A White Paper: Empowering Nigerian Secondary Physics Teachers through Information and Communication Technology Integration

Hemamalini Srinivasan (Primary author)
Department of Science, Indian Language School
Oba Nle Aro Ave, Lagos 100252, Nigeria

Michelle McCraney
Riley College of Education, Walden University
Washington Ave S, Minneapolis, MN 55401, USA

Richard Penny
Riley College of Education, Walden University
Washington Ave S, Minneapolis, MN 55401, USA

Sumedha Mohan
Department of Psychology, Heriot Watt University
Al Sufouh Knowledge Park, Dubai 501745, UAE

Abstract
The integration of information and communication technology (ICT) into K-12 institutions remains a major challenge, significantly affecting students' performance and learning outcomes. This white paper examined deeper into the challenges for technology integration in secondary physics education in a southwestern state in Nigeria. The study drew insights from semistructured interviews with 12 secondary school physics teachers and identified inadequate infrastructure, lack of technical support, and limited teacher training as the key roadblocks to effective ICT integration. To address these barriers, the paper proposed four recommendations. By attending to these recommendations, policymakers, school administrators, educators, and stakeholders can endeavor to establish a more student-centered and technologically advanced learning environment in secondary school physics classrooms in Nigeria.
Keywords: *White paper, technology education, physics education, instructional technology, information and communication technology, professional development, teacher education.*
DOI: 10.7176/JEP/16-2-01
Publication date: February 28th 2025

1. Introduction

Nigerian national education policy emphasizes the importance of information and communication technology (ICT) for improving student outcomes. Despite calls for integrating technology and utilizing ICT tools to move away from teacher-centered approaches and embrace more modern educational methods, Nigerian public senior secondary schools are still struggling to achieve this goal. Researchers have attributed this struggle to lack of necessary technological expertise among secondary teachers and inadequate technology infrastructure in schools (Ifinedo & Kankaanranta, 2021; Opeyemi et al., 2019). Such inadequacy in training and infrastructure poses challenges to teachers in ICT integration and forces them to often resort to traditional teaching methods, limiting the impact of ICT on the secondary school curriculum (Jimoh et al., 2020).

A white paper is a detailed report explaining a problem and a practical solution by presenting research and evidence to support its claims (Hayes, 2023). This white paper builds on the findings of Srinivasan et al. (2024), which explored the perceptions and lived experiences of secondary school teachers in integrating ICT into their physics classrooms in a southwestern state of Nigeria. While the earlier study provided significant insights into the challenges and opportunities of technology integration, this white paper proposes recommendations, specifically focusing on particular resources and support mechanisms required to facilitate ICT integration in secondary school physics classrooms. The white paper has been crafted to inform stakeholders within the state's education community, particularly policymakers and school administrators, about the potential of effectively integrating ICT into higher secondary physics classrooms. By outlining a series of implementable steps, this paper aims to influence positive change and facilitate a shift towards technology-enhanced physics education that promotes a joyful experience for students.

2. The Local Problem

Students have developed a strong interest in technology due to the growing availability of digital tools, yet technology adoption remains low creating disconnect between student enthusiasm for technology and its actual use in secondary school physics classrooms in the target state. Nigerian education policy actively promotes the integration of technology into teaching practices. The Federal Ministry of Education's 2013 policy and 2019 directives (Federal Ministry of Education, 2013, 2019) emphasize the value of ICT pedagogy for improving student learning outcomes. However, this research identified a significant gap between policy pronouncements and the realities experienced by schools in the target state.

Despite ministerial support for ICT integration, many schools within the state struggle to fully embrace this approach. This limited adoption restricts the impact of initiatives aimed at incorporating ICT into the secondary school curriculum. Several infrastructural challenges impede effective ICT integration. Many school buildings lack essential resources, such as strong technology infrastructure, consistent electricity, and reliable internet connectivity. Furthermore, high student-teacher ratios, reaching up to 80:1 in public senior secondary schools, create significant challenges for teachers. These large class sizes make it difficult for teachers to implement traditional, teacher-centered pedagogy, let alone incorporate more technology-intensive methods. The consequence of these challenges is a struggle for Nigerian secondary school students to achieve desired learning outcomes, particularly in physics. Limited ICT integration hinders the development of skills crucial for success in an increasingly ICT-dependent world. This is further evidenced by Nigerian students' consistent lower performance in physics compared to international benchmarks (UNESCO, 2020). The present research addresses the challenges faced by secondary school physics teachers in integrating ICT into their classrooms within the target state in Nigeria. By identifying these challenges and proposing recommendations, this research aims to inform stakeholders and provide the necessary support to empower teachers to integrate ICT effectively, enhancing student learning outcomes in physics education.

