for understanding how adaptive pedagogical innovations can effectively support Digital Information Literacy Skills Development in rural educational settings.

Digital Information Literacy Skills Development

Digital Information Literacy Skills Development (DILSD) has become a critical educational outcome in the digital era as learners are increasingly required to access, evaluate, create, and communicate information using digital technologies. Unlike basic digital literacy, which focuses on operating technological devices, digital information literacy encompasses the ability to identify information needs, locate relevant information, evaluate the credibility of digital sources, synthesize information from multiple sources, communicate knowledge effectively, and use information ethically. These competencies are essential for lifelong learning, informed decision-making, and active participation in the knowledge society (UNESCO, 2023).

Contemporary literature recognizes digital information literacy as a multidimensional construct that integrates technological competence, information literacy, critical thinking, problem-solving, communication, and ethical digital citizenship. Mbandje et al. (2024) argue that digital competence and information literacy are complementary because effective participation in digital environments requires both technical proficiency and the cognitive ability to critically evaluate information. Similarly, UNESCO (2023) emphasizes that learners should develop competencies in searching for information, assessing the reliability of digital resources, analysing evidence, communicating findings through digital platforms, and adhering to ethical principles such as copyright, privacy, and responsible online behaviour. These competencies align closely with the goals of competency-based education, which seeks to develop independent, innovative, and digitally competent learners.

The increasing availability of online information has further heightened the importance of digital information literacy. Learners are exposed to vast amounts of information from websites, social media, digital libraries, and artificial intelligence-generated content, making critical evaluation and informed decision-making essential skills. Chourio-Acevedo et al. (2024) observed that effective information literacy education emphasizes critical evaluation, reflective thinking, and ethical information use to enable learners to distinguish credible information from misinformation and disinformation. Likewise, Kumar and Bhatt (2024) found that learners with strong information literacy competencies demonstrate better academic performance, critical thinking, independent learning, and problem-solving abilities.

Technology-enhanced pedagogies have been shown to play an important role in developing digital information literacy. Instructional approaches such as inquiry-based learning, project-based learning, collaborative learning, and digital storytelling provide authentic opportunities for learners to search for information, evaluate digital resources, analyse evidence, and communicate knowledge using digital technologies (Chiappe et al., 2024). Within Adaptive Digital Storytelling environments, learners actively engage with multimedia resources, explore alternative learning pathways, receive personalized feedback, and construct knowledge through interactive problem-solving activities. These experiences reinforce higher-order cognitive skills while strengthening learners' ability to locate, evaluate, organize, and ethically use digital information.

Despite its growing importance, Digital Information Literacy Skills Development remains a challenge in many rural schools due to inadequate ICT infrastructure, limited internet connectivity, insufficient digital learning resources, and inadequate teacher preparedness (Ngugi & Goosen, 2024; Nyamboki et al., 2025). Furthermore, most previous studies have examined digital literacy or information literacy independently, with limited attention to Digital Information Literacy Skills Development as an outcome of Adaptive Digital Storytelling. This study addresses this gap by examining Digital Information Literacy Skills Development as the dependent variable and investigating how School ICT Infrastructure influences the effectiveness of Adaptive Digital Storytelling in enhancing learners' digital information literacy competencies within rural public primary school

Relationship between Adaptive Digital Storytelling, School ICT Infrastructure and Digital Information Literacy Skills Development

The effectiveness of technology-enhanced learning depends not only on instructional design but also on the contextual conditions within which learning occurs. Contemporary educational

technology research recognizes that school-level factors, particularly ICT infrastructure, teacher competence, and institutional support, influence the extent to which digital pedagogies improve learner outcomes. Consequently, researchers increasingly conceptualize School ICT Infrastructure as a contextual variable that may strengthen or weaken the relationship between innovative instructional approaches and educational outcomes rather than functioning solely as an independent predictor of learner achievement (Ajani et al., 2025; Ngugi & Goosen, 2024).

Adaptive Digital Storytelling (ADS) relies heavily on adequate ICT infrastructure to deliver personalized and interactive learning experiences. Its adaptive features including learner analytics, branching narratives, multimedia content, intelligent feedback, and real-time assessment require reliable digital devices, internet connectivity, electricity, educational software, and technical support. Schools with adequate ICT infrastructure provide learners with uninterrupted access to these technologies, enabling effective learner interaction, timely feedback, and personalized learning experiences. Conversely, inadequate infrastructure may disrupt instructional continuity, reduce learner engagement, and limit the educational benefits of Adaptive Digital Storytelling (Nyamboki et al., 2025).

Empirical studies indicate that learner-centred digital pedagogies are more effective when implemented within supportive technological environments. Hariyanto et al. (2025) found that adaptive learning systems significantly improve learner engagement, self-regulated learning, and academic achievement when supported by reliable technological infrastructure. Similarly, Isaacs et al. (2024) reported that digital storytelling produces greater improvements in learner motivation, collaboration, and critical thinking when learners have consistent access to digital resources and interactive technologies. These findings suggest that School ICT Infrastructure provides favourable conditions that enable Adaptive Digital Storytelling to realize its full instructional potential.

However, recent literature also cautions that ICT infrastructure alone cannot guarantee improved learning outcomes. UNESCO (2023) and the World Bank (2024) emphasize that educational technologies become effective only when integrated with learner-centred pedagogy, teacher competence, curriculum alignment, and institutional leadership. Thus, infrastructure should be viewed as an enabling condition that supports effective instructional practice rather than a direct determinant of educational success. This perspective aligns with moderation theory, which proposes that contextual factors influence the strength or direction of relationships between independent and dependent variables (Hayes, 2022).

Despite growing interest in educational technology, limited empirical research has examined the moderating role of School ICT Infrastructure in the relationship between Adaptive Digital Storytelling and Digital Information Literacy Skills Development, particularly within rural primary schools in Sub-Saharan Africa. Most previous studies have focused on the direct effects of ICT infrastructure or digital pedagogies independently, leaving an important contextual gap in the literature. Addressing this gap, the present study conceptualizes School ICT Infrastructure as a moderator of the relationship between Adaptive Digital Storytelling and Digital Information Literacy Skills Development among learners in selected rural public primary schools in Nyeri County, Kenya. Accordingly, the study tested the following null hypothesis:

H₀₁: School ICT Infrastructure does not significantly moderate the relationship between Adaptive Digital Storytelling and Digital Information Literacy Skills Development among learners in selected rural public primary schools in Nyeri County, Kenya.

