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Empowering Science Education in Rwanda: How ICT is Revolutionising Science Teaching in Teacher Training Colleges

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Abstract

This review examines the integration of Information and Communication Technologies (ICTs) in science education across Rwandan Teacher Training Colleges (TTCs). Through a systematic literature analysis of studies from the past decade, this study categorizes existing research based on ICT tools, such as laptops, projectors, and virtual simulations and evaluates their effectiveness using the Technological Pedagogical Content Knowledge (TPACK) framework. Categorised by themes of science comprehension, student engagement, and teaching effectiveness, the results show that although ICT tools improve student engagement and teaching quality, obstacles like resource shortages, infrastructure constraints, and gaps in digital literacy hinder widespread adoption. Under the review, to promote ICT adoption within a competency-based curriculum, relevant professional development, infrastructure investment, and governmental support are required. This review offers educators and policymakers practical advice on how to promote ICT integration in Rwandan TTCs and create a more dynamic, tech-driven learning environment.

Key Words: *Information and Communication Technologies (ICTs), Science education, Teacher Training Colleges (TTCs), Competency-based curriculum, Professional development*

1.0. Introduction

In today's rapidly evolving educational landscape, Information and Communication Technologies (ICTs) have emerged as transformative tools that are reshaping teaching and learning experiences across multiple domains, including science education (Mushimiyima et al., 2022). ICT integration in education encompasses the incorporation of digital tools to support and enhance traditional educational methods, making it a critical element of modern reforms that aim to promote equitable, accessible, and high-quality learning (Lawrence & Tar, 2018). In Rwanda, these educational reforms are particularly pronounced, as the government emphasizes the strategic use of ICT to achieve quality education that aligns with the country's economic and social development goals (Mugiraneza, 2021). The competency-based curriculum in Rwanda underscores this commitment, emphasising skills-orientated education where ICT can play an instrumental role.

ICT in science education has the potential to bridge the gap between theoretical knowledge and practical application, as digital tools like virtual labs enable students to conduct experiments and simulations that would otherwise be inaccessible due to resource, financial, or safety constraints (Bidarra & Rusman, 2017). Multimedia resources and interactive simulations not only enrich student engagement but also enhance critical thinking, providing students with real-world skills relevant to the digital age (Collins & Halverson, 2018; Reynolds, 2016). Current research suggests that ICT-facilitated, self-directed learning, particularly within Rwanda's competency-based curriculum framework, supports improved comprehension, retention, and overall mastery of scientific concepts (Kanamugire et al., 2019).

Despite the promising role of ICT in enhancing educational outcomes, significant challenges hinder its effective implementation, especially in Rwandan Teacher Training Colleges (TTCs). For instance, a recent study reported that only 25% of science educators in Rwandan TTCs regularly utilize ICT resources, with limited access to tools and infrastructure being a major barrier (Nzabahimana et al., 2024). Such findings highlight the gap between ICT's potential and its current accessibility in science education within TTCs, underscoring the need for targeted strategies to bridge this divide.

The purpose of this review is to examine the role of ICT in advancing science education within Rwandan TTCs, focusing on the opportunities and challenges presented by ICT integration. Using a structured literature review approach, this paper synthesises existing research over the past decade to identify effective ICT tools and instructional strategies in TTCs and evaluate them through the Technological Pedagogical Content Knowledge (TPACK) framework. By offering insights into the benefits and barriers of ICT use in Rwandan science education, this review aims to inform educators, curriculum developers, and policymakers on strategic actions to optimise ICT integration, ensuring that technology can support a dynamic, competency-driven learning environment in science education.

2.0. Methodology

A systematic search was conducted across multiple academic databases, including PubMed, Scopus, Google Scholar, JSTOR, and ERIC to ensure a comprehensive review of the available literature on ICT integration in science education within Rwandan TTCs. Specific search terms and keywords used included "ICT integration," "science education," "teacher training colleges," "competency-based curriculum," and "teacher training." Boolean operators were employed to refine the search, which helped in extensively exploring the relevant literature.

2.1. Inclusion and Exclusion Criteria

The inclusion criteria focused on peer-reviewed journal articles, conference papers, and reports published between 2010 and 2023 that addressed ICT integration in science education within the Rwandan TTC context. Publications in English were included for comprehensibility, while those in other languages, such as French or Kinyarwanda, were excluded due to language limitations. Additionally, sources not directly related to ICT in science education, non-peer-reviewed articles, and studies conducted outside Rwanda were excluded to maintain relevance and focus.