3. Literature Review

To establish a strong theoretical foundation for this project study, a comprehensive review of relevant literature was conducted. Scholarly and peer-reviewed articles were obtained from credible academic databases, including Walden Library database, Google Scholar, and ProQuest. Given the international context of the research site, the review specifically included research findings from different countries with similar educational environments. Keywords such as *white paper, physics education and ICT integration, challenges in teacher technology integration*, and *professional development for technology integration* guided the literature search.

3.1 Physics Education and Information and Communication Technology Integration

Physics education is important in nurturing scientific literacy and critical thinking skills in students. However, educators using traditional pedagogies often struggle to effectively engage students with complex physical concepts. Integration of ICT has emerged as a powerful pedagogy for enhancing physics education by creating dynamic and interactive learning environments (Hasas et al., 2024). Research has suggested that ICT integration offers a range of benefits for physics education.

3.2 Enhanced Visualization and Simulation

ICT tools allow for the creation of interactive simulations and visualizations of physical phenomena. These tools help students visualize abstract concepts and processes that are difficult to grasp through traditional methods (Ameziane et al., 2023). Realistic visualizations and virtual experiments in simulation-based learning provided a tangible representation of theoretical principles in physics, making the ideas more accessible and comprehensible (Banda & Nzabahlmana, 2022). Physics educators and researchers have posited that simulations foster active learning and critical thinking skills by allowing students to control different parameters and test hypotheses in a controlled environment (Ali et al., 2023; Dachraoui et al., 2023; Hasas et al., 2024). Literature on ICT-integrated physics education has also highlighted the immersive approach of virtual-reality-based instructions and experiments to not only enhance understanding, but also cultivate curiosity, enthusiasm, and confidence in tackling challenging physics concepts (Dier & Asrizal, 2023).

3.3 Improved Engagement and Motivation

ICT-enabled learning environments have the potential to cultivate heightened student involvement with the subject matter. Studies by Tuyizere and Yadav (2023) and Moro and Billote (2023) have shown that ICT integration can increase student motivation and induce active participation in physics lessons. The authors recorded that animations, virtual labs, and interactive simulations make physics learning more dynamic and exciting, encouraging students to explore concepts in depth and independently. Neroni et al. (2021) documented that collaborative technological educational tools facilitate peer interaction and knowledge sharing, promoting problem-solving skills and strengthening real-world applications of the theories in physics. The impact of activities that were computerized simulations on the academic performance of 200 high-school students in physics was studied by Batuyong and Antonio (2018). The authors concluded that the students' academic achievements improved noticeably on blending technology into educational processes.

3.4 Personalized Learning and Assessment

Technology-integrated pedagogies can be used to create individual and differentiated lesson plans for students in physics education. Studying the outcome of ICT-integrated simulations on physics learning of 20 high school students, Trikolis (2021) concluded that adaptive learning platforms tailored content and difficulty levels to individual student needs and pacing. Additionally, Wibowo (2023) recorded that simulations accommodated diverse learning styles and abilities, allowing students to gauge their understanding and adjust their learning strategies. Furthermore, Banda and Nzabahimana (2023) highlighted the real-time feedback and assessment opportunities provided by ICT-integrated pedagogies, allowing educators to monitor student progress, identify areas of difficulty, and provide timely support.

3.5 Collaboration and Communication

ICT tools facilitate collaboration and communication between students and teachers. Online platforms allow for asynchronous communication and discussion forums where physics students in senior high school can share ideas and work on projects remotely (Novitra et al., 2021). The authors recommended that these tools can be particularly beneficial for collaborative problem-solving activities and peer learning in physics education. Studies on physics students' collaborative skills by Kauts and Samita (2024) also revealed that video conferencing tools facilitated virtual meetings and peer tutoring sessions, breaking down geographical barriers and promoting interaction among students from diverse backgrounds. The authors posited that web 4.0 tools provide channels for creating a sense of community among physics students, enhancing their learning experience.

3.6 Augmented Learning Experience

Mobile technologies and augmented reality (AR) offer new possibilities for learning physics outside the classroom (Gurevych et al., 2021). Gurevych et al. (2021) investigated recent advancements in AR technology for improved quality of physics education in higher education institutions. The authors concluded that AR can intrinsically motivate students for self-directed learning by fostering a deeper engagement with educational materials. This increased interest can cultivate a desire to explore and utilize modern interactive technologies, potentially leading to a shift away from traditional static resources such as textbooks and towards multimedia computer models within physics classrooms. In other research, Rahmat et al. (2023) examined the effect of mobile AR on physics learning outcomes for junior high school students in Indonesia. Their findings, based on student feedback, suggested that AR offered a novel and effective learning environment in physics and facilitated comprehension of abstract physics concepts. Furthermore, the study indicated that students perceived an improvement in their understanding of physics concepts after utilizing mobile AR technology. Recent research with 370 teacher-students in Morocco explored the effect of AR-based learning on physics experiments (Laila et al., 2024). The research highlighted the potential advantages of incorporating AR technology within physics laboratory settings. The authors advocated for the exploration of this technology by educators, emphasizing its ability to enrich the learning experience for students.