The reviewed literature demonstrates that Adaptive Digital Storytelling enhances learner engagement, personalization, and higher-order thinking, while Digital Information Literacy Skills Development equips learners with essential competencies for locating, evaluating, creating, and ethically using digital information. School ICT Infrastructure provides the technological foundation required to support these technology-enhanced learning environments. However, existing studies have largely examined the direct effects of ICT infrastructure and digital pedagogies independently, with limited attention to the moderating role of ICT infrastructure. Moreover, empirical evidence from rural primary schools in Sub-Saharan Africa remains scarce. This study addressed these gaps by investigating whether School ICT Infrastructure moderates the relationship between Adaptive Digital Storytelling and Digital Information Literacy Skills Development among learners in selected rural public primary schools in Nyeri County, Kenya, thereby contributing to educational technology, Information Systems, and digital literacy research.

Theoretical Framework

This study is anchored on Constructivist Learning Theory, Experiential Learning Theory (ELT), and the Technological Pedagogical Content Knowledge (TPACK) framework, which collectively explain how adaptive digital learning environments and school technological resources influence learners' Digital Information Literacy Skills Development (DILSD).

Constructivist Learning Theory, advanced by Piaget (1972) and further developed by Vygotsky (1978), posits that learners actively construct knowledge through meaningful interactions with learning experiences and their environment. Rather than passively receiving information, learners engage in exploration, collaboration, reflection, and problem-solving. Adaptive Digital Storytelling aligns with constructivist principles by providing interactive and learner-centred experiences that encourage learners to analyse information, make decisions, and construct knowledge. The theory therefore explains how Adaptive Digital Storytelling promotes Digital Information Literacy Skills Development through active learner engagement.

Experiential Learning Theory (ELT), proposed by Kolb (1984), explains learning as a continuous cycle involving concrete experience, reflective observation, abstract conceptualization, and active experimentation. Adaptive Digital Storytelling provides learners with authentic digital experiences through interactive narratives, multimedia resources, personalized feedback, and problem-solving activities. These experiences enable learners to develop critical information literacy competencies by applying, reflecting on, and refining their knowledge within real-world digital contexts.

The Technological Pedagogical Content Knowledge (TPACK) framework (Mishra & Koehler, 2006) emphasizes that effective technology integration requires the interaction of technological, pedagogical, and content knowledge. In this study, School ICT Infrastructure represents the technological environment that supports the implementation of Adaptive Digital Storytelling. Adequate digital devices, internet connectivity, reliable electricity, and technical support enable teachers to integrate adaptive technologies effectively, thereby creating favourable conditions for developing learners' Digital Information Literacy Skills

Development. Conversely, inadequate ICT infrastructure may constrain the effectiveness of technology-enhanced pedagogies.

Collectively, these theoretical perspectives provide a foundation for understanding how Adaptive Digital Storytelling facilitates learner-centred knowledge construction and experiential learning, while School ICT Infrastructure provides the contextual environment that may strengthen or limit its effectiveness in promoting Digital Information Literacy Skills Development.

The novelty of this study lies in examining School ICT Infrastructure as a moderating variable rather than merely as an independent predictor of educational outcomes. Most previous studies have investigated the direct effects of ICT infrastructure, digital storytelling, or adaptive learning on learner achievement (Albishi, 2022; Ngugi & Goosen, 2024; UNESCO, 2023). In contrast, this study examines whether School ICT Infrastructure changes the strength of the relationship between Adaptive Digital Storytelling (ADS) and Digital Information Literacy Skills Development (DILSD). This moderation perspective provides a deeper understanding of the contextual conditions under which Adaptive Digital Storytelling becomes more or less effective in rural learning environments, consistent with moderation theory, which emphasizes that contextual variables influence the strength or direction of relationships between predictor and outcome variables (Hayes, 2022).

Additionally, the study focused on Digital Information Literacy Skills Development, an educational outcome that has received comparatively limited empirical attention within Adaptive Digital Storytelling research, particularly in primary education (Chourio-Acevedo et al., 2024; Mbandje et al., 2024). By integrating adaptive pedagogy, digital information literacy, and School ICT Infrastructure into a single Covariance-Based Structural Equation Model (CB-SEM), the study extends current educational technology literature by providing empirical evidence from rural primary schools in Kenya, a context that remains underrepresented in studies of adaptive learning and digital storytelling (Ginting et al., 2024; Hariyanto et al., 2025; Ngugi & Goosen, 2024).

Previous Adaptive Digital Storytelling research has primarily examined outcomes such as learner engagement, motivation, academic achievement, creativity, and critical thinking. Most studies have focused on higher education or technologically advanced learning environments and have evaluated only the direct effects of Adaptive Digital Storytelling.

This study extends previous research in four important ways. First, it investigates Digital Information Literacy Skills Development as the primary educational outcome, an area that has received comparatively limited empirical attention. Secondly, it introduces School ICT Infrastructure as a moderating variable, demonstrating that contextual factors should be considered when evaluating adaptive learning interventions and thirdly, it provides empirical evidence from rural public primary schools in Kenya, addressing the limited representation of Sub-Saharan African contexts in Adaptive Digital Storytelling research. Finally, the study employs Covariance-Based Structural Equation Modelling (CB-SEM) to validate both the measurement and structural models simultaneously, providing stronger theoretical and statistical evidence than many previous studies that relied on simpler regression techniques.

Conceptual Framework

The conceptual framework which is figure 1 below, proposes that Adaptive Digital Storytelling (ADS) positively influences Digital Information Literacy Skills Development (DILSD), while

School ICT Infrastructure (ICTI) moderates this relationship. Adaptive Digital Storytelling serves as the independent variable by providing personalized, interactive, and learner-centred digital learning experiences that enhance learners' ability to locate, evaluate, analyse, create, and ethically use digital information. Digital Information Literacy Skills Development is the dependent variable representing the acquisition of these competencies.

