

Assessment of Smart Classroom Components in Rural Secondary Schools: Evidence from Rwanda

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ABSTRACT

The rapid digital transformation of education has positioned smart classrooms as critical tools for enhancing teaching quality, equity, and learner engagement. Rwanda launched the Smart Classroom Project in 2016 under Vision 2050 and the National Strategy for Transformation, equipping most secondary schools with ICT facilities. However, utilization remains limited in rural districts. This study assesses the adequacy of smart classroom components in public secondary schools of Gicumbi District, focusing on technological infrastructure, pedagogical readiness, learning environment, and institutional support. A sequential explanatory mixed-methods design was employed, beginning with a survey of 175 Senior Three students, followed by focus group discussions with 143 Senior Six students, interviews with 22 teachers, 5 headteachers, 12 parents, and the District Director of Education, complemented by classroom observations. Quantitative findings revealed consistent weaknesses across all components, with infrastructure and institutional support receiving the lowest ratings. Reliability and validity were confirmed (KMO > .85; Bartlett's $p < .001$; Cronbach's $\alpha \geq .86$), underscoring robust measurement. Qualitative insights contextualized these results, highlighting outdated equipment, irregular maintenance, low teacher confidence, overcrowded classrooms, and weak leadership as systemic barriers. The integration of findings demonstrates that technology provision alone is insufficient to transform teaching and learning. Effective utilization requires sustainable maintenance systems, continuous professional development in digital pedagogy, flexible classroom design, and strengthened institutional frameworks with clear policies, technical support, and accountability mechanisms. The study contributes to the growing body of ICT-in-education scholarship in sub-Saharan Africa and provides actionable recommendations for policymakers and school leaders to optimize smart classroom utilization in Rwanda.

Keywords: *Smart classrooms, technological infrastructure, pedagogical readiness, learning environment, institutional support*

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INTRODUCTION

The twenty-first century is characterized by rapid digital transformation, with education systems increasingly shaped by technology integration. Smart classrooms, equipped with computers, projectors, internet connectivity, and interactive tools, are promoted globally as mechanisms for improving teaching quality, equity, and innovation. UNESCO (2019) emphasized that smart classrooms contribute to Sustainable Development Goal 4 by promoting inclusive and equitable education, while the Organisation for Economic Co-operation and Development [OECD] (2021) highlighted their role in cultivating twenty-first century competencies such as creativity, critical thinking, and collaboration. Evidence from advanced economies illustrates these benefits. For example, Lim and Wang (2020) reported that Singapore's ICT Masterplan transformed pedagogy by embedding interactivity, and Telecom Review Asia (2025) found that South Korea's reforms in digital education enhanced collaborative inquiry-based learning. In China, Zhou and Li (2021)

showed that digital classrooms expanded rapidly during the COVID-19 pandemic to sustain learning continuity, while Da Silva (2024) observed that Brazil's adoption of blended smart classrooms strengthened the resilience of education systems during disruption.

In sub-Saharan Africa, the effectiveness of smart classroom initiatives has been mixed. Otieno (2022) documented how Kenya's digital literacy program, despite distributing thousands of devices, was undermined by weak maintenance and insufficient teacher training. Similarly, Nyakito, Amimo, and Allida (2021) found that ICT-supported science classrooms in Uganda improved outcomes but struggled with scalability in rural areas. In South Africa, Chomunorwa and Mugobo (2023) observed that learners in rural schools faced challenges in accessing e-learning tools, and Akinyemi, Amaechi, and Etoh (2022) reported that Nigerian schools continued to face barriers of inadequate infrastructure and limited teacher readiness. Research in Ghana stressed the need for sustained professional development to support digital pedagogy (Boadu & Essel, 2020), while studies in Senegal identified similar constraints, particularly weak institutional frameworks (Mawhood & Gross, 2014). These findings collectively suggest that technology provision alone is insufficient; sustainability requires teacher capacity, supportive leadership, and enabling environments.

Rwanda has positioned itself as a regional leader in ICT-in-education through the Smart Classroom Project launched in 2016, which equipped most secondary schools with computers, projectors, and internet access. Ministry of Education [MINEDUC] (2016, 2018) and the Global Partnership for Education & Government of Rwanda (2023) reported that by 2018, nearly 70 percent of schools had at least one smart classroom, reflecting strong policy commitment under the National Strategy for Transformation (NST1) and Vision 2050 (Government of Rwanda [GoR], 2017). However, utilization remains limited, especially in rural districts such as Gicumbi, where teachers continue to rely on traditional chalk-and-talk methods. Mushimiyimana and Dushimimana (2021) found that schools in Gicumbi face challenges including overcrowding, outdated equipment, unstable internet, and lack of technical staff. Training programs emphasize technical ICT skills but often neglect digital pedagogy, and institutional weaknesses such as insufficient maintenance budgets and lack of scheduling frameworks further constrain effective use. These systemic barriers reduce the potential of smart classrooms to transform teaching and learning in Rwanda.

This study addresses this gap by assessing the adequacy of technological infrastructure, pedagogical readiness, learning environments, and institutional support in public secondary schools in Gicumbi District. It is guided by the Smart Learning Environment theory (Kinshuk, Chen, Cheng, & Chew, 2016) and the Community of Inquiry framework (Garrison, Anderson, & Archer, 2000). The study contributes to broader debates on digital learning in resource-constrained contexts while providing insights for policymakers and education leaders seeking to optimize smart classroom utilization in Rwanda.

LITERATURE REVIEW

The integration of smart classrooms is increasingly viewed as a transformative pathway for enhancing quality, equity, and innovation in education. Globally, smart classrooms are expected to equip learners with twenty-first century skills, while in developing contexts they are framed as tools for bridging digital divides. This review explores international and regional experiences with smart classroom initiatives, highlights Rwanda's national efforts, and analyses the four key components of adequacy: technological infrastructure, pedagogical readiness, learning environment, and institutional support. It also draws on theoretical perspectives to frame the multidimensional nature of technology integration and concludes by identifying knowledge gaps that inform this study.