3.7 Challenges in Teacher Technology Integration

Although the advantages of incorporating ICT in classroom instructions are widely acknowledged, several challenges impede teachers' successful adoption. Literature delves into the complex array of these hurdles, concentrating on barriers related to hardware availability, training opportunities, administrative backing, time limitations, teacher confidence, and other factors influencing the effective integration of technology. Unequal technology access and unreliable internet connectivity remains a significant obstacle in many schools. This digital divide created an environment where some students had access to advanced technology tools while other lacked the necessary resources to participate in technology-driven learning activities (Ifinedo et al., 2020). Restricted access to hardware, such as computers, tablets, or specialized lab equipment, limited teachers' ability to implement innovative ICT-based lesson plans (Munje & Jita, 2020). Munje and Jita (2020) studied how insufficient technical assistance for maintaining ICT equipment disrupted the seamless delivery of instruction within classrooms. An extensive literature review was conducted by Hunduma and Mekuria (2023) to inquire into the barriers impeding technology integration in the public schools in Ethiopia. The findings of the study illustrated that deficient infrastructure and the lack of well-equipped computer laboratories created a setback in teachers integrating technology to enhance classroom instructions.

Successful technology integration requires teachers to possess a strong foundation in both pedagogy and technology (Karim & Zoker, 2023). Investigating the perceptions of senior secondary school teachers in Sierra Leone about the issues in technology integration, Karim and Zoker (2023) recorded many teachers being ill prepared to blend technology into their classrooms due to limited training opportunities. Additionally, traditional teacher education programs often lack a strong focus on technology integration, leaving teachers struggling to navigate complex hardware, software functionalities, and identify appropriate learning technologies for specific curriculum objectives (Wong et al., 2023). Furthermore, a study on Nepal's teacher education revealed the absence of planned teacher training strategies leading to ineffective implementation of ICT-integrated teaching practices (Rana & Rana, 2020).

The level of administrative support also plays a critical role in fostering technology integration within schools. Studies showed that without clear administrative vision and dedicated resources, teachers felt unsupported in their efforts to adopt new technologies (Dong et al., 2020). Research findings also revealed that lack of administrative assistance created an environment where ICT integration turned into an additional burden for the teachers, hindering their motivation and enthusiasm for innovation (Rintaningrum, 2023). Manubag et al. (2023) studied the significance of technology within technical vocational education in the Philippines. Their findings suggested that administrators who display reluctance or resistance towards embracing technological progress inadvertently discourage educators from adopting innovative teaching methods or experimenting with ICT tools. This resistance to change among teachers hampers creativity and innovation within the classroom, consequently hindering the integration of technology into pedagogical approaches, diminishing student engagement, and impacting learning outcomes.

The constraints of a teacher's schedule restrict the opportunity to explore and incorporate new technologies into established lesson plans (Kucuk, 2023). Numerous studies identified educators being overwhelmed by curriculum obligations, the pressures of standardized tests, and administrative responsibilities, leaving them with minimal time to engage in the learning and application of new technologies into their classroom pedagogies in a meaningful manner (Francom, 2020; Pappa et al., 2023; Starks & Reich, 2023). These researchers recorded that technology integration required meticulous planning, selection of appropriate digital tools and applications, familiarity with software features, modification of existing lesson plans accordingly. Teachers participating in these research studies expressed that without dedicated time for such necessities, ICT integration became a mere rushed and superficial endeavor, ultimately falling short of realizing its potential benefits.

Another crucial factor that challenges teachers in classroom technology integration is teacher efficacy. This concept refers to a teacher's belief in their ability to positively influence student learning outcomes (Hershkovitz et al., 2023). Studying the elements influencing teachers' self-efficacy in ICT integration, Williams et al. (2023) posited that educators with low self-efficacy regarding technology exhibited reluctance to blend new technologies into their pedagogies. The authors' findings suggested that this reluctance stemmed from a fear of failure, a sense of inadequacy when faced with technical challenges, or a general anxiety around technology itself. A recent research was carried out by Al-khresheh and Alkursheh (2024) to study how teachers' confidence on ICT-integrated instructional practices influenced students' academic achievements. Their findings explained that teachers felt overwhelmed by the rapid pace of technology advancements which in turn contributed to their anxiety to experiment with new technological tools and experiments.