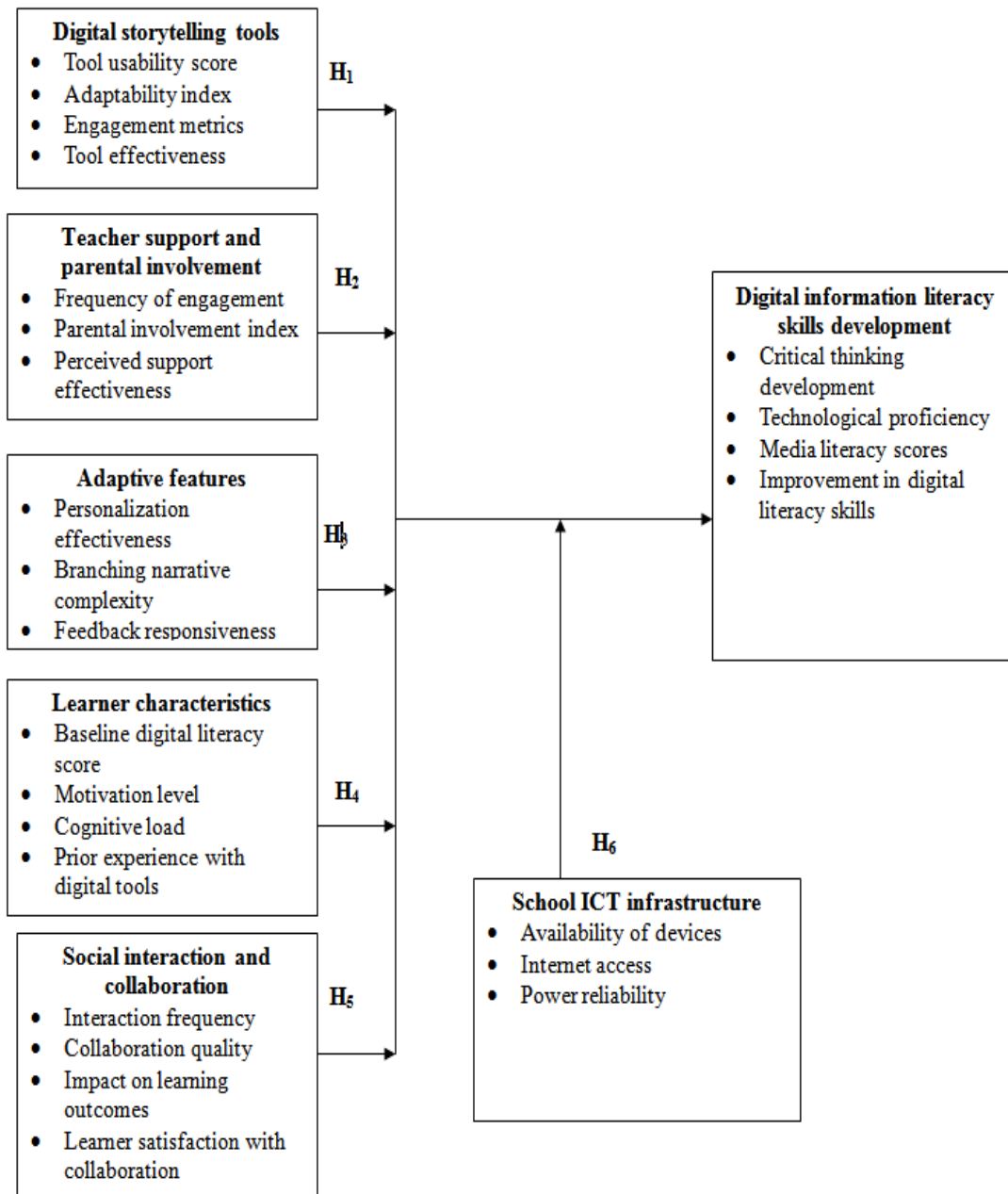


Figure 1: Conceptual Framework

School ICT Infrastructure is conceptualized as the moderating variable because the availability of digital devices, reliable internet connectivity, and stable electricity may strengthen or weaken the effectiveness of Adaptive Digital Storytelling. Schools with adequate ICT infrastructure provide favourable conditions for implementing adaptive learning technologies,

whereas inadequate infrastructure may constrain learner interaction and reduce the educational benefits of adaptive digital storytelling.

Methodology

Research Philosophy

This study was anchored on the positivist research philosophy, which assumes that reality is objective, measurable, and independent of the researcher. Positivism is appropriate for studies seeking to test theoretical relationships among variables using quantitative methods and statistical analysis. The philosophy emphasizes hypothesis testing, empirical observation, objectivity, and the use of standardized research instruments to generate reliable and generalizable findings.

The choice of positivism was informed by the objective of examining whether School ICT Infrastructure significantly moderates the relationship between Adaptive Digital Storytelling and Digital Information Literacy Skills Development. Since the study sought to establish statistically significant relationships among latent constructs using Covariance-Based Structural Equation Modelling (CB-SEM), positivism provided an appropriate philosophical foundation. The approach also minimized researcher bias by employing structured questionnaires, probability sampling techniques, and objective statistical procedures.

Recent educational technology research has increasingly adopted positivist approaches when evaluating digital learning interventions because they facilitate rigorous hypothesis testing, model validation, and theory confirmation using empirical data (Albishi, 2022; Ngugi & Goosen, 2024).

Research Design

The study employed a quantitative cross-sectional survey research design. A cross-sectional survey collects data from respondents at a single point in time, making it suitable for examining relationships among variables without manipulating the study environment. The design was appropriate because the study sought to investigate the moderating influence of School ICT Infrastructure on the relationship between Adaptive Digital Storytelling and Digital Information Literacy Skills Development among learners in rural public primary schools.

Cross-sectional surveys are widely used in educational technology research because they permit the collection of large datasets within a relatively short period while providing sufficient statistical power for Structural Equation Modelling. Furthermore, the design allows researchers to investigate complex relationships among latent variables using standardized measurement instruments while minimizing costs and logistical challenges associated with longitudinal studies.

Study Area

The study was conducted in Nyeri County, Kenya, which is located in the Central Highlands of Kenya. Nyeri County comprises eight administrative sub-counties: Nyeri Town, Tetu, Othaya, Mukurwe-ini, Mathira East, Mathira West, Kieni East, and Kieni West. The county

has experienced considerable investment in digital education through the Government of Kenya's Digital Literacy Programme (DLP). Nevertheless, significant disparities remain in ICT resource availability across rural public primary schools, making the county an appropriate setting for examining the influence of School ICT Infrastructure on digital learning outcomes.