Global Perspectives on Smart Classrooms

International research consistently shows that when adequately resourced and supported, smart classrooms improve engagement, collaboration, and higher-order thinking. UNESCO (2019) observed that technology-rich learning environments contribute to inclusive and equitable education aligned with Sustainable Development Goal 4. OECD (2021) emphasized that digital classrooms cultivate critical thinking, collaboration, and problem-solving, which are essential competencies for knowledge economies. Several high-performing systems illustrate this potential. Singapore's ICT Masterplans invested in reliable broadband, interactive devices, and sustained teacher training, resulting in a shift from traditional instruction to interactive pedagogy (Lim & Wang, 2020). South Korea embedded broadband and digital devices nationwide,

supporting collaborative and inquiry-driven teaching (Telecom Review Asia, 2025). During the COVID-19 pandemic, digital classrooms in China maintained continuity of learning when schools were closed (Zhou & Li, 2021), while Brazil's blended smart classroom approaches were recognized as effective strategies for system resilience (Da Silva, 2024). These cases suggest that smart classrooms succeed where infrastructure, pedagogy, and institutional frameworks are integrated.

Smart Classrooms in Sub-Saharan Africa

In sub-Saharan Africa, implementation has been more uneven. Kenya's Digital Literacy Programme distributed thousands of laptops, but weak maintenance structures and lack of teacher readiness limited sustainability (Otieno, 2022). Uganda piloted ICT-supported science classrooms that improved learning outcomes, yet poor internet connectivity and limited scalability restricted their reach in rural areas (Nyakito, Amimo, & Allida, 2021). Studies from South Africa and Nigeria highlight enduring rural-urban divides. Chomunorwa and Mugobo (2023) reported that learners in rural South African schools had limited access to digital resources, while Akinyemi, Amaechi, and Etoh (2022) noted that insufficient teacher training hindered the effective use of technology in Nigeria. Ghanaian research stressed the importance of continuous teacher professional development (Boadu & Essel, 2020), and Senegalese evidence underscored weak institutional frameworks as a barrier to sustainability (Mawhood & Gross, 2014). Collectively, these findings confirm that infrastructure alone is insufficient; success requires trained teachers, supportive institutions, and conducive environments.

Rwanda's Smart Classroom Experience

Rwanda has aligned its ICT-in-education agenda with Vision 2050 and the National Strategy for Transformation, launching the Smart Classroom Project in 2016 (Government of Rwanda [GoR], 2017). By 2018, nearly 70 percent of secondary schools had at least one smart classroom (Ministry of Education [MINEDUC], 2018; Global Partnership for Education & Government of Rwanda, 2023). Despite this rapid rollout, rural districts face persistent challenges. Mushimiyimana and Dushimiyimana (2021) observed that teachers in such contexts often revert to chalk-and-talk methods due to unreliable internet, outdated devices, and overcrowded classrooms. Mugisha Ngendabanga, Nsanzimana, Nduwayezu, Umuhoza, & Nkurunziza (2021) reported that lack of maintenance budgets, insufficient technical staff, and weak leadership contributed to underutilization of existing facilities. These findings highlight a gap between national policy ambitions and the realities of rural schools such as those in Gicumbi District.

Key Components of Adequacy

The literature highlights four interdependent components of smart classroom adequacy. Technological infrastructure remains the cornerstone. Devices, internet connectivity, and electricity are essential but must be reliable and accessible in daily teaching (OECD, 2021; UNESCO, 2019). Rwanda's achievements in expanding access are tempered by recurring issues of functionality, maintenance, and electricity reliability, particularly in rural schools (Global Partnership for Education & Government of Rwanda, 2023). Pedagogical readiness determines whether technology is used meaningfully. Research shows that teachers require more than basic ICT literacy; they need digital-pedagogical capacity to design interactive lessons and integrate formative assessment tools. Sustained professional development has been associated with effective classroom integration in high-performing systems (Lim & Wang, 2020), while African studies emphasize that limited teacher capacity remains a recurring barrier (Otieno, 2022; Nyakito et al., 2021). In Rwanda, many teachers are familiar with basic technology but lack confidence in leveraging it for collaborative and inquiry-based learning (Mushimiyimana & Dushimiyimana, 2021). The learning environment shapes how technology supports collaboration and engagement. OECD (2021) and Zhou and Li (2021) noted that flexible layouts, adequate visibility of displays, and supportive socio-emotional climates encourage active participation.

In sub-Saharan Africa, structural barriers such as overcrowding and rigid seating arrangements have been shown to undermine smart classroom benefits (Chomunorwa & Mugobo, 2023). In Rwanda, overcrowding and poor classroom design in rural schools reduce opportunities for peer interaction and group work (Mushimiyimana & Dushimiyimana, 2021). Institutional support ensures the sustainability of smart classrooms. Strong leadership, clear policies, scheduled use, technical support, and budget allocations for

maintenance are vital for effective integration (UNESCO, 2019; OECD, 2021). International evidence demonstrates that systematic monitoring and accountability strengthen adoption, as seen in South Korea's smart education reforms (Eom & Lee, 2022) and India's DIKSHA platform (Ministry of Education India, 2017). In Rwanda, however, weak institutional frameworks, absence of ICT technicians, and limited monitoring mechanisms often result in underutilization of smart classrooms (Mugisha Ngendabanga et al., 2021).