3.8 Professional Development for Technology Integration

The 21st century classroom demands a shift towards technology-integrated pedagogies. Although the advantages of blending ICT into instruction are widely recognized, successful implementation hinges on the professional development (PD) provided to educators (Yurtseven Avci et al., 2020). Through this part of the literature review, the crucial role of PD in building teachers' confidence towards ICT-integrated innovative instructional methodologies was explored. The different requirements for effective PD programs through the strategic use of instructional technology were also examined.

Traditional instructional methods may no longer adequately prepare students for the demands of a technology-driven world. Educational technology (EdTech) offers a plethora of tools and resources that can enhance student learning, engagement, and critical thinking skills (Shin et al., 2023). However, Shin et al. (2023) posited that simply providing teachers with access to technology is insufficient. The authors examined that effective integration of technology necessitated teachers to possess a strong foundation in pedagogy, technology skills, and a critical understanding of these elements. Bowman et al (2022) investigated the influence of professional development exposure on teachers' quality of ICT integration among 724 teachers from middle and high school. Many teachers in the study reported feeling inadequately prepared due to limited opportunities for technology-focused training. They expressed that traditional teacher education programs often lack a robust focus on technology integration, leaving them with limited knowledge of specific tools, pedagogical strategies for using technology effectively, and the ability to navigate the ever-evolving EdTech landscape.

The review of literature carried out in the current project study informed various requirements for successful professional development programs in teachers' technology integration. The foremost requirement identified in the review was the focus on pedagogy over technology. Researchers argued that technology should not be the end goal but should serve as a catalyst to enhance the knowledge gaining process (Fawns, 2022; Rapanta et al., 2021). Rapanta et al. (2021) recommended that professional development programs should focus on the pedagogical significance of ICT integration, aligning the use of specific tools with clear learning objectives and curriculum frameworks. Presenting an entangled pedagogy model, Fawns (2022) outlined that instead of simply training teachers on the use software, professional training sessions need to support teachers in understanding how technology can support differentiated instruction and foster problem solving skills in students.

Research studies affirm another requirement of teachers' professional development as the need to address teacher needs and curriculum alignment. Identifying the specific needs, challenges, and technology comfort levels of participating teachers ensures that the professional development content is relevant and addresses their immediate concerns (Warr et al., 2023). Emphasizing on alignment with curriculum frameworks and learning objectives, Huang (2023) posited that professional development programs should provide teachers with practical examples and strategies for integrating technology into existing lesson plans, ensuring a seamless implementation within their specific disciplines. Schmitz et al. (2023) highlighted the other requirement of professional development programs – teachers' technology skills and confidence. Although pedagogical knowledge and alignment with curricular objectives is crucial for teachers integrating technology, Schmitz et al. (2023) reiterated that teachers also require a solid foundation in technology skills. The authors affirmed that professional development programs should offer hands-on training and active learning experiences that equip teachers with the technical proficiency to navigate chosen tools effectively. However, Williams et al. (2023) argued that continuous learning for teachers should also place focus on building confidence in their ability to utilize technology effectively.

An additional requirement of teachers' upskilling initiatives identified is the ongoing support and collaboration provided to teachers. Kilag et al. (2024) studied that effective educators' upskilling programs should recognize the need for ongoing support as technology integration is not a one-time event. The authors recommended for providing access to online resources, technical support personnel, and opportunities for collaboration that can assist teachers in overcoming challenges and sharing best practices throughout the integration process. The final requirement of professional development as examined by this literature review is addressing the issue of digital literacy disparities among students. Addressing the digital divide among students, Afzal et al. (2023) recorded that teachers' professional development should involve equipping teachers with strategies for differentiated instruction and providing resources to bridge the digital divide within the student body. Additionally, the authors also recommended that the ethical considerations, such as data privacy and responsible online behavior, demand resolution within teachers' learning programs to ensure safe and responsible technology integration.