The selection of Nyeri County was informed by the presence of both relatively well-equipped and resource-constrained rural schools, thereby providing adequate variability in ICT infrastructure necessary for moderation analysis. This context enabled the study to evaluate whether differences in technological infrastructure altered the effectiveness of Adaptive Digital Storytelling in promoting Digital Information Literacy Skills Development.

Nyeri County provides a valuable context because it represents many rural counties in Kenya that have participated in the Digital Literacy Programme (DLP) and implemented the Competency-Based Curriculum (CBC) while continuing to experience unequal ICT resource distribution (Ministry of Education, 2024; Nyamboki et al., 2025; UNESCO, 2023). Although many schools possess basic digital devices, variations in internet connectivity, electricity reliability, and technical support remain substantial across schools, particularly in rural settings, limiting the effective integration of digital technologies into teaching and learning (Ngugi & Goosen, 2024; World Bank, 2024).

This diversity creates an ideal natural setting for examining whether differences in School ICT Infrastructure influence the effectiveness of Adaptive Digital Storytelling. Moreover, empirical studies investigating adaptive educational technologies within rural Kenyan primary schools remain limited, making Nyeri County an important case for generating context-specific evidence that can inform policy and practice across similar resource-constrained educational settings (Ajani et al., 2025; Ginting et al., 2024; Hariyanto et al., 2025).

Target Population

The target population comprised learners enrolled in public primary schools within rural areas of Nyeri County. These learners represented the population expected to benefit from technology-supported instructional approaches introduced through the Competency-Based Curriculum and the Digital Literacy Programme.

The study focused on learners because they are the primary beneficiaries of Adaptive Digital Storytelling interventions and directly experience the influence of school ICT infrastructure during classroom instruction.

Sample Size and Sampling Procedure

A multi-stage probability sampling technique was employed to obtain a representative sample of learners from selected rural public primary schools. Initially, rural public primary schools were stratified according to sub-counties. Subsequently, schools were selected using probability sampling techniques to ensure proportional representation across the study area. Finally, learners were selected using simple random sampling within participating schools.

Sample Size Determination

The minimum required sample size for the quantitative strand was determined a priori using Cochran's (1977) sample size formula, validated against the sample size table developed by

Krejcie and Morgan (1970), and further evaluated in accordance with covariance-based structural equation modelling (CB-SEM) sample size recommendations (Kline, 2023; Wolf et al., 2013).

Step 1: Cochran's formula for an infinite population

Cochran's (1977) formula for the required sample size in a large or infinite population is:

$$n_0 = \frac{Z^2 pq}{e^2}$$

where n_0 is the required sample size, Z is the standard-normal critical value for the chosen confidence level (1.96 for 95% confidence), p is the estimated proportion of the population possessing the attribute of interest, $q = 1 - p$, and e is the desired margin of error. Following standard sample size determination practice, p was set at .50 to maximise variance and produce the most conservative (largest) sample size estimate, while e was set at .05 (Bartlett et al., 2015; Cochran & Chambers, 1965). Substituting these values into Cochran's (1977) formula:

$$n_0 = \frac{(1.96)^2(0.5)(0.5)}{(0.05)^2} = \frac{3.8416 \times 0.25}{0.0025} = \frac{0.9604}{0.0025}$$

The uncorrected minimum sample was therefore 384 learners.

Step 2: Finite-population correction

Because the accessible population is finite ($N = 96,337$), Cochran's (1977) finite-population correction was applied:

$$n = \frac{n_0}{1 + \frac{(n_0 - 1)}{N}} = \frac{384}{1 + \frac{(384 - 1)}{96,337}} = \frac{384}{1 + 0.003975}$$

Because the population is very large relative to n_0 , the correction was negligible, leaving a corrected minimum of approximately 383 learners (Cochran, 1977).

Step 3: Cross-validation against the Krejcie and Morgan table

The computed minimum was cross-checked against (Krejcie & Morgan, 1970) tabulated values. For populations exceeding 75,000, their table recommends a sample of approximately 382 to 384, which corresponds closely to the value obtained from Cochran's formula and confirms its adequacy (Krejcie & Morgan, 1970).

Step 4: Cross-validation against CB-SEM sample-size requirements

Because the study tested a complex higher-order reflective model comprising multiple latent variables and a large number of observed indicators, the conventional survey minimum of approximately 384 respondents was treated only as a lower-bound estimate. Hair, Risher, et al. (2019), Kline (2023), and Wolf et al. (2013) indicate that covariance-based structural equation modelling (CB-SEM) models involving multiple latent variables and numerous indicators generally require several hundred cases for stable estimation, with larger samples becoming

necessary as model complexity, the number of estimated parameters, and the level of missing data increase. Common heuristic guidelines, including recommended ratios of approximately 10–20 cases per estimated parameter and at least 10 cases per observed indicator, further support the need for a substantially larger sample than the minimum survey requirement (Hair, Risher, et al., 2019; Kline, 2023). Given the full instrument comprised 125 observed items, applying the more conservative 20-cases-per-indicator heuristic would suggest a substantially larger sample requirement. Consequently, the study did not rely solely on the statistical minimum but sought to utilise the larger proportionate sampling frame of eligible learners presented in Table 1.

The proportionate 10% sampling design produced an eligible sampling frame of up to 9,634 learners across 39 schools. The realised sample was smaller than this maximum because participation depended on the return of signed parental consent and learner assent forms, learner attendance during the data collection period, and the completeness of submitted questionnaires (Borgers et al., 2022; Creswell, 2023). Following consent procedures, questionnaire administration, data screening, and removal of incomplete responses through listwise deletion, the final analytic sample comprised 2,894 complete cases, representing a within-frame response rate of approximately 30% (2,894/9,634). Listwise deletion did not remove any additional cases from the final analytic dataset; therefore, all 2,894 cases contained complete data for the variables included in the structural model.