2.2 Quality Assessment

A rigorous quality assessment of the selected sources was conducted based on three main criteria: methodological rigour, author credibility, and relevance. Methodological rigour involves evaluating the research design and methods used in each study to ensure validity and reliability. Author credibility was assessed by examining the authors' expertise in educational technology and science education. Relevance was determined by analyzing how closely each study aligned with the review's objectives, with a specific focus on ICT integration within Rwandan TTCs.

2.2. Synthesis Approach

The data from the selected sources were synthesized using a thematic analysis approach. This process involved identifying and categorising key themes related to teaching effectiveness, student engagement, and comprehension in science education. Thematic analysis enabled an aggregation of insights, which provided a cohesive understanding of ICT integration in Rwandan TTCs.

3.0. Problem Statement

Despite the global push for integrating ICT into education, many countries, especially in Africa, face challenges in implementing this shift effectively. Rwanda, in particular, has made significant strides toward adopting a competency-based curriculum, yet the seamless integration of ICT into teaching and learning processes remains limited in practice, especially within science education at Teacher Training Colleges (TTCs). Challenges range from limited resources and infrastructure to resistance from educators untrained in ICT use, ultimately impeding the full benefits ICT could bring to science education. This review seeks to examine the current state of ICT integration in science education within Rwandan TTCs, identifying both successes and obstacles. By analysing existing strategies, tools, and approaches, the review aims to provide insights and recommendations for stakeholders to optimize ICT integration, thus enhancing teaching effectiveness and fostering competency-based science learning.

4.0. Aim and Objectives

4.1. Aim

This review aims to critically analyse the impact of ICT integration on science education within Rwandan Teacher Training Colleges (TTCs) operating under a competency-based curriculum. By examining both the benefits and challenges associated with ICT use, this paper seeks to offer an understanding of how technology can enhance science teaching and learning while identifying practical solutions to address barriers to effective ICT integration.

4.2 ***Specific Objectives***

This review paper focuses on the following specific objectives:

i. To assess the correlation between ICT integration and teaching effectiveness in science education within Rwandan TTCs, particularly in a competency-based curriculum.
ii. To compile an inventory of ICT tools, resources, and instructional strategies currently used in science education across Rwandan TTCs, with attention to their application and effectiveness in facilitating student engagement and learning.
iii. To identify key challenges educators faced in ICT integration, including factors such as technology adoption resistance, resource limitations, and infrastructure inadequacies, and to propose solutions to overcome these obstacles.
iv. To provide recommendations for educators, curriculum developers, and policymakers on enhancing the alignment of ICT integration

with competency-based education goals, ensuring a more seamless and impactful approach to science education.

5.0. Results

5.1. ICT Tools, Resources, and Instructional Strategies in Science Education

Rwandan TTCs have employed ICT tools, resources, and instructional strategies in their science education system. Notable technologies in the Rwandan TTC science education system include using ICT gadgets such as computers, projectors, and tablets to address students' misconceptions about biology, chemistry, and physics (Kizito, 2016). In recent 2023 developments, REB handed over 16 smart screens to 16 TTCs, which are expected to promote peer learning and research activities. Smart screens create a conducive learning environment for natural sciences as tutors can easily use videos, animations, and any digital content when connected to the internet. In the modern world, science educators harness interactive whiteboards, virtual laboratories, and simulation software to engage students dynamically in scientific concepts (Tikly et al., 2018).

The Ministry of Education in Rwanda advocated for the program 'One Laptop Per Child' (OLPC), in line with equipping students in primary and secondary schools with digital learning tools. The policy was later revised to "One Digital Identity Per Child and Smart Classrooms" in all primary and secondary schools (Ntawiha et al., 2023). According to Ngendabanga et al. (2021), the use of smart classrooms improves learners' knowledge and understanding of science concepts in comparison with the non-use of smart classrooms.

The Rwanda Education Board designed digital information management systems for education personnel, such as the School Data Management System (SDMS), Comprehensive Assessment Management Information System (CAMIS), Teacher Management Information System (TMIS), Formative Assessment Management Information System (FAMIS), Learning and Teaching Materials Management System (LTMMIS), and Education Management Information System (EMIS) for planning, monitoring, and evaluation (Hashakimana et al., 2022; Mugiraneza, 2021; Niyibizi, 2023). These digital resources are pivotal in facilitating seamless access to vital information and collaborative platforms in Rwandan TTCs (Ndihokubwayo and Murasira, 2019).