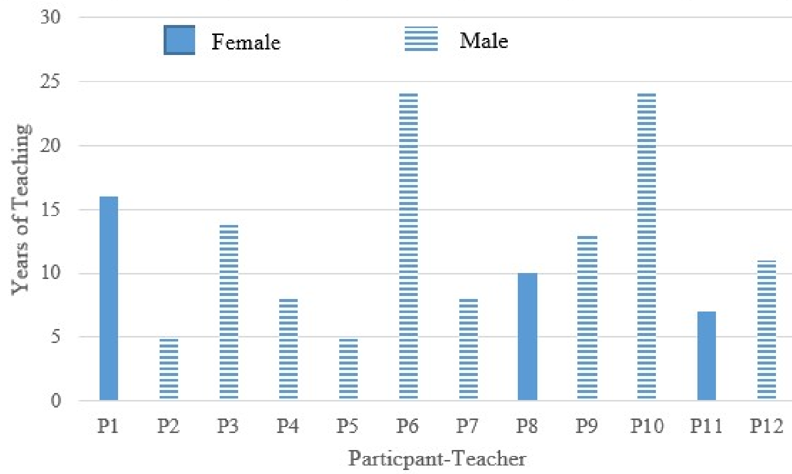
4. Methodology

The current project study delves into the perspectives of secondary school physics teachers within a specific Nigerian state. The research focused on uncovering the challenges that hinder them from effectively integrating ICT into their physics classrooms and developing practical recommendations. These recommendations can be used by stakeholders to support more effective ICT integration within physics education, ultimately leading to improved student learning outcomes. Following a comprehensive literature review that established the research gap, a basic qualitative design was chosen for its suitability in exploring the lived experiences and perspectives of secondary school physics teachers (Merriam & Tisdell, 2016). This approach allowed for in-depth examination of teachers' perceptions concerning barriers to ICT integration within the specific context of this study.

The unified theory of acceptance and use of technology (UTAUT) model, proposed by Venkatesh et al. (2003), provided the theoretical foundation for the study. This model was chosen due to its focus on understanding factors that influence the adoption and use of technology in various contexts. The UTAUT framework served as a guide for exploring the attitudes and beliefs of physics teachers related to ICT integration and its application in their classrooms.

A purposeful sampling strategy was employed to recruit participants who possessed specific characteristics relevant to the research questions (see Merriam & Tisdell, 2016). The teacher-participants comprised secondary school physics teachers within the chosen state. Collaboration with the physics teachers' association within the district under study facilitated participant recruitment. From the received responses, a sample of 12 physics teachers, representing various secondary schools within a specific administrative division, were selected for semistructured interviews. Figure 1 represents the participants' experience in handling senior secondary physics students.

Figure 1
Teacher-Participants' Experience



The credibility of the research findings, which was paramount, was achieved by implementing several strategies. Following the interviews, transcripts were shared with each participant for review, verification and member checking, ensuring the accuracy of captured information and reflecting their true perspectives (see Muzari et al., 2022). Throughout the research process, the authors maintained a reflective journal to document personal biases and assumptions that could potentially influence the interpretation of data (see Phillippi & Lauderdale, 2018).

Geographical limitations necessitated the use of online interviews as the primary data collection method. With the informed consent of participants, interviews were conducted via Zoom, a video conferencing platform. This approach offered several advantages. Online interviews facilitated participation for geographically dispersed teachers, overcoming travel constraints. The video conferencing format enabled capturing both verbal and non-verbal cues, leading to richer and more nuanced insights from participants (see Żadkowska et al., 2022). With participant permission, interviews were recorded and stored securely on a password-protected Zoom account, allowing for later review and transcription.

Following data collection, a multilevel and iterative approach was employed for data analysis. Audio recordings of the interviews were transcribed using NVivo software, a qualitative data analysis tool. A coding process was conducted on each transcript, involving initial coding, identification of patterns within the data, and the development of thematic categories that emerged from the teachers' perspectives (Saldaña, 2021). To enhance the credibility of the findings, triangulation was achieved by analyzing data from multiple sources, in this case, the interviews with a diverse group of physics teachers across different schools within the chosen administrative division. This multisource approach ensured that the identified themes (Table 1) were representative of the broader population of physics teachers within the study context.

Table 1
Nine Themes Aligned With the Research Study

Themes	
1	Physics is a complex subject that requires effective instructional methodologies to elucidate and deliver it to students.
2	Technology integration in teaching simplifies and strengthens the understanding of abstract physics concepts.
3	Technology integration in teaching ensures enhanced student engagement in learning and improves student outcomes in physics.
4	Secondary school physics teachers faced challenges when integrating technology in instructional methodology.
5	Secondary school physics teachers believed their school administration expected regular use of technological instructional strategies.
6	Secondary school physics teachers received very limited support from their administrative division
7	Secondary school physics teachers required strong support from the school administration and the local government for effective ICT integration.

8	Secondary school physics teachers perceived professional training and development to support their use of ICT in classroom teaching practices.
9	Secondary school physics teachers yearned to learn from training sessions to create classrooms that incorporated a fun-way of learning physics.

5. Why a White Paper?

Data analysis revealed critical areas for improvement regarding technology integration within the studied school buildings. Analysis of infrastructure data highlighted the need for strengthening digital infrastructure, including potential upgrades to equipment and network capabilities. Additionally, the analysis indicated the necessity for exploring alternative solutions for ensuring reliable electric power supply and internet connectivity. Furthermore, interviews with teachers revealed a significant need for additional training to support teachers in effectively integrating technology into their teaching practices. To present these findings and propose evidence-based recommendations for change, a white paper was chosen as the primary communication format for this research.