Theoretical Review

Two theoretical perspectives provide the analytical foundation for understanding smart classroom adequacy. Smart Learning Environment (SLE) theory conceptualizes classrooms as adaptive systems where technological infrastructure, pedagogy, learning environment, and institutional support must function together to enable effective learning (Kinshuk, Chen, Cheng, & Chew, 2016). Any weakness in these components undermines the entire system. The Community of Inquiry (CoI) framework complements SLE by emphasizing that teaching presence, social presence, and cognitive presence are essential for meaningful learning (Garrison, Anderson, & Archer, 2000). In the context of smart classrooms, CoI highlights the role of teacher proficiency, learner engagement, and peer support in mediating how infrastructure and institutions translate into classroom practice. Together, these theories justify a multidimensional approach to assessing adequacy in Rwanda's schools.

Synthesis and Research Gap

The reviewed literature demonstrates that while smart classrooms have transformed learning in well-resourced contexts, their impact in sub-Saharan Africa remains constrained by infrastructure deficits, limited teacher preparation, overcrowded classrooms, and fragile institutional support. In Rwanda, significant investments have expanded access, yet utilization remains uneven, especially in rural districts. Few studies have systematically examined the adequacy of smart classroom components across multiple dimensions in such contexts. This study addresses this gap by assessing technological infrastructure, pedagogical readiness, learning environment, and institutional support in public secondary schools in Gicumbi District, thereby contributing to both national policy debates and broader regional scholarship on technology integration in education.

RESEARCH METHOD

Research Model

This study employed a sequential explanatory mixed-methods design (Creswell & Creswell, 2018), which integrates quantitative and qualitative approaches in two connected phases. The quantitative phase used a structured survey with Senior Three students to measure the adequacy of smart classroom components, while the qualitative phase explored the same issues through focus group discussions with Senior Six students, interviews with teachers, headteachers, parents, and the District Director of Education (DDE), and classroom observations. This design was chosen because it allowed statistical trends to be identified first and then interpreted through contextual perspectives, ensuring both breadth and depth of understanding.

Participants

The study was conducted in Gicumbi District, Northern Rwanda, where smart classrooms have been introduced in both rural and semi-urban secondary schools. Five schools were purposively selected based on three criteria: (i) smart classrooms had been in place for at least five years, ensuring maturity of use; (ii) each offered both O'Level (Senior Three) and A'Level (Senior Six science combinations), enabling comparisons across academic levels; and (iii) the sample reflected diversity across rural and semi-urban, day and boarding contexts. A total of 358 participants were included. These comprised 175 Senior Three learners (survey) and 143 Senior Six science learners (focus groups), who were selected because of their direct and extended exposure to smart classroom tools. The teacher sample included 22 educators (13 O'Level and 9 A'Level) with a minimum of five years of teaching experience and active engagement with smart classrooms. Leadership perspectives were gathered from five headteachers (three day schools and two boarding schools) and the

DDE. Finally, 12 parents (seven rural and five semi-urban) with children in the sampled schools were included to provide household perspectives. This purposive sample ensured balanced representation across students, teachers, parents, and administrators.

Table 1. *Distribution of Research Participants*

		n
Students	Senior Three (S3)	175
	Senior Six (S6, Science)	143
Teachers	O'Level (various subjects)	13
	A'Level (science combinations)	9
Headteachers	Day Schools	3
	Boarding Schools	2
Parents	Rural Parents	7
	Sub-urban Parents	5
Officials	District Director of Education	1
Total		358

Data Collection Tool

Quantitative data were collected using a structured Likert-scale questionnaire designed to measure four constructs: technological infrastructure, pedagogical readiness, learning environment, and institutional support. The questionnaire items were adapted from existing ICT-in-education studies and validated for contextual relevance. Qualitative data were collected using semi-structured interview guides for teachers, headteachers, parents, and the DDE; focus group protocols for students; and an observation checklist for classroom practices.

Collection of Data

The survey was administered to Senior Three students during regular school hours with the support of class teachers. Focus group discussions with Senior Six students were organized in groups of 10–12 to encourage open dialogue. Semi-structured interviews with teachers, headteachers, parents, and the DDE were conducted in school settings at scheduled times. Classroom observations were carried out alongside teaching sessions to capture real-time practices of smart classroom use.

Data Analysis

Quantitative data were entered into SPSS version 26 and analyzed using descriptive statistics, including frequencies and percentages, to assess the adequacy of the four smart classroom components. Construct validity was tested through exploratory factor analysis supported by the Kaiser-Meyer-Olkin (KMO) measure and Bartlett’s test of sphericity. Reliability was established through Cronbach’s alpha coefficients, all exceeding the 0.70 threshold. Qualitative data from interviews, focus groups, and observations were transcribed and analyzed thematically following Braun and Clarke’s (2006) six-phase framework. Deductive codes were derived from the four constructs, while inductive coding allowed new insights to emerge. Findings were compared across respondent groups and triangulated with quantitative results, with integration occurring during interpretation to generate comprehensive explanations. The study focused primarily on descriptive statistics to assess the adequacy of smart classroom components as perceived by participants. Given the exploratory nature of the study and its emphasis on contextual understanding, inferential statistical techniques such as ANOVA or regression were not applied. However, future studies may employ such techniques to examine differences across school categories and relationships among key variables.

Validity and Credibility

Instrument validity was established through expert review, pilot testing, and statistical verification. Reliability was confirmed through Cronbach’s alpha, while factor analysis enhanced construct validity. Credibility of qualitative findings was ensured through triangulation across methods, member checking with participants, and peer debriefing. Thick description of participant accounts provided contextual depth, and

consistency in coding enhanced dependability.

Ethical Considerations

Ethical approval was obtained from the Kabale University Research Ethics Committee and the Gicumbi District Education Office. Informed consent was obtained from all adult participants, while assent from students was complemented by parental consent. Participation was voluntary, confidentiality was assured through anonymized codes, and all data were securely stored.