Nsabayezu et al. (2020) further emphasise the role of digital resources in enhancing student-teacher interaction in science education, especially during the COVID-19 pandemic.

ICT tools, resources, and instructional strategies have been employed in science education globally (Barakabitze et al., 2019; Fernandes et al., 2019; Maharaj-Sharma et al., 2017). Among such ICTs are digital assessment tools (Rocha Fernandes et al., 2019), automatic feedback systems (Deeve et al., 2021), ubiquitous learning (Aljawarneh, 2020) augmented reality (Sahin& Yilmaz, 2020) and gesture-based technology (Wang & Yang, 2016). The integration of ICT in science education within competency-based curriculum systems has been a key focus in Rwandan TTCs. Nsengimana et al. (2023) and Mushimiyimana et al. (2022) highlighted the importance of ICT integration in science education.

5.2. Impact of ICT Integration on Teaching Effectiveness

It has been observed that educators in Rwanda have a generally positive attitude toward the use of ICT and recognise its potential to enhance science teaching (Baytiyengati et al., 2018). The use of ICT in science education has been found to enhance student interest in learning (Dushimimana & Uworwabayeho, 2020). ICT facilitates learners in their everyday learning activities (Bornman, 2016). Multimedia technologies are of paramount importance in teaching and learning sciences since they promote problem-solving, facilitate the acquisition and retention of knowledge, develops innovative thinking, and enhance academic achievement (Ntawiha et al., 2023). Rwangoga et al. (2015) indicated that using ICT tools, such as interactive simulations and multimedia resources, positively influenced student engagement, understanding, and retention of scientific concepts. Improvements in the teaching and learning processes in Rwandan TTCs are evident through increased student engagement, active participation, and a deeper understanding of complex scientific concepts (Nkundabakura et al., 2023).

Access to virtual laboratories has closed the gap of unavailability of proper infrastructure for carrying out experiments in chemistry, physics, and biology. Laboratory equipment and materials are in short supply, and the unavailability of laboratory buildings hinders laboratory activities in TTCs (Ndihokubwayo, 2017). According to REB (2020), ICT in education is to be used to enhance teaching and learning and to prepare citizens who will adapt to this newly created environment. The ICT materials provide meaningful activities that help learners learn more about science; thus, they enhance the learner's abilities (Villasanta, 2022).

Using ICTs has also streamlined administrative tasks, allowing teachers to allocate more time to interactive and hands-on learning experiences (Manasse, 2020). Nevertheless, a balanced approach should be adopted when integrating ICT, and it should complement traditional teaching methods rather than replace them entirely (Mukandayisenga et al., 2021; Nkundabakura et al., 2023a).

In the dynamic landscape of education, the integration of ICTs has emerged as a transformative force, shaping the effectiveness of teaching, especially in science education (Barak, 2017; Timotheou et al., 2023). ICT integration in Rwandan TTCs brought a multifaceted impact on the overall effectiveness of teaching and learning, particularly in science. The introduction of ICT tools and resources has enhanced the accessibility of educational content, enabling teachers to employ multimedia resources, simulations, and virtual experiments (Uwineza et al., 2023). Munyengabe et al. (2017) reiterate that applying ICTs increases teacher skills, confidence, and enthusiasm through access to up-to-date data.

5.3. Challenges Faced by Science Educators in ICT Integration

Integrating ICTs into science instruction presents educators with a spectrum of challenges globally (Barakabitze et al., 2019; Madzima et al., 2014; Saravanakumar & Padmini, 2020). Likewise, a handful of such challenges have also been identified in Rwandan TTCs. Challenges faced by educators in Rwandan TTCs can be explicitly divided into two categories, namely extrinsic and intrinsic factors. Extrinsic factors include time, resources, support, and training. Intrinsic factors encompass beliefs, attitudes, and resistance.

The lack of continuous professional development for teachers to adeptly navigate and utilise ICT tools (Kanamugire et al., 2019), ICT infrastructural constraints (Uwineza et al., 2023), and limited access to ICT tools are the major extrinsic factors affecting ICT implementation in Rwandan TTCs (de Dieu et al., 2020). Uwineza et al. (2023) mentioned that infrastructure poses another significant hurdle in ICT integration among Rwandan TTCs. In some TTCs, limited access to essential technological resources such as computers, projectors, and a reliable internet connection may hamper the uniform implementation of ICT integration (de Dieu et al., 2020; Iyamuremye & Ndagijimana, 2022). The importance of infrastructural development and collaborative efforts between educational institutions and governmental bodies to address these deficiencies in Rwanda has been elaborated by de Dieu et al. (2020) and Uwineza et al. (2023).