Table 1: Sampling Frame and Proportionate Allocation by Sub-County

Sub-county	No. of public primary schools	Learner population (Boys + Girls)	10% sample of schools	10% sample of learners	Learners in Grade 2 and 3
Nyeri Central	52	13,123	5	1,312	635
Nyeri South (Othaya)	47	11,876	5	1,188	262
Mathira East	45	12,014	5	1,201	401
Mathira West	43	11,347	4	1,135	170
Tetu	40	10,212	4	1,021	252
Kieni East	65	14,982	7	1,498	579
Kieni West	60	12,738	6	1,274	323
Mukurwe-ini	30	9,045	3	905	272
Total	382	96,337	39	9,634	2,894

Note. Learner population figures are the accessible lower-primary enrolment per sub-county from data collection. The proportionate ten-percent design defined an eligible frame of 39 schools and 2,894 learners.

The realised sample of 2,894 respondents was adequate according to all sample-size criteria considered. It exceeded the Cochran and Chambers (1965) corrected minimum requirement of 383 respondents by approximately 7.5 times, substantially exceeded the recommendation provided by Krejcie and Morgan (1970), and met CB-SEM sample-size recommendations for complex structural models (Kline, 2023; Wolf et al., 2013). With 125 observed indicators, the realised sample provided approximately 23 cases per indicator, exceeding commonly applied heuristic thresholds. Furthermore, the ratios were higher for the individual objective-specific models because these models involved fewer indicators (Hair, Risher, et al., 2019; Kline, 2023).

The realised sample also demonstrated a balanced distribution across the demographic characteristics examined, comprising 1,459 and 1,435 learners across the two gender categories and 987, 980, and 927 learners in Grades 1, 2, and 3, respectively. This distribution supports the representativeness of the analytic dataset within the sampled population (Kenya National Bureau of Statistics [KNBS], 2019). The final sample consisted of 2,894 learners drawn from 39 rural public primary schools. This sample size exceeded the minimum recommendations for Covariance-Based Structural Equation Modelling and provided sufficient statistical power for estimating moderation effects involving latent variables.

Data Collection Instrument

Primary data were collected using a structured questionnaire developed from validated instruments reported in previous educational technology and information literacy studies. The questionnaire consisted of closed-ended items measured on a five-point Likert scale ranging from 1 (Strongly Disagree) to 5 (Strongly Agree).

The questionnaire was organized into sections measuring; adaptive digital storytelling, school ICT infrastructure, digital information literacy skills development and demographic characteristics. The structured questionnaire facilitated standardized data collection, reduced interviewer bias, and enabled statistical comparison across respondents.

Measurement of Variables

Adaptive Digital Storytelling

Adaptive Digital Storytelling was operationalized using indicators measuring: Tool usability, Adaptive instructional capability, Learner engagement and Tool effectiveness. These indicators assessed learners' perceptions regarding personalization, interactivity, multimedia integration, adaptive feedback, and instructional support provided by digital storytelling applications.

School ICT Infrastructure

School ICT Infrastructure served as the moderating variable. The construct was measured using indicators reflecting the technological learning environment available within schools. These included: Availability of computers and digital devices, internet connectivity, reliability of electricity supply, availability of educational software, accessibility of ICT laboratories, technical support services and maintenance of ICT equipment. Higher scores represented schools possessing relatively stronger technological infrastructure capable of supporting adaptive digital learning environments.

Digital Information Literacy Skills Development

Digital Information Literacy Skills Development constituted the dependent variable and was measured using indicators assessing learners' ability to: Identify information needs, search for digital information, evaluate information credibility, analyse digital information, organize information, create digital content, communicate information effectively and apply ethical principles during information use. These indicators reflected internationally recognized digital information literacy competencies consistent with UNESCO and information literacy frameworks.

Pilot Study

Prior to the main data collection exercise, a pilot study was conducted to evaluate the clarity, relevance, reliability, and validity of the research instrument. Responses obtained during the pilot study were excluded from the final analysis. Feedback obtained from respondents enabled refinement of questionnaire wording, sequencing of items, and improvement of measurement accuracy before administering the instrument to the main study sample.

Reliability and Validity

The psychometric properties of the measurement model were evaluated before hypothesis testing. Internal consistency reliability was assessed using Cronbach's alpha and Composite Reliability (CR). Values exceeding 0.70 were considered acceptable for establishing construct reliability. Convergent validity was assessed using Average Variance Extracted (AVE), with values greater than 0.50 indicating that constructs explained more than half of the variance associated with their indicators. Discriminant validity was evaluated using the Fornell–Larcker Criterion and examination of cross-loadings to confirm that each construct measured a concept distinct from other constructs within the measurement model. Prior to Structural Equation Modelling, Exploratory Factor Analysis (EFA) was performed to confirm construct dimensionality. Sampling adequacy was assessed using the Kaiser-Meyer-Olkin (KMO) statistic, while Bartlett's Test of Sphericity evaluated the suitability of factor analysis.

Data Collection Procedure

Approval to conduct the study was obtained from the university research committee before seeking authorization from the National Commission for Science, Technology and Innovation (NACOSTI). Additional permission was obtained from the Ministry of Education, County education authorities, and school administrators before data collection commenced. Questionnaires were administered physically to learners within their respective schools under the supervision of teachers and the researcher. Respondents were guided on how to complete the questionnaires while maintaining confidentiality and minimizing response bias. Completed questionnaires were examined for completeness before coding and entry into IBM SPSS for preliminary analysis.

Data Analysis

Data analysis was undertaken in two stages. The first stage involved descriptive statistics, including frequencies, percentages, means, and standard deviations, to summarize respondents' demographic characteristics and describe the study variables. The second stage involved inferential statistical analysis using Covariance-Based Structural Equation Modelling (CB-SEM) implemented in IBM SPSS AMOS. The analysis followed two sequential phases which were the measurement model assessment and structural model assessment. The measurement model assessment included the following tests; reliability analysis, Exploratory Factor

Analysis, Confirmatory Factor Analysis, Composite Reliability, Average Variance Extracted, Discriminant validity and Model fit assessment. The structural model assessment included the following; direct path analysis, Interaction term estimation, moderation analysis and hypothesis testing. The moderating effect of School ICT Infrastructure was examined by estimating the interaction between Adaptive Digital Storytelling and School ICT Infrastructure within the structural model. Statistical significance was evaluated using standardized path coefficients (β), Critical Ratios (CR), p-values, and confidence intervals. A significance level of $\alpha = 0.05$ was adopted for hypothesis testing.