FINDINGS

This section presents the findings on the adequacy of smart classroom components in public secondary schools of Gicumbi District. The study followed a sequential explanatory design, beginning with quantitative evidence from 175 Senior Three students and later integrating qualitative insights from teachers, headteachers, parents, Senior Six students, and the District Director of Education. Classroom observations were also conducted to triangulate reported practices. Construct validity of the survey scales was confirmed ($KMO > .85$; Bartlett’s $p < .001$; Cronbach’s $\alpha \geq .86$), indicating strong reliability. Results are organized thematically across four components: technological infrastructure, pedagogical readiness, learning environment, and institutional support.

Return Rate

The study targeted a total of 368 respondents. Of the 185 questionnaires distributed to Senior Three students, 175 were returned (94.6%). All 143 Senior Six students participated in focus group discussions, and full participation was also achieved from teachers (22), headteachers (5), parents (12), and the District Director of Education. The overall response rate was 97.3%, which is considered highly reliable for both quantitative and qualitative analyses.

Table 2. Return Rate of Respondents (N = 368)

Respondent Category	Target Sample	Actual Responses	Return Rate (%)
Senior Three Students (Survey)	185	175	94.6
Senior Six Students (FGDs)	143	143	100.0
Teachers (Interviews)	22	22	100.0
Headteachers (Interviews)	5	5	100.0
Parents (Interviews)	12	12	100.0
District Director of Education (Interview)	1	1	100.0
Total	368	358	97.3

Measurement Reliability and Validity

To ensure robustness of the constructs, factor analysis and reliability tests were conducted. All scales demonstrated sampling adequacy (KMO values $> .85$), significant Bartlett’s tests ($p < .001$), and high internal consistency (Cronbach’s $\alpha \geq .86$). This confirms that the items reliably measured the four key components of smart classroom adequacy.

Table 3. Summary of Reliability and Validity of Constructs

Construct	KMO	Bartlett’s Test (p)	Cronbach’s α	Retained Items
Technological Infrastructure	0.872	$< .001$	0.893	7
Pedagogical Readiness	0.861	$< .001$	0.881	6
Learning Environment	0.874	$< .001$	0.887	6
Institutional Support	0.852	$< .001$	0.861	5

Technological Infrastructure

Survey results showed that infrastructure remains one of the weakest components. Nearly half of students disagreed that internet services were reliable (22.9% strongly disagreed; 26.3% disagreed), and

54.3% indicated that technical support was rarely available. Only about one-third (33.1%) agreed or strongly agreed that projectors and smart boards were functional, and a similar share (35.4%) confirmed curriculum alignment of digital resources. These results underscore recurring issues of unreliable connectivity, outdated devices, and insufficient maintenance.

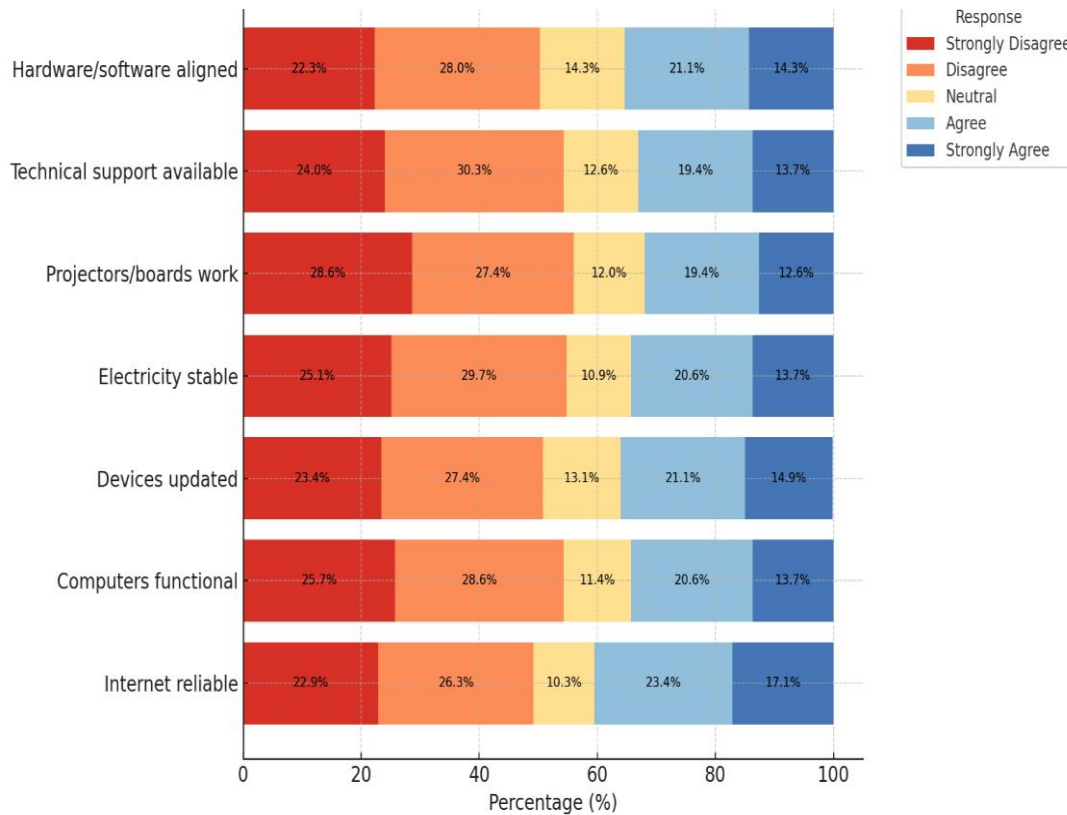


Figure 1. Student Ratings on Technological Infrastructure (N = 175).

Qualitative evidence reinforced these gaps. Teachers reported that “many computers take a long time to start, and sometimes half are not working.” Students expressed frustration at being limited to watching projectors rather than using devices, while parents questioned whether ICT investments were meaningful. Headteachers acknowledged irregular maintenance, and observations revealed idle projectors, weak internet, and non-functional computers. The District Director of Education confirmed that “functionality is a challenge” due to outdated software, breakdowns, and slow repair systems.