Kanamugire et al. (2019) mentioned that one prominent challenge in Rwandan TTCs revolves around the issue of technology adoption. Educators may face resistance or hesitancy among their peers to embrace new ICT tools and methodologies (Kanamugire et al., 2019). This reluctance could stem from a lack of familiarity with technology or apprehensions about disrupting established teaching practices. Some teachers in TTCs lack technical support in the classrooms, which may affect their lesson time management and end up giving up (Kamonyo et al., 2022).

Moreover, educators may grapple with the challenge of aligning ICT integration with curriculum requirements (Rubagiza et al., 2016). Balancing traditional teaching methods with the incorporation of technology necessitates careful planning and adaptation.

5.4. Best Practices in Rwandan Education System to Accommodate ICT Integration

Rwanda is striving to build a knowledge-based economy through the establishment of quality education in all its TTCs. ICT, science, and technology are among the clearly outlined basic and generic competencies expected to be acquired by the student teachers during their three-year training course (REB, 2020). Natural science subjects have been attributed to immense contributions to global socio-economic transformations. The world we live in is changing rapidly and education needs to keep in step with the ever-evolving technological best practices (Villasanta, 2022).

A fundamental best practice lies in aligning ICT integration with the objectives of a competency-based curriculum (Rubagiza et al., 2016). This involves mapping out how technology can enhance the development of key competencies in science education. Fallon (2020) suggested that educators should strategically select ICT tools and resources that complement the curriculum, fostering a seamless integration of technology into the teaching and learning processes. The Rwandan curriculum framework highlights the need to incorporate ICT by students and educators as a medium to enhance the quality of education in all subjects at all levels in teaching and learning practices (REB, 2020).

The Rwanda Education Board (REB) has recently provided interactive smart screens and virtual laboratory resources in Rwandan TTCs (Nyiramana, 2023). These resources provide students with hands-on experiences, allowing them to explore scientific concepts in a controlled and engaging virtual environment. Successful implementations of these approaches demonstrated improved conceptual understanding, critical thinking skills, and a deeper appreciation for scientific inquiry among students. Collaborative learning approaches represent another best practice. Online forums, discussion boards, and collaborative projects enable students to interact with peers, share ideas, and engage in collective problem-solving. Driskell et al. (2018) noted that collaborative platforms enhance collaboration and reflect the real-world dynamics of scientific research and teamwork. In this regard, Rwanda's implementation of co-teaching between local and Zimbabwean tutors was a strategic move that aligns with the findings of Kafyulilo et al. (2016), MacDonald et al. (2019), and Terblanché (2018). These studies emphasise the importance of collaboration and teamwork in science education, particularly in the context of science teaching and the use of ICTs. The co-teaching approach in Rwanda not only facilitates knowledge and skill sharing but also creates a collaborative atmosphere, which is crucial for the professional development of teachers.

Professional development for educators is a critical component of successful ICT integration. Rwandan TTC administrative leaders and science educators have been remarkably engaged in professional development training across the country (Nkundabakura et al., 2023b; Uworwabayeho et al., 2020). Best practices involve ongoing training programs that empower teachers with the skills to effectively incorporate technology into their teaching methodologies. This includes workshops, webinars, and mentorship programmes to ensure continuous growth and adaptation to evolving technological trends.

The implementation of SDMS, CAMIS, TMIS, FAMIS, LTMMIS, and EMIS in Rwandan TTCs has significantly modernised teaching and learning (Mushimiyimana, 2022). Monitoring and assessment strategies tailored for an ICT-integrated environment are essential for a smooth flow of educational operations. In this regard, implementing information management systems in Rwandan TTCs has been essential in improving assessment and record keeping in TTCs. Implementing adaptive assessments and digital assessment tools can effectively provide valuable insights into student progress, allowing educators to make informed decisions for continuous improvement (Gabriel et al., 2022; Solar et al., 2013).

5.5.Major Findings

This review provides a comprehensive analysis of the positive impact of ICT integration on science education within the competency-based curriculum framework in Rwandan Teacher Training Colleges (TTCs). A key finding is the strong correlation between ICT integration and improved teaching effectiveness, where digital tools' adoption has led to a more dynamic and engaging learning environment. This aligns closely with the principles of competency-based education, which prioritises active learning and real-world applications of scientific concepts.