Results

Descriptive Analysis of School ICT Infrastructure

School ICT Infrastructure (ICTI) was examined as the moderating variable in this study to determine whether it influenced the relationship between Adaptive Digital Storytelling (ADS) and Digital Information Literacy Skills Development (DILSD). The construct was operationalized using three dimensions: Availability of Digital Devices (ADD), Internet Access (IA), and Power Reliability (PR). Descriptive statistics were computed to establish respondents' perceptions of the level of ICT infrastructure available in their schools before conducting the moderation analysis.

The descriptive findings in table 2 indicated that respondents generally perceived the level of School ICT Infrastructure to be moderate across all dimensions. Specifically, the Availability of Digital Devices (ADD) recorded mean scores ranging from 3.28 to 3.31, suggesting that digital devices were available in schools to a moderate extent but not sufficiently to support optimal technology-enhanced learning. The relatively consistent standard deviations of approximately 1.00 indicate moderate variation in learners' perceptions, implying differences in access to digital devices across participating schools. Similarly, Internet Access (IA) recorded mean scores ranging from 3.10 to 3.13, representing the lowest ratings among the ICT infrastructure dimensions. These findings suggest that although schools may possess digital devices, reliable internet connectivity remains limited. Inconsistent internet access may therefore constrain the implementation of Adaptive Digital Storytelling, particularly where instructional activities depend on online resources, multimedia content, and interactive digital platforms.

Table 2: Descriptive Statistics for ICTI

Parameter	Mean	Std. Deviation	Parameter	Mean	Std. Deviation	Parameter	Mean	Std. Deviation
ADD1	3.31	1.013	IA1	3.11	1.012	PR1	3.21	1.015
ADD2	3.31	1.009	IA2	3.13	1.000	PR2	3.21	1.019
ADD3	3.30	1.002	IA3	3.10	1.003	PR3	3.20	1.008
ADD4	3.30	1.004	IA4	3.10	1.018	PR4	3.21	1.003
ADD5	3.28	1.004	IA5	3.11	1.000	PR5	3.22	1.000

The Power Reliability (PR) dimension recorded mean scores ranging from 3.20 to 3.22, indicating that electricity supply was perceived to be relatively more reliable than internet connectivity. Nevertheless, these values also reflect only a moderate level of infrastructure reliability, suggesting that occasional power interruptions may continue to affect technology-supported learning activities in rural schools. Overall, the descriptive analysis demonstrates that School ICT Infrastructure in the participating rural public primary schools is moderately developed but not yet optimal. Although respondents perceived reasonable availability of digital devices and electricity, internet connectivity remains comparatively weaker. These findings suggest that infrastructural limitations continue to present challenges for the effective implementation of Adaptive Digital Storytelling and other digital learning initiatives.

Structural Equation Modelling Results

Following the assessment of descriptive statistics and measurement properties, Structural Equation Modelling (SEM) was employed to examine the hypothesized relationships among the study constructs. The structural model evaluated the direct influence of Adaptive Digital Storytelling on Digital Information Literacy Skills Development as well as the moderating influence of School ICT Infrastructure.

The results demonstrated that Adaptive Digital Storytelling positively influenced Digital Information Literacy Skills Development, with a standardized path coefficient of $\beta = 0.300$. This finding indicates that learner-centred adaptive storytelling environments substantially enhance learners' digital information literacy competencies. Digital Information Literacy Skills Development was measured using Critical Thinking Development, Technological Proficiency, Media Literacy Skills, and Improvement in Digital Literacy, whose standardized factor loadings ranged from 0.526 to 0.555, confirming acceptable construct validity.

Moderating Influence of School ICT Infrastructure

The primary objective of this study was to determine whether School ICT Infrastructure moderates the relationship between Adaptive Digital Storytelling and Digital Information Literacy Skills Development.

The SEM analysis revealed a positive but weak moderating effect, with a standardized interaction coefficient of $\beta = 0.003$. The positive coefficient suggests that improvements in School ICT Infrastructure slightly strengthen the positive relationship between Adaptive Digital Storytelling and Digital Information Literacy Skills Development. However, the magnitude of the interaction effect is extremely small, indicating that the contribution of ICT infrastructure to strengthening this relationship is limited.

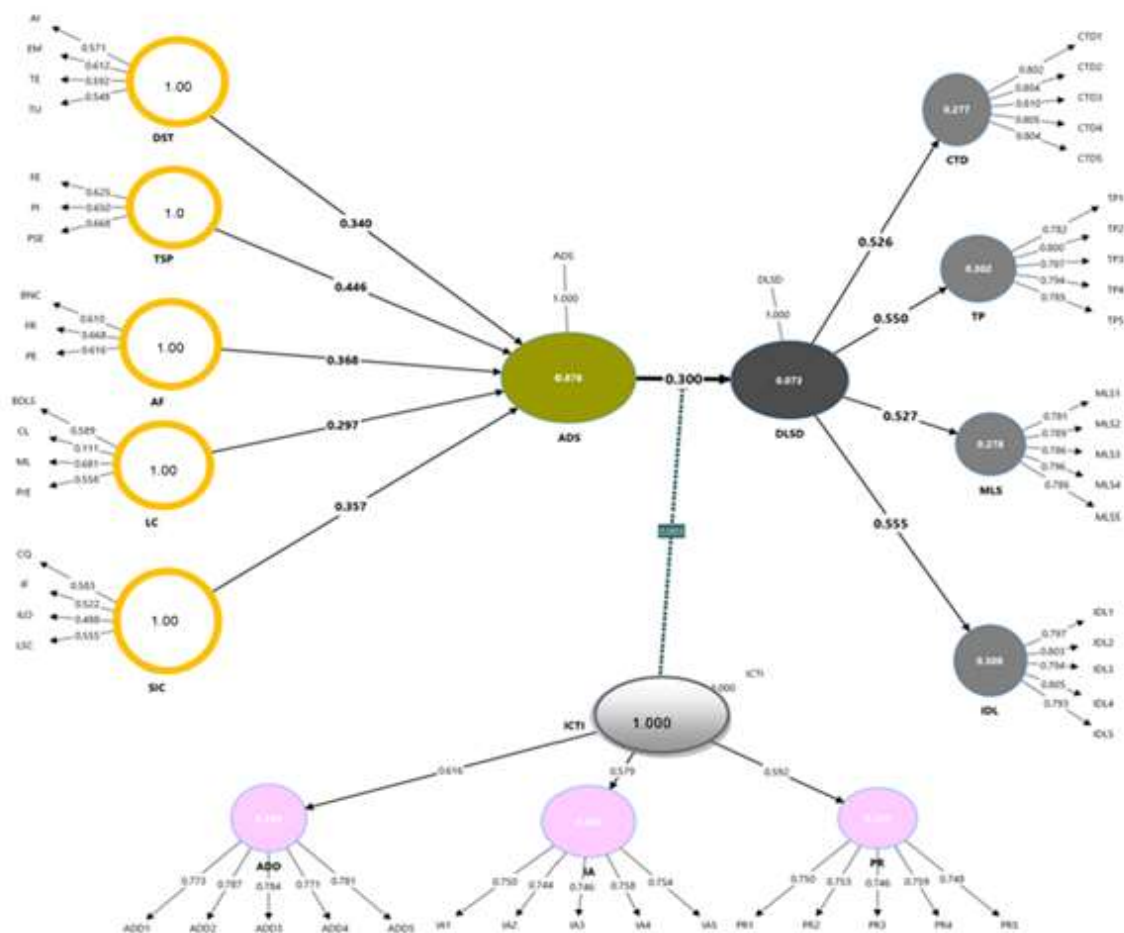
The analysis further revealed a negative direct effect of School ICT Infrastructure on Digital Information Literacy Skills Development ($\beta = -0.093$). This finding may reflect disparities in ICT resource availability, unequal distribution of digital facilities across schools, implementation challenges associated with educational technology initiatives, or differences in the utilization of available ICT resources. It suggests that merely providing technological infrastructure may not automatically translate into improved learner outcomes unless accompanied by effective pedagogical integration and teacher support.