Pedagogical Readiness

Students perceived teaching practices as inconsistent in leveraging smart classroom tools. While 40.6% agreed that teachers made lessons interactive, an almost equal proportion (41.1%) disagreed. Smart tools were considered helpful for critical thinking by 38.9% of students, though 34.8% disagreed. Assessment and teacher confidence scored lowest: nearly half (46.8%) reported that teachers did not use smart tools for assessment, and 50.3% said teachers lacked confidence with technology.

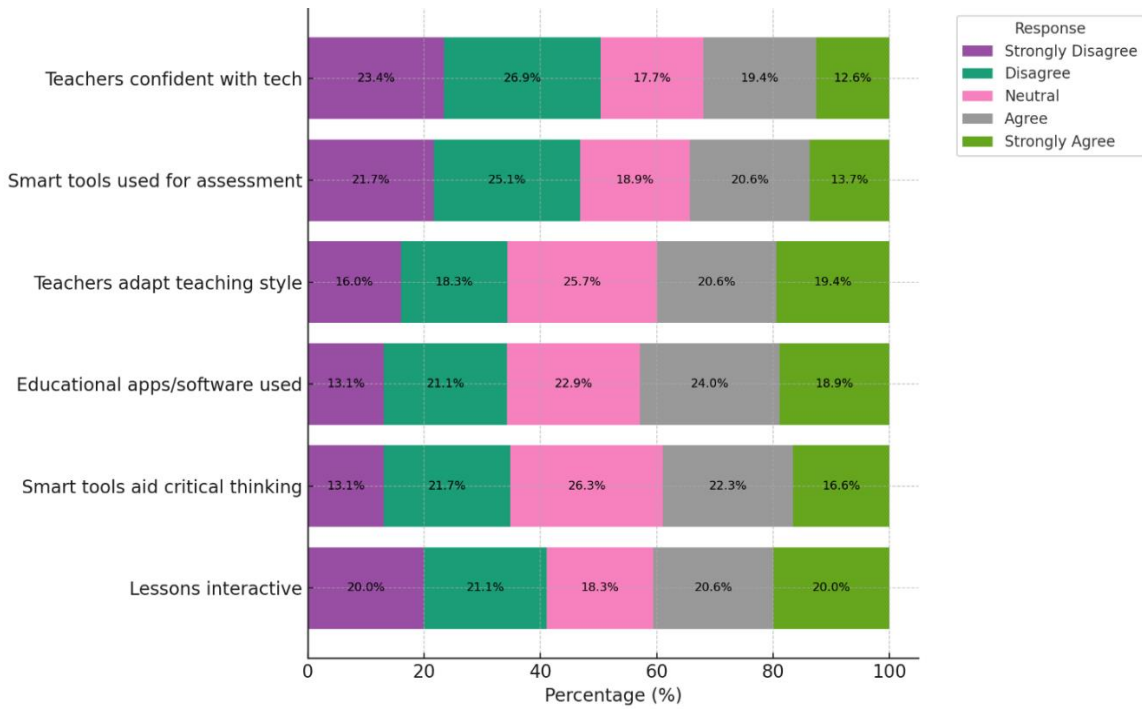


Figure 2. Student Ratings on Pedagogical Readiness (N = 175).

Qualitative findings explained these patterns. A few ICT and science teachers used simulations or videos, but most admitted relying on chalk-and-talk methods. One teacher confessed, “we are afraid of breaking the machines, so it is safer to use the chalkboard.” Students described lessons as “one-way communication,” while parents expressed disappointment with the lack of interactive pedagogy. Headteachers acknowledged that staff training was limited and irregular, and the DDE noted that professional development was externally driven, leaving teachers with only basic orientation.

Learning Environment

Findings on the learning environment were mixed. Just over two-fifths (41.1%) agreed or strongly agreed that classroom design supported effective technology use, while 35.4% disagreed. Seating arrangements were problematic: 42.3% disagreed they promoted interaction, compared to 40.0% who agreed. Similarly, 42.8% agreed that classroom setup encouraged group work, but 40.6% disagreed. More positively, 46.3% felt smart classrooms reduced distractions, though motivation for active participation was divided (40.5% agreed; 41.1% disagreed).