A white paper serves as a platform for researchers to present their findings on a specific issue and offer actionable recommendations to a targeted audience (Basu et al., 2021). A white paper also adheres to a fixed format to ensure clarity and comprehensibility for the reader (Shih et al., 2020). This format aligns well with the current study's goal, as it allows for the dissemination of research findings and recommendations to stakeholders within the state regarding the specific challenge to effective ICT integration in physics education. To gain a deeper understanding of this format and its intended purpose, a review of existing white papers were conducted. Through the review, the role of white papers was examined, focusing on the strengths and limitations of this approach.

White papers offer several advantages in presenting research findings. Researchers use white papers to target stakeholders within specific contexts, such as school districts or industry leaders. Through their white paper, the Korea Ministry of Education (2017) informed stakeholders with the particular case of transforming computer-literacy education to ICT-supported and ICT-integrated smart education. Hamadan et al. (2013) presented a white paper to foster awareness of the flipped classroom model, enhance student interaction, and increase students' engagement in hands-on learning. The researchers advocated for change in classroom pedagogy based on the findings of their research. A review of the research by Hamadan et al. (2013) and the Korean Ministry of Education (2017) highlighted the disseminating and advocating benefits of a white paper.

Analysis of existing research revealed that white papers were also designed to be solution-oriented. Basu et al. (2021) highlighted the challenges faced by computer science teachers and proposed a solution to mitigate them. The researchers suggested computer science teachers' capacity building through sustainable and scalable teacher professional development programs as a potential solution, focusing on promoting the teachers' ability to effectively teach the subject. Likewise, in their white paper presented on teacher education, Shih et al. (2020) offered essential insights and approaches aimed at enhancing ethical standards, accountability, diligence, and long-term viability among teachers in Taiwan. The researchers identified these as fundamental principles to support educators who are deeply committed to their profession and dedicated to upholding the values of education. Such white papers, focused on actionable recommendations, make this format particularly valuable for project studies aimed to influencing policy or practice.

A white paper presented by an independent nonprofit organization (Education.org, 2021) utilized clear and concise language, avoiding overly technical language. The paper advocated for collaboration among all involved in education to bridge the divide between theory and practice. The organization, with utmost clarity in its white paper, called for teachers to establish a repository of educational research findings. This simple yet comprehensive language ensured that stakeholders readily understood the research implications and recommendations, regardless of their academic background. Furthermore, a review of the white paper created by Haley and Jack (2023) affirmed that white papers adhered to a specific structure, often including an introduction, background information, methodology, findings, recommendations, and a conclusion. Presenting the research findings in such a structured format, the authors ensured a logical presentation of the research components.

Researchers opined that white papers do not undergo the same rigorous peer-review process as academic articles (Dev et al., 2024). The authors suggested that this limitation raised concerns regarding the methodological rigor and validity of the research presented. Stelzner (2006) recommended that project studies incorporating white papers might need to address these concerns by ensuring methodological soundness and providing clear references for further exploration. Haley and Jack (2023) pointed out the possibility of potential bias in white papers as the papers often aim to influence stakeholders or advocate for specific solutions. To avoid bias, project studies using white papers should strive for objectivity in presenting findings and ensure that recommendations are grounded in the research area. Furthermore, white papers are concise documents when compared to academic journal articles (Stelzner, 2006). This might limit the depth of analysis and discussion.

A thorough synthesis of previous studies revealed that white papers serve as a valuable tool for researchers and practitioners within the context of project studies, in terms of dissemination, actionable recommendations, accessibility, and structured format. However, it is important to recognize possible constraints, such as the lack of thorough peer review and the potential for bias. When utilized adeptly, white papers can enable studies to connect research with practical applications. This thorough review process ultimately established the white paper as the most suitable method for presenting recommendations within the framework of the current qualitative research study.

6. Recommendations

A comprehensive study of ICT implementation in education across various states within the country revealed promising results, with potential for significant improvements across educational sectors (Ambe et al., 2024; Bolaji & Ajia, 2023; Bolaji & Jimoh, 2023). However, achieving long-lasting and substantial change necessitates a long-term commitment from all stakeholders involved. A comprehensive, systematic, and phased approach, tailored to address specific needs and adapting to evolving environments, is crucial for successful implementation of technology integration. Drawing upon these insights and informed by the perspectives of teacher-participants in this study alongside experiences from other countries, this research proposes four key recommendations to guide the successful implementation of ICT in education within the state under study. These recommendations have been formulated with a focus on four major factors critical for successful ICT integration in educational institutions: access to technology resources, teacher training and support, cost considerations, and a strategic implementation plan.