A significant highlight of the review is the compilation of an inventory of ICT tools, resources, and instructional strategies currently employed in Rwandan TTCs to enhance science education. This includes a diverse range of digital tools, such as computers, projectors, smart screens, virtual laboratories, collaborative learning platforms, and multimedia resources. For example, Nzabahimana et al.'s (2024) survey showed a 30% increase in student engagement when these ICT resources were incorporated, especially tools like virtual labs, interactive simulations, and real-time feedback mechanisms. Such resources enable students to deepen their understanding of scientific concepts through interactive and experiential learning, thereby promoting critical thinking and problem-solving skills.

Moreover, the review emphasises the importance of ongoing professional development for educators, noting that effective ICT integration is closely tied to teacher training programs. Educators who received targeted training demonstrated greater confidence and competence in utilising ICT tools to support competency-based learning outcomes. This finding underscores the transformative potential of ICT not only to enhance student engagement but also to equip educators with the necessary skills to foster a supportive and interactive science learning environment.

6.0. Conclusions

ICTs' integration in science education within Rwandan TTCs has proven to be transformative, enhancing teaching effectiveness and aligning well with the competency-based curriculum framework. Despite challenges such as limited infrastructure, resource constraints, and varying levels of digital literacy among educators, the overall trend is positive. ICTs have demonstrated their potential to create engaging, competency-driven learning environments, enabling students to interact with scientific concepts through dynamic and immersive tools. This transformation is particularly evident in initiatives like using virtual simulations, which provide practical, safe, and resource-efficient alternatives to traditional labs.

The findings show the need for a holistic approach to address the challenges of ICT integration. Key to this strategy is continuous professional development, where educators receive targeted, skills-focused training to confidently incorporate ICT tools into their teaching. Additionally, infrastructure improvements and strong policy support are essential for creating an environment conducive to sustained ICT use. A structured inventory of ICT tools and resources outlined in this review offers practical guidance to educators, providing a clear reference point for the diverse applications of technology in science education.

This review also highlights the importance of aligning ICT integration efforts with the broader goals of competency-based education, ensuring that digital tools not only enhance engagement but also foster critical thinking, problem-solving, and collaboration. By addressing infrastructure and resource constraints through coordinated efforts among educational institutions, policymakers, and technology providers, Rwanda's TTCs can continue to advance toward becoming a regional model for ICT-supported science education.

The insights presented provide a roadmap for stakeholders, including educators, curriculum developers, and policymakers to collaboratively promote effective ICT integration. This collective approach holds the potential to enhance science education quality and accessibility in Rwanda's TTCs, setting a foundation for future technological innovations that support the nation's educational and economic goals.

7.0. Recommendations

This review identified several challenges impacting the effective integration of ICT in science education within Rwandan Teacher Training Colleges (TTCs). A major obstacle is the limited access to infrastructure, including computers, reliable internet, and technical support. According to Barakabitze et al. 2019, most African educational institutions, including TTCs still have intermittent internet access, which limits both students' and teachers' access to essential online resources. Addressing these infrastructure constraints requires a collaborative approach involving educational institutions, government agencies, and technology providers to ensure consistent access to basic technological resources and reliable connectivity. Additionally, regular maintenance of ICT devices is essential to prevent disruptions and extend the usability of available tools.

Resistance to technology adoption among educators is another key challenge, often rooted in limited familiarity with digital tools and a preference for traditional teaching methods (Kanamugire et al., 2019). Establishing targeted professional development programs can mitigate this resistance by equipping educators with practical skills for integrating ICT into science education. Such programmes should also emphasise the value of ICT as a complement to traditional approaches, fostering a mindset shift toward embracing digital tools in education. Continuous professional development is particularly crucial; as technology advances rapidly, workshops, webinars, and mentorship initiatives can help educators stay updated on new tools and techniques, promoting adaptability and innovation (Uwineza et al., 2023; de Dieu et al., 2020).

Resource constraints, especially in underserved regions, exacerbate these challenges. Limited access to ICT facilities in rural TTCs hinders consistent integration and amplifies disparities between urban and rural educational settings. Senior administrators should encourage both teachers and students to maximise using existing ICT resources. A collaborative effort is recommended to improve access through establishing well-equipped ICT laboratories and promoting government partnerships to bridge resource gaps.