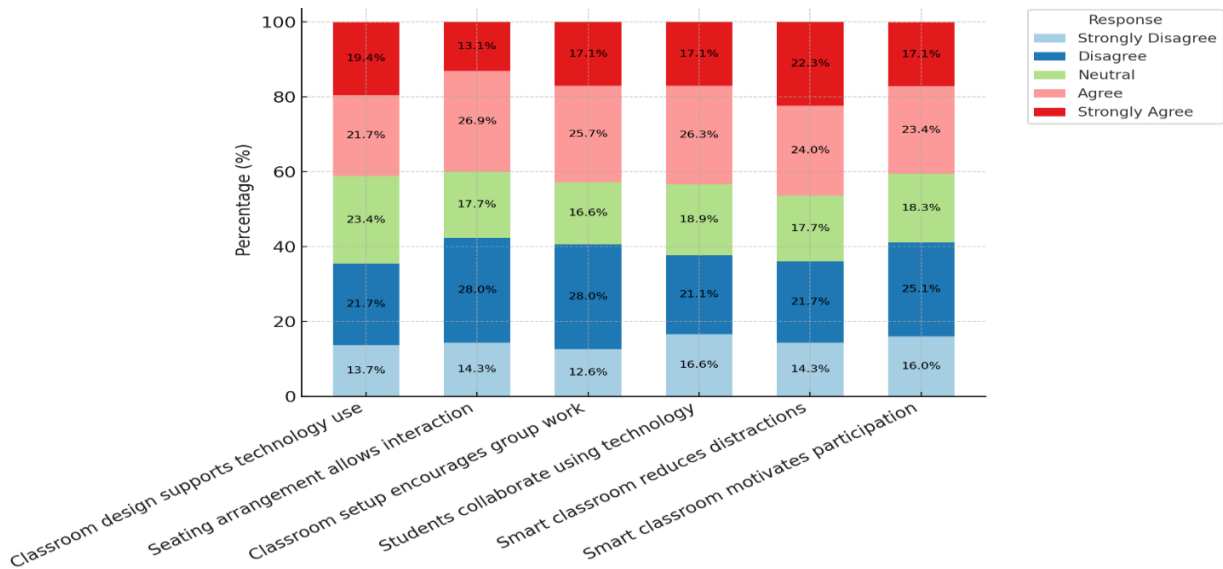


Figure 3. Student Ratings on Learning Environment (N = 175).

Qualitative accounts provided context. Teachers described overcrowded classrooms that limited effective use, while students reported competing for limited functional computers. Parents noted that children rarely mentioned collaborative learning, and observations revealed fixed seating, poor ventilation, and frequent power cuts. The DDE stressed that rural schools were particularly disadvantaged by unstable electricity and weak internet, undermining the intended benefits of smart classrooms.

Institutional Support

Institutional support was perceived as insufficient across most indicators. Only 34.3% of students agreed that school leaders encouraged smart classroom use, while nearly half (46.8%) disagreed. Just 37.2% said teachers provided clear guidance, and 48.6% reported that technical assistance was unavailable when devices failed. Training opportunities were especially limited, with 50.9% reporting no training, compared to only 31.4% who confirmed receiving it.

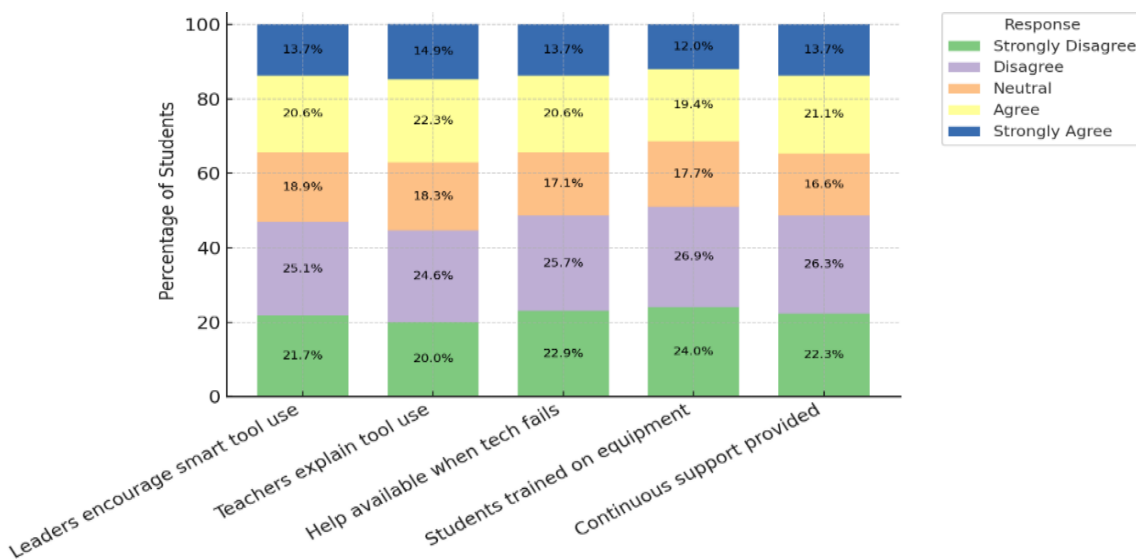


Figure 4. Student Ratings on Institutional Support (N = 175).

Qualitative narratives deepened these insights. Teachers reported limited guidance, while students said access was informal and unstructured. Parents highlighted a lack of communication on ICT use, and headteachers admitted most schools had no specific smart classroom policy. Observations confirmed that facilities were often idle due to absence of ICT support staff. The DDE acknowledged oversight was irregular and depended heavily on school leadership commitment.

Integration of Findings

The combination of quantitative and qualitative data highlights a consistent pattern: although smart classrooms are physically present in Gicumbi schools, they are underutilized due to systemic barriers. Weak infrastructure, limited teacher training, overcrowded classrooms, and insufficient institutional support all contribute to this underuse. These findings confirm that technology provision alone is insufficient; effective utilization requires holistic investment in infrastructure, teacher development, classroom design, and strong institutional frameworks. These findings reinforce the need for an integrated systems-based approach to smart classroom utilization, where technological infrastructure, pedagogical readiness, learning environment, and institutional support operate as interdependent components.

DISCUSSION AND CONCLUSION

This study examined the adequacy of smart classroom components in public secondary schools of Gicumbi District, Rwanda, focusing on technological infrastructure, pedagogical readiness, learning environment, and institutional support. The findings reveal that although most schools possess smart classroom facilities, their utilization remains constrained by systemic weaknesses. Technological infrastructure emerged as the most inadequate component. Students reported unreliable internet, insufficient functional computers, and poor technical support. Teachers and headteachers confirmed that

equipment was often outdated, slow, or in disrepair, with maintenance delays lasting weeks. These results reinforce UNESCO (2019) and OECD (2021) who argue that infrastructure quality, rather than simple provision, determines the effectiveness of digital learning. They also mirror challenges in Kenya and Uganda where large-scale device distribution was undermined by poor maintenance and limited connectivity (Otieno, 2022; Nyakito, Amimo, & Allida, 2021). Although official reports (MINEDUC, 2018; GPE & GoR, 2023) indicate high coverage of smart classrooms, the present study demonstrates that functionality and accessibility remain significant bottlenecks in rural schools.