The measurement indicators for School ICT Infrastructure demonstrated acceptable standardized factor loadings, namely Availability of Digital Devices (0.616), Internet Access (0.579), and Power Reliability (0.592). These values confirm that the observed indicators

adequately represented the latent construct and provided a reliable basis for estimating the moderation effect within the structural model.

The study employed Covariance-Based Structural Equation Modelling (CB-SEM) to examine the moderating influence of School ICT Infrastructure (ICTI) on the relationship between Adaptive Digital Storytelling (ADS) and Digital Information Literacy Skills Development (DILSD). SEM was selected because it simultaneously evaluates the measurement properties of latent constructs and the structural relationships among variables, making it appropriate for testing moderation effects within complex theoretical models (Hair et al., 2019; Kline, 2022).

The path diagram in figure 2 combined the measurement model constructs and their indicators with the structural model paths between constructs. The structural model conceptualized Adaptive Digital Storytelling (ADS) as the central construct influenced by five exogenous variables: Digital Storytelling Tools (DST), Teacher Support and Parental Involvement (TSP), Adaptive Features (AF), Learner Characteristics (LC), and Social Interaction and Collaboration (SIC).



Chi-square (χ^2) = 399, DF = 230, p-Value = 0.089, CMIN/DF (χ^2 / df) = 1.74, RMSEA = 0.016, TLI = 0.889, CFI = 0.908, NFI = 0.811, GFI = 0.989, AGFI = 0.986

Figure 2: Path Diagram for Moderating Variable

These constructs positively influenced ADS, with Teacher Support and Parental Involvement exhibiting the strongest effect ($\beta = .446$), followed by Adaptive Features ($\beta = .370$), Social Interaction and Collaboration ($\beta = .358$), Digital Storytelling Tools ($\beta = .346$), and Learner Characteristics ($\beta = .309$). Adaptive Digital Storytelling, in turn, positively influenced Digital Information Literacy Skills Development ($\beta = .300$), demonstrating that learner-centred, adaptive storytelling environments enhance learners' digital information literacy competencies.

School ICT Infrastructure was modelled as a moderating variable measured through the availability of digital devices, internet access, and power reliability. The moderation analysis revealed a weak positive moderating effect ($\beta = .003$), indicating that ICT infrastructure marginally strengthened the relationship between Adaptive Digital Storytelling and Digital Information Literacy Skills Development. Although the effect was relatively small, it highlights the importance of adequate technological infrastructure in supporting the implementation of adaptive digital learning environments. The direct effect of ICTI on DILSD was negative ($\beta = -.093$), suggesting that infrastructure alone is insufficient to improve learning outcomes without effective pedagogical integration. The structural model demonstrated excellent fit (CFI = 1.000, TLI = 1.000, RMSEA = .003, SRMR = .014, GFI = .993), confirming the robustness and adequacy of the proposed framework.

Overall, the moderation results indicate that although School ICT Infrastructure contributes positively to the effectiveness of Adaptive Digital Storytelling, its moderating influence is relatively weak. This finding suggests that infrastructure alone is insufficient to substantially improve Digital Information Literacy Skills Development. Rather, the effectiveness of Adaptive Digital Storytelling appears to depend more strongly on instructional design, learner engagement, adaptive features, and pedagogical implementation than on infrastructure availability alone. Nevertheless, ICT infrastructure remains an important enabling condition that facilitates the successful implementation of adaptive digital learning environments, particularly in rural schools.

Discussion

The findings indicate that Adaptive Digital Storytelling remains an effective instructional approach for enhancing Digital Information Literacy Skills Development among learners in rural primary schools. The positive relationship observed supports recent studies that emphasize the capacity of adaptive digital learning environments to promote learner engagement, critical thinking, personalized learning, and digital competence. These findings are consistent with recent educational technology literature, which argues that adaptive learning environments improve learning outcomes by providing individualized instructional pathways and timely learner feedback (Albishi, 2022; Hariyanto et al., 2025).

The study further established that School ICT Infrastructure exerted only a weak moderating influence on the relationship between Adaptive Digital Storytelling and Digital Information Literacy Skills Development. This suggests that although adequate ICT infrastructure creates favourable conditions for technology-enhanced learning, it does not substantially strengthen the effectiveness of adaptive instructional approaches on its own. This finding supports UNESCO (2023), which argues that educational technologies yield meaningful learning outcomes only when accompanied by effective pedagogy, teacher competence, and learner-centred instructional practices.