Finally, aligning ICT integration with the competency-based curriculum is essential for cohesive learning experiences. This alignment requires cooperative planning between educators and curriculum designers to ensure digital resources support curriculum goals and foster critical thinking in science education. Embracing a holistic approach that addresses both technological and pedagogical needs can ultimately enhance the effectiveness of ICT integration across Rwandan TTCs.

8.0. Contributions of the Study

This review provides valuable insights into the integration of ICT in science education within Rwandan TTCs, highlighting its transformative potential for both students and educators. ICT tools such as virtual reality (VR) simulations offer students experiential learning opportunities that transcend resource limitations and safety concerns of physical labs. A pilot project at Rwandan schools has demonstrated improved lab-related test scores among students using VR compared to those in traditional settings, underscoring ICT's role in enhancing understanding and retention of complex scientific concepts (Nzabahimana et al., 2024). These findings affirm that ICT integration can make science education more accessible, interactive, and aligned with Rwanda's tech-driven educational goals.

The paper's inventory of ICT tools and strategies used in Rwandan TTCs is a practical resource for policymakers and educators, offering insights into effective applications of digital resources in science education. This inventory supports the competency-based curriculum model, where ICT tools can facilitate self-paced and individualised learning, crucial for cultivating critical thinking skills and preparing students for STEM careers.

Furthermore, the review highlights the importance of long-term, skills-focused teacher training, suggesting that professional development programmes tailored to ICT can build educators' digital confidence and improve instructional outcomes. Finally, the review advocates for collaborative policy efforts, recommending partnerships between educational institutions, government agencies, and technology providers to address infrastructure and resource constraints. By presenting a structured roadmap, the review contributes a comprehensive perspective that can guide stakeholders in effectively advancing ICT integration in Rwandan science education.

References

Aljawarneh, S. A. (2020). Reviewing and exploring innovative ubiquitous learning tools in higher education. *Journal of Computing in Higher Education, 32*, 57-73.

Barak, M. (2017). Science teacher education in the twenty-first century: A pedagogical framework for technology-integrated social constructivism. *Research in Science Education, 47*, 283-303.

Barakabitze, A. A., William-Andey Lazaro, A., Ainea, N., Mkwizu, M. H., Maziku, H., Matofali, A. X., ... & Sanga, C. (2019). Transforming African education systems in science, technology, engineering, and mathematics (STEM) using ICTs: Challenges and opportunities. *Education Research International, 2019*, 1-29.

Bidarra, J., &Rusman, E. (2017). Towards a pedagogical model for science education: bridging educational contexts through a blended learning approach. *Open Learning: The Journal of Open, Distance and E-learning, 32*(1), 6-20.

Collins, A., & Halverson, R. (2018). *Rethinking education in the age of technology: The digital revolution and schooling in America.* Teachers College Press.

de Dieu, H. J., Theogene, H., Philothere, N., &Ke, Z. (2020). Quality Education in Rwanda: A Critical Analysis of Quality Indicators. *IOSR Journal of Humanities and Social Science, 27*(2), 52-70.

Deeva, G., Bogdanova, D., Serral, E., Snoeck, M., & De Weerdt, J. (2021). A review of automated feedback systems for learners: Classification framework, challenges and opportunities. *Computers & Education, 162*, 104094.

Driskell, J. E., Salas, E., & Driskell, T. (2018). Foundations of teamwork and collaboration. *American Psychologist, 73*(4), 334.

Dushimimana, J. C., &Uworwabayeho, A. (2020). Teacher training college student performance in statistics and probability exams in Rwanda. *Rwandan Journal of Education, 5*(1). 68-81.

Falloon, G. (2020). From digital literacy to digital competence: the teacher digital competency (TDC) framework. *Educational Technology Research and Development, 68*, 2449-2472.

Fernandes, G. W. R., Rodrigues, A. M., & Ferreira, C. A. R. (2019). *Using ICT in inquiry-based science education*. Springer International Publishing.

Gabriel, F., Marrone, R., Van Sebille, Y., Kovanovic, V., & de Laat, M. (2022). Digital education strategies around the world: practices and policies. *Irish Educational Studies, 41*(1), 85-106.

Hashakimana, T., Habyarimana, J. D., Nshimyumuremyi, E., &Ngendahayo, E. (2022). School data management system and school management in Rwanda. *IOSR Journal of Humanities and Social Sciences (IOSR-JHSS), 27*(9), 1-11.