Pedagogical readiness was inconsistent. Some ICT and science teachers used digital tools effectively, but most lacked confidence and defaulted to traditional methods. Students described smart classrooms as projection spaces rather than interactive learning environments, with little use of technology for assessment or critical thinking. This confirms Mushimiyimana and Dushimimana (2021) who observed that many Rwandan teachers continue to rely on conventional methods despite ICT investment. It also contrasts with international cases such as Singapore and South Korea where sustained professional development shifted pedagogy toward interactive and student-centered approaches (Lim & Wang, 2020; Telecom Review Asia, 2025). The absence of continuous training in Gicumbi underscores the central role of teacher preparation in realizing the transformative potential of smart classrooms. The learning environment was only moderately supportive.

Overcrowded classrooms, rigid seating arrangements, and poor ventilation limited opportunities for collaboration and active engagement. In some schools, more than 60 students shared fewer than 20 working computers, leaving many as passive observers. While some respondents acknowledged that smart classrooms reduced distractions and improved concentration, perceptions of interactivity and motivation remained inconsistent. These findings align with reports from South Africa and Nigeria where structural and organizational barriers undermined the benefits of smart classrooms (Chomunorwa & Mugobo, 2023; Akinyemi, Amaechi, & Etoh, 2022). In contrast, OECD (2021) and Zhou and Li (2021) emphasized that flexible layouts and supportive socio-emotional climates are critical for collaboration and participation, conditions largely absent in Gicumbi.

Institutional support was perceived as the weakest dimension. Students and teachers reported minimal leadership encouragement, lack of timetabling, and absence of ICT technicians. Parents observed that communication about ICT use was rare, while headteachers admitted that policies were informal and inconsistent. The District Director of Education confirmed that oversight varied between schools and was not standardized. These findings support Mugisha Ngendabanga et al. (2021) who concluded that weak leadership and institutional frameworks limit ICT integration in Rwanda. They also reinforce UNESCO (2019) and OECD (2021) who argued that systematic monitoring, leadership, and resource allocation are indispensable. By contrast, South Korea's structured reforms and India's DIKSHA platform illustrate how institutional accountability sustains adoption (Eom & Lee, 2022; Ministry of Education India, 2017). Taken together, the findings demonstrate that smart classrooms in Gicumbi District are constrained by interconnected weaknesses. The Smart Learning Environment theory (Kinshuk, Chen, Cheng, & Chew, 2016) emphasizes that infrastructure, pedagogy, learning environment, and institutional support must function together.

In this case, deficits across all four dimensions weakened the overall system. The Community of Inquiry framework (Garrison, Anderson, & Archer, 2000) further highlights that teaching presence, social presence, and cognitive presence cannot be sustained when infrastructure is unreliable and institutional support is lacking. This study contributes to the growing body of literature on ICT in education in sub-Saharan Africa by providing empirical evidence from a rural context where utilization remains limited despite strong national investment. It extends earlier research by showing how deficiencies in infrastructure, pedagogy, environment, and leadership interact to constrain smart classroom use. The results underscore that technology provision alone is insufficient. To optimize smart classroom utilization in Rwanda, sustained infrastructure maintenance, continuous professional development in digital pedagogy, classroom redesign, and strong institutional frameworks with technical support and accountability are essential. Addressing these areas will enable smart classrooms to evolve from symbolic facilities into genuine platforms for interactive, equitable, and future-ready learning.

Limitations and Recommendations

This study has several limitations that should be acknowledged. First, the research was confined to public secondary schools in Gicumbi District, which may limit the generalizability of the findings to other regions of Rwanda or Sub-Saharan Africa. Second, the study relied partly on self-reported data from students, which may be subject to response bias. Third, the cross-sectional design captures conditions at a single point in time and does not account for changes in smart classroom utilization over time. Despite these limitations, the study provides valuable insights into the systemic challenges affecting smart classroom utilization in rural contexts.

To ensure the effective and sustainable use of smart classrooms, a comprehensive and coordinated approach is required. First, schools should prioritize the regular updating of hardware and software, while also ensuring reliable electricity and stable internet connectivity; this must be supported by dedicated budgets for ongoing maintenance and timely repairs. In parallel, continuous professional development programs in digital pedagogy should be institutionalized, incorporating peer learning, mentoring, and in-service workshops to strengthen teachers' confidence and foster innovative instructional practices. Physical learning environments also need attention: classrooms should be redesigned to reduce overcrowding, improve ventilation and lighting, and adopt flexible layouts that promote collaboration and active student participation. Moreover, the use of smart classrooms should be regulated through structured timetables, clear access rules, and accountability mechanisms, supported by the recruitment or training of ICT technicians. At the institutional level, stronger leadership and policy frameworks are essential, including the allocation of dedicated ICT budgets, the development of clear implementation guidelines, and the enforcement of accountability measures for technology integration. Sustainability can be further enhanced by actively engaging parents, local communities, and private stakeholders in supporting smart classroom initiatives, thereby fostering a sense of shared responsibility. Additionally, systematic monitoring and evaluation processes should be established to track usage patterns, identify challenges, and inform continuous improvement at both school and district levels. Finally, future research should adopt longitudinal designs to examine changes in smart classroom utilization over time and their impact on student learning outcomes, while also testing integrated smart classroom frameworks across diverse contexts and employing inferential statistical techniques to analyze the relationships among technological infrastructure, pedagogical readiness, learning environments, institutional support, and educational outcomes.