The first recommendation is to ensure equitable access to high-quality ICT resources for all students and educators across the state being studied. This includes establishing infrastructure for reliable internet connectivity, providing schools with necessary devices, and ensuring software and technology tools are aligned with curriculum requirements. The second recommendation is to furnish ongoing professional development opportunities for teachers to develop their skills and confidence in blending technology into their pedagogy. These programs should address pedagogical approaches for effective technology use, troubleshooting skills, and content-specific applications of ICT in lesson plans. The third recommendation is to develop a sustainable funding model to support the ongoing costs associated with ICT in education implementation. This may involve public-private partnerships, as adopted in several African countries like Somalia, Kenya, and Ghana (Hassan & Ahmed, 2024; Kiarie & Jones, 2024; Manu et al., 2024), cost-sharing initiatives between schools and districts, and identifying potential grants or federal funding opportunities. The fourth recommendation is to implement ICT in education in a phased approach, starting with pilot programs in select schools and gradually scaling up based on successes and identified challenges. Regular monitoring and evaluation should be conducted to assess the effectiveness of the implementation and make adjustments as needed.

6.1 Recommendation 1: Ensure Equitable Access to Information and Communication Technology

The first recommendation is made to ensure equitable access to ICT in schools across the state. The current state of internet connectivity in schools needs to be assessed and areas in the state with reliable internet access and those requiring upgrades or new installations to be identified. The availability of computers, tablets, or other technology devices within schools needs to be identified, considering factors like the student-to-device ratio and the types of devices currently available. The existing software applications and educational technology tools utilized in schools needs to be reviewed. The degree of alignment of these software applications with curriculum requirements and learning objectives need to be assessed. The potential barrier to this recommendation in the project would be sufficient funding. Upgrading infrastructure and purchasing new devices can be expensive with limitations on funding faced by the district. This makes identifying sustainable funding sources crucial. As analyzed from the semistructured interviews, schools in remote areas may require extensive infrastructure development compared to schools in urban areas. A comprehensive plan for infrastructure upgrades and expansion, prioritizing underserved schools is to be developed. Alternative electrical power supply options such as solar panels is to be explored. Partnership with educational technology companies needs to be established to provide curriculum-aligned software and resources at discounted rates.

6.2 Recommendation 2: Invest in Teacher Training and Support

Investing in ongoing teacher training and support is paramount for successful ICT integration in physics education. This recommendation requires a comprehensive approach. In the first instance, a critical evaluation of existing professional development opportunities for teachers regarding technology integration should be conducted. Additionally, teacher assessments through surveys or self-assessments are necessary to gauge current skill levels and confidence in using technology within the physics curriculum. Understanding these needs allows for the development of targeted training programs that address specific skill gaps and equip teachers for effective technology use in their classrooms. Recognizing the heavy workloads faced by educators, dedicated time and resources must be allocated for participation in these training programs. School administration plays a crucial role in supporting this initiative by ensuring that both teachers and leadership teams have the time needed to participate effectively. Furthermore, school leaders should actively participate in the implementation process and dedicate time to share training experiences and best practices with their faculty. This collaborative approach fosters a supportive environment for ICT integration within the school community.

The training itself should be multifaceted. A multi-tiered approach that caters to various skill levels and technology needs will ensure all teachers are adequately prepared. Additionally, providing on-site technical support personnel within schools can be invaluable. These individuals can assist teachers in troubleshooting issues and utilizing technology effectively for instructional purposes. Finally, fostering collaboration through teacher learning communities focused on sharing best practices and creative approaches to ICT integration can provide pedagogical advancement opportunities for teachers. By implementing these strategies, teachers will be better equipped to leverage technology for improved physics education and ultimately, enhance student learning outcomes.

6.3 Recommendation 3: Address Cost Considerations

A critical challenge to integrating ICT in physics classrooms is cost. This recommendation emphasizes strategic financial planning to address these barriers. The first step involves a thorough analysis of current school technology budgets. This analysis should also identify existing funding streams, such as grants or state initiatives that can support ICT integration efforts. However, technology costs extend beyond initial infrastructure and devices. Ongoing expenses include software licenses, maintenance, and potential upgrades. To address these ongoing costs, schools must explore diverse funding avenues. Potential sources include grants, public-private partnerships, or dedicated technology acquisition budgets.

Given the high costs of ICT tools, software, and subscriptions, a strategic investment approach is essential. This involves meticulous planning to prioritize needs. Exploring innovative funding models, such as cost-sharing initiatives or open-source software options, can be highly beneficial. Additionally, fostering collaboration and resource-sharing networks between schools can maximize efficiency and minimize overall expenditures. Implementing bulk licensing agreements can further contribute to cost savings. By adopting a comprehensive and strategic approach to cost considerations, this recommendation lays the groundwork for sustainable ICT integration within physics education programs. This ensures long-term success and maximizes the potential of technology to enhance student learning experiences.