The negative direct effect of School ICT Infrastructure further demonstrates that investments in hardware, internet connectivity, and electricity alone are insufficient to improve learners' digital information literacy skills. Effective utilization of available infrastructure requires complementary investments in teacher professional development, curriculum integration, instructional design, and institutional support. Consequently, successful implementation of digital education initiatives should adopt a holistic approach that combines technological resources with innovative pedagogical strategies.

From a theoretical perspective, the findings reinforce the assumptions of Constructivist Learning Theory, Experiential Learning Theory, and the Technological Pedagogical Content Knowledge (TPACK) framework by demonstrating that meaningful learning emerges through active learner engagement with appropriately designed instructional experiences rather than through technology availability alone. The study therefore contributes empirical evidence that School ICT Infrastructure functions primarily as an enabling contextual factor rather than a dominant determinant of Digital Information Literacy Skills Development.

Conclusion

This study examined the moderating influence of School ICT Infrastructure on the relationship between Adaptive Digital Storytelling and Digital Information Literacy Skills Development among learners in selected rural public primary schools in Nyeri County, Kenya. The findings established that Adaptive Digital Storytelling positively contributes to the development of learners' digital information literacy skills by providing interactive, learner-centred, and personalized learning experiences. However, School ICT Infrastructure exhibited only a weak positive moderating effect on this relationship, indicating that improvements in infrastructure alone do not substantially strengthen the educational benefits of Adaptive Digital Storytelling. The study further found that the direct influence of School ICT Infrastructure on Digital Information Literacy Skills Development was negative, suggesting that the mere availability of ICT resources is insufficient to improve learner outcomes. These findings demonstrate that meaningful improvements in digital information literacy depend on effective pedagogical integration, teacher competence, and purposeful utilization of available technological resources rather than infrastructure alone. Overall, the study concludes that while School ICT Infrastructure remains an important enabling factor for technology-enhanced learning, its educational value is realized only when combined with innovative instructional approaches such as Adaptive Digital Storytelling. Consequently, successful implementation of digital education initiatives should adopt a holistic approach that integrates infrastructure development, teacher professional development, learner-centred pedagogy, and curriculum alignment.

Recommendations

Based on the findings, the study recommends that the Ministry of Education, the Teachers Service Commission, and school administrators prioritize the integration of Adaptive Digital Storytelling into classroom instruction to enhance learners' Digital Information Literacy Skills Development. Professional development programmes should equip teachers with the pedagogical and technical competencies required to design and implement adaptive digital learning experiences effectively. Although ICT infrastructure alone was found to have a limited moderating influence, continuous investment in reliable internet connectivity, digital devices,

stable electricity supply, educational software, and technical support remains necessary to create enabling learning environments. Such investments should be complemented by institutional policies that promote effective utilization of available technological resources rather than focusing solely on infrastructure acquisition. Curriculum developers should also integrate digital information literacy competencies across learning areas within the Competency-Based Curriculum (CBC) to ensure that learners consistently develop information searching, evaluation, analysis, ethical information use, and digital communication skills through authentic learning activities.

Contribution to Knowledge

This study contributes to educational technology and Information Systems research by empirically examining School ICT Infrastructure as a moderating variable in the relationship between Adaptive Digital Storytelling and Digital Information Literacy Skills Development. Unlike previous studies that predominantly investigated ICT infrastructure as an independent predictor of educational outcomes, this study demonstrates its contextual role within adaptive learning environments. The findings also extend the application of Constructivist Learning Theory, Experiential Learning Theory, and the Technological Pedagogical Content Knowledge (TPACK) framework by providing empirical evidence that effective digital learning depends on the interaction between pedagogy and technological context rather than technological infrastructure alone. Furthermore, the study provides evidence from rural public primary schools in Kenya, thereby addressing an important gap in educational technology literature from Sub-Saharan Africa.

Limitations of the Study

The study employed a cross-sectional survey design, which limited the examination of changes in learners' digital information literacy skills over time. Data were collected from rural public primary schools within Nyeri County only, and therefore the findings may not be directly generalizable to urban schools, private institutions, or other counties with different ICT contexts. In addition, the study relied primarily on questionnaire data, which may be subject to respondent bias despite the measures taken to ensure reliability and validity.

Suggestions for Further Research

Future studies should employ longitudinal research designs to examine how improvements in School ICT Infrastructure influence the long-term effectiveness of Adaptive Digital Storytelling interventions. Comparative studies involving rural and urban schools, as well as public and private institutions, would provide broader insights into contextual differences affecting digital learning outcomes. Further research should also investigate additional moderating and mediating variables, including teacher digital competence, leadership support, learner motivation, parental involvement, and school digital culture, to provide a more comprehensive understanding of factors influencing Digital Information Literacy Skills Development. Finally, qualitative and mixed-methods studies are recommended to explore teachers' and learners' experiences in implementing Adaptive Digital Storytelling within diverse educational settings.

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Authorship Statement

Tabitha Muthoni Kihara conceptualised the study, developed the research framework and methodology, conducted the data collection, performed the data analysis, interpreted the findings, and prepared the manuscript. Prof. Jimmy Macharia, , provided academic and scholarly guidance in the conceptualisation, theoretical framing, methodological development, interpretation of findings, and critical review of the manuscript. Dr. Collins Odour, as a PhD supervisor and co-author, provided academic and scholarly guidance in the refinement of the research framework and methodology, interpretation of findings, and critical review and revision of the manuscript.

All authors critically reviewed and approved the final version of the manuscript and agreed to be accountable for the integrity and accuracy of the work.

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Declaration of Competing Interests

The authors declare that they have no competing interests that could have influenced the research, analysis, interpretation of the findings, or publication of this article.

Ethical Approval and Research Licenses

Ethical approval for the study was granted by the United States International University – Africa (USIU-Africa) institutional research ethics review while research permit was obtained from the National Commission for Science, Technology and Innovation (NACOSTI), Kenya. Institutional and administrative permissions were obtained from the ministry of education authorities and participating public primary schools in Nyeri County. Participation was voluntary, and the required informed consent and assent procedures were followed in accordance with the approved research protocol. All data were handled confidentially and used solely for academic research purposes.

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