Iyamuremye, F., &Ndagijimana, J. B. (2022). Challenges Facing the Use of Multimedia in Teaching and Learning in Secondary Schools in Muhanga District, Rwanda. *International Journal on Integrated Education*, *5*(9), 86-109.

Kafyulilo, A., Fisser, P., &Voogt, J. (2016). Teacher design in teams as a professional development arrangement for developing technology integration knowledge and skills of science teachers in Tanzania. *Education and Information Technologies, 21*, 301-318.

Kanamugire, C., Yadav, L. L., &Mbonyiryivuze, A. (2019). Tutors' perceptions about science curriculum reforms and challenges for their implementation in Teacher Training Colleges in Rwanda. *African Journal of Educational Studies in Mathematics and Sciences, 15*(1), 101-116.

Kizito, N. (2016). *Research on Improvised Experiment Materials for Science Lesson in Rwanda* (Master's Thesis, Hiroshima University).

Lawrence, J. E., & Tar, U. A. (2018). Factors that influence teachers' adoption and integration of ICT in teaching/learning process. *Educational Media International, 55*(1), 79-105.

MacDonald, F., Easton, B., & Bottrell, D. (2019). Beyond me-ism: Teamwork, team building and cooperation in flexible learning environments. In *Harnessing the transformative power of education* (pp. 167-179). Brill.

Madzima, K., Dube, E. L., &Mashwama, P. M. (2013). ICT education in Swaziland secondary schools: Opportunities and challenges. *Google Scholar*.

Maharaj-Sharma, R., Sharma, A., & Sharma, A. (2017). Using ICT-based instructional technologies to teach science: Perspectives from teachers in Trinidad and Tobago. Australian *Journal of Teacher Education (Online), 42*(10), 23-35.

Manasse, N. (2020). *The use of ICT resources and teachers' performance in government aided secondary schools of Rwamagana District-Rwanda* (Doctoral dissertation, Mount Kenya University Rwanda).

Mugiraneza, J. P. (2021). Digitalization in teaching and education in Rwanda. *The report*, *28*.

Mukandayisenga, S., David, O., & Nsengimana, V. (2021). Teachers' Perceptions on the Effectiveness of the Inquiry-Based Learning towards Students' Achievement in Biology: The Case of schools of Rwanda. *African Journal of Educational Studies in Mathematics and Sciences, 17*(2), 95-113.

Munyengabe, S., Yiyi, Z., Haiyan, H., &Hitimana, S. (2017). Primary teachers' perceptions on ICT integration for enhancing teaching and learning through the implementation of one laptop per child program in primary schools of Rwanda. *Eurasia Journal of Mathematics, Science and Technology Education*, *13*(11), 7193-7204.

Mushimiyimana, J. B., Bazimaziki, G., &Tuyishime, D. (2022). ICT Integration in Educational curriculum in Higher Education:

Challenges and opportunities in the University of Rwanda-College of Education. *International Journal of Humanities and Education Development (IJHED)*, *4*(2), 118-137.

Ndihokubwayo, K. (2017). Investigating the status and barriers of science laboratory activities in Rwandan teacher training colleges towards improvisation practice. *Rwandan Journal of Education*, *4*(1), 47-54.

Ndihokubwayo, K., &Murasira, G. (2019). Teachers' Training College Learners' Expectations for Their Future Teaching Career. *LWATI:A Journal of Contemporary Research, 16*(2), 1-10.

Ngoyi, L. (2013). *Benefits and Challenges Associated with Using Virtual Labs and Solutions to Overcome Them* (Doctoral dissertation, Virginia Tech).

Niyibizi, O. (2023). *The perception of teachers on the use of ICT facilities to teach mathematics: a case of selected public secondary schools in Gasabo district, Rwanda* (Doctoral dissertation, University of Rwanda).

Nkundabakura, P., Nsengimana, T., Nyirahabimana, P., Nkurunziza, J. B., Mukamwambali, C., Dushimimana, J. C., ... &Ndihokubwayo, K. (2023a). Usage of modernized tools and innovative methods in teaching and learning mathematics and sciences: A case of 10 districts in Rwanda. *Education and Information Technologies*, 1-22.

Nsabayezu, E., Iyamuremye, A., de Dieu Kwitonda, J., &Mbonyiryivuze, A. (2020). Teachers' perceptions towards the utilization of WhatsApp in supporting teaching and learning of chemistry during COVID-19 pandemic in Rwandan secondary schools. African Journal of *Educational Studies in Mathematics and Sciences, 16*(2), 83-96.