REFERENCES

- Akinyemi, I. A., Amaechi, L. I., & Etoh, L. C. (2022). Digitalization of education in Nigerian secondary schools: Benefits and challenges. *Journal of Education and Humanities Research*, 13(1), 34-42. Retrieved from <http://journal.uob.edu.pk/journal/index.php/jehr/article/view/324>
- Boadu, G., & Essel, H. B. (2020). Teachers' professional development and the integration of information and communication technology in teaching: Evidence from Ghana. *Journal of Education and Practice*, 11(12), 12-23. <https://doi.org/10.7176/JEP>
- Braun, V., & Clarke, V. (2006). Using thematic analysis in psychology. *Qualitative Research in Psychology*, 3(2), 77-101. <https://doi.org/10.1191/1478088706qp063oa>
- Chomunorwa, S., & Mugobo, V. V. (2023). Challenges of e-learning adoption in South African public schools: Learners' perspectives. *Journal of Education and e-Learning Research*, 10(1), 80-85.
- Creswell, J. W., & Creswell, J. D. (2018). *Research design: Qualitative, quantitative, and mixed methods approaches* (5th ed.). Sage. Retrieved from <https://www.tandfonline.com/doi/full/10.1080/15424065.2022.2046231>
- Da Silva, S. P. (2024). *Pedagogical resilience, from class to digital room: A comparative study of technology adoption in Brazilian higher education before and during the pandemic*. Editora Dialética. Retrieved from https://books.google.rw/books?hl=en&lr=&id=N_wQEQAQBAJ&oi=fnd&pg=PA2004
- Eom, S.-J., & Lee, J. (2022). Digital government transformation in turbulent times: Responses, challenges, and future direction. *Government Information Quarterly*, 39(2), 101690.

<https://doi.org/10.1016/j.giq.2022.101690>

- Garrison, D. R., Anderson, T., & Archer, W. (2000). Critical inquiry in a text-based environment: Computer conferencing in higher education. *The Internet and Higher Education*, 2(2–3), 807-105. [https://doi.org/10.1016/S1096-7516\(00\)00016-6](https://doi.org/10.1016/S1096-7516(00)00016-6)
- Global Partnership for Education, & Government of Rwanda. (2023). *ESPIG annual progress report- Rwanda*. Global Partnership for Education. Retrieved from <https://www.globalpartnership.org/node/document/download?file=document%2Ffile%2F2024-06-gpe-annual-progress-report-espig-rwanda.pdf>
- Government of Rwanda. (2017). *National Strategy for Transformation (NST1) 2017-2024 & Vision 2050*. Government of Rwanda. Retrieved from <https://faolex.fao.org/docs/pdf/rwa206814.pdf>
- Kinshuk, Chen, N.-S., Cheng, I.-L., & Chew, S.-W. (2016). Evolution is not enough: Revolutionizing current learning environments to smart learning environments. *International Journal of Artificial Intelligence in Education*, 26(2), 561–581. <https://doi.org/10.1007/s40593-016-0108-x>
- Lim, C. P., & Wang, L. (2020). Enacting the ICT Masterplan in Singapore schools: Pedagogical shifts and sustainability. *British Journal of Educational Technology*, 51(2), 427-442.
- Mawhood, R., & Gross, R. (2014). Institutional barriers to a ‘perfect’ policy: A case study of the Senegalese Rural Electrification Plan. *Energy Policy*, 73, 480–490. <https://doi.org/10.1016/j.enpol.2014.05.047>
- Ministry of Education, Government of India. (2017). *DIKSHA: National teacher platform* [Digital platform]. Retrieved from <https://diksha.gov.in>
- Ministry of Education. (2016). *ICT in education policy*. Government of Rwanda. Retrieved from https://planipolis.iiep.unesco.org/sites/default/files/ressources/rwanda_ict_in_educationpolicy_approved.pdf
- Ministry of Education. (2018). *Education Sector Strategic Plan 2018-2024*. Government of Rwanda. Retrieved from https://www.mineduc.gov.rw/fileadmin/user_upload/Mineduc/Publications/ESSP/1_Education_Sector_Strategic_Plan_2018_2024.pdf
- Mugisha Ngendabanga, C., Nsanzimana, P., Nduwayezu, F., Umuhoza, V., & Nkurunziza, J. B. (2021). Effect of smart classroom on learners’ performance in organic chemistry: A case study of senior five students in Kicukiro District–Rwanda. *GSC Biological and Pharmaceutical Sciences*, 16(2), 204–211. <https://doi.org/10.30574/gscbps.2021.16.2.0251>
- Mushimiyimana, J. D. D., & Dushimimana, J. D. D. (2021). *Effect of blended learning on learners’ academic performance: Case of Gicumbi District (2015–2020)*. *Voice of Research*, 10(3), 8-16. Retrieved from https://voiceofresearch.org/Doc/Dec-2021/Dec-2021_2.pdf
- Nyakito, C., Amimo, C., & Allida, V. B. (2021). Challenges of integrating information and communication technology in teaching among national teachers’ colleges in Uganda. *East African Journal of Education and Social Sciences*, 2(3), 1–12. <https://doi.org/10.46606/eajess2021v02i03.0114>
- Organisation for Economic Co-operation and Development (OECD). (2021). *OECD Skills Outlook 2021: Learning for Life*. OECD Publishing. <https://doi.org/10.1787/0ae365b4-en>
- Otieno, A. (2022). Challenges in the implementation of Kenya’s digital literacy program: Insights from public primary schools. *Journal of African Education*, 3(1), 23–38. <https://doi.org/10.53832/edtechhub.0159>
- Telecom Review Asia. (2025, May 9). South Korea’s binary broadband push: Bridging the digital divide, one village at a time. *Telecom Review Asia*. <https://www.telecomreviewasia.com>
- United Nations Educational, Scientific and Cultural Organization. (2019). *Education and technology in a changing world: Advancing Sustainable Development Goal 4*. UNESCO. <https://unesdoc.unesco.org/ark:/48223/pf0000370304>
- Zhou, Y., & Li, X. (2021). Smart classrooms in China during COVID-19: Expanding digital learning to ensure continuity. *Journal of Educational Technology Development and Exchange*, 14(2), 45-60.