Nsengimana, T., Bazimaziki, G., Nyirahabimana, A., Mushimiyimana, J. B., Mutarutinya, V., Mugabo, L. R., & Nsengimana, V. (2021). Online learning during COVID-19 pandemic in Rwanda: experience of postgraduate students on language of instruction, mathematics and science education. *Contemporary Mathematics and Science Education, 2*(1), ep21009.

Ntawiha, P., Nasiforo, B. M., Buhigiro, L. J., &Barayagwiza, P. (2023). Enhancing quality of teaching and learning sciences through multimedia in selected secondary schools in Rwanda. *The Cradle of Knowledge: African Journal of Educational and Social Science Research*, *11*(2), 100-106.

Nyiramana, C. (2023). *Quality of Teacher Education: Experiences of Student Teachers vis-à-vis Teachers' Feedback* (Vol. 5). University of Bamberg Press.

Nzabahimana, J., Ndihokubwayo, K., &Mugabo, L. R. (2024). Teachers' Experiences with the Use of Virtual Laboratories in the Teaching of Physics in Rwandan Secondary Schools: A Survey Design. *African Journal of Research in Mathematics, Science and Technology Education*, 1-14.

REB. (2020). *Summary of curriculum framework for teacher training colleges*. Kigali: Rwanda Education Board.

Reynolds, R. (2016). Defining, designing for, and measuring "social constructivist digital literacy" development in learners: A proposed framework. *Educational Technology Research and Development, 64*(4), 735-762.

Rocha Fernandes, G. W., Rodrigues, A. M., Rosa Ferreira, C. A., Rocha Fernandes, G. W., Rodrigues, A. M., & Rosa Ferreira, C. A. (2019). ICT-based science education: Main digital resources and characterisation. *Using ICT in Inquiry-Based Science Education*, 1-37.

Rubagiza, J., Umutoni, J., &Kaleeba, A. (2016). Teachers as agents of change: Promoting peacebuilding and social cohesion in schools in Rwanda. *Education as Change, 20*(3), 202-224.

Rwangoga, E., Mugabo, M., &Munezero, N. (2015). The use of information and communication technology tools in teaching sciences: The case of secondary schools in Rwanda. *International Journal of Education and Development using ICT, 11*(2), 65-76.

Sahin, D., & Yilmaz, R. M. (2020). The effect of Augmented Reality Technology on middle school students' achievements and attitudes towards science education. *Computers & Education, 144*, 103710.

Saravanakumar, A. R., & Padmini Devi, K. R. (2020). Indian higher education: Issues and opportunities. *Journal of Critical Reviews, 7*(2), 542-545.

Solar, M., Sabattin, J., & Parada, V. (2013). A maturity model for assessing the use of ICT in school education. *Journal of Educational Technology & Society, 16*(1), 206-218.

Terblanché, E. (2018). Collaborative Endeavours and Challenges of 21st-Century Skills in Tertiary Distance Education. *Commonwealth Youth & Development, 16*(1).

Tikly, L., Joubert, M., Barrett, A. M., Bainton, D., Cameron, L., & Doyle, H. (2018). Supporting secondary school STEM education for sustainable development in Africa. *University of Bristol, Bristol Working Papers in Education Series.*

Timotheou, S., Miliou, O., Dimitriadis, Y., Sobrino, S. V., Giannoutsou, N., Cachia, R., ... &Ioannou, A. (2023). Impacts of digital technologies on education and factors influencing schools' digital capacity and transformation: A literature review. *Education and Information Technologies, 28*(6), 6695-6726.

Uwineza, I., Uworwabayeho, A., & Yokoyama, K. (2023). Lower and upper primary learners' difference in performance and conceptual understanding: Support of interactive mathematics software for Rwanda. *Education and Information Technologies*, 1-27.

Uworwabayeho, A., Flink, I., Nyirahabimana, A., Peeraer, J., Muhire, I., &Gasozi, A. N. (2020). Developing the capacity of education local leaders for sustaining professional learning communities in Rwanda. *Social Sciences & Humanities Open, 2*(1), 100092.

Villasanta, R. A. (2022). Improving the Performance Practice of 21st Century Music of Grade 10 Students Through Digital Learning Material. *American Journal of Multidisciplinary Research and Innovation*, *1*(3), 1-6.

Wang, T. H., & Yang, K. T. (2016). Technology-enhanced science teaching and learning: Issues and trends. Science education research and practice in Asia: *Challenges and Opportunities*, 461-481.