6.4 Recommendation 4: Implement a Phased Approach with Evaluation

To ensure successful and sustainable ICT integration within the target state's educational system, a phased approach with ongoing evaluation is recommended. This approach prioritizes a methodical and data-driven implementation process to maximize the impact of ICT on student learning outcomes. The initial phase should involve a comprehensive analysis of existing ICT initiatives within the state. This analysis should identify past successes, areas for improvement, and probable challenges associated with previous ICT integration efforts. A key barrier to successful implementation is the lack of a comprehensive plan, often leading to inefficiencies, wasted resources, and a lack of direction. Furthermore, without established evaluation tools, it becomes difficult to ascertain the impact of ICT integration on student outcomes. Building upon this analysis, a detailed implementation plan outlining clear phases is crucial. This plan should strategically implement pilot programs in select schools, chosen based on factors such as specific needs and readiness for ICT integration. Measurable goals and objectives for ICT integration should be established for each phase.

Additionally, clear metrics to track progress and assess the impact on student learning outcomes must be defined. These metrics could include student engagement, academic performance in physics, and overall satisfaction with the learning experience. A robust evaluation system that utilizes data to identify challenges and areas for improvement is essential for ongoing success. This system should provide valuable insights into the effectiveness of the implemented strategies and allow for course correction as needed. Furthermore, fostering a culture of data-driven decision making within schools empowers educators to leverage evaluation results to inform future ICT integration efforts. This iterative approach ensures that the implementation process continuously adapts and improves based on real-world data and feedback from stakeholders. By adopting a phased approach with ongoing evaluation, this recommendation lays the groundwork for sustainable ICT integration within the state's physics education curriculum.

7. Dissemination and Implementation of the Recommendations

The successful implementation of the recommendations outlined in the white paper hinges upon effective dissemination and review by key stakeholders within the investigated state in Nigeria. The dissemination process commences with the presentation of a white paper summary report to the tutor general and the district commissioner of education. A dedicated meeting will be scheduled to facilitate a comprehensive review of the full white paper. To enhance comprehension and encourage informed discussion, a concise, two- to three-page executive summary of the research will be provided alongside the white paper. This summary serves the dual purpose of informing the reviewers and allowing them to formulate any questions, comments, or concerns regarding the proposed recommendations. To broaden stakeholder engagement, the executive summary will be made readily available to all state education leaders who express interest in reviewing it. Should the tutor general and the commissioner require further dialogue to discuss their initial feedback, an additional meeting will be convened prior to presenting the report to the entire board of education.

Following the initial review by the tutor general and the commissioner, a subsequent meeting will be held to engage in a collaborative exploration of the recommendations. This discussion will focus on potential implementation steps and the development of a practical action plan. Crucially, approval for presenting the findings to the full board of education will be sought at this juncture. With the approval of the tutor general and the commissioner, a dedicated session will be conducted to present the white paper's recommendations to the board of education. The board will then be granted a designated period to meticulously examine the full white paper and raise any questions concerning the study methodology, data collection procedures, or the proposed recommendations themselves. Upon receiving board approval, a one-month window will be allocated for the tutor general and the commissioner of education to conduct a more in-depth review of the white paper. This timeframe allows for the development of any constructive feedback they may wish to share with the researcher or broader district leadership.

The primary responsibility of the authors throughout this project encompassed conducting the research and presenting the white paper summary report to the state education department leaders and the board of education. Following the delivery of the white paper and executive summary, the state department of education leadership team will engage in a deliberative process to reach informed decisions regarding the proposed recommendations. If the leadership team requires clarification or deeper insights on specific points within the white paper, the authors will transition into a consultant role to provide further explanation and address any lingering questions. Ultimately, the onus of determining the next steps for implementing the recommendations within the schools falls upon the state department of education leadership, including the tutor general and the commissioner of education. Their collaborative efforts will be crucial in translating the research findings into a practical and actionable plan for successful ICT integration within the schools in the southwestern state of Nigeria.

7.1 Project Evaluation Plan

The current project utilized a white paper summary report as the primary research communication tool. This format allowed for a clear presentation of the research findings and recommendations in relation to the project's initial goals. By analyzing data on the beliefs of secondary school teachers, the study aimed to identify everyday challenges, ideas, and facilitating conditions needing improvement within the state's ICT integration efforts in secondary school physics classrooms.

The initial reviewers of the white paper's recommendations will be the tutor general and the district commissioner of education. Their assessment will concentrate on determining the purposefulness, significance, and overall value of the proposed recommendations for potential presentation to the state education board. If the tutor general and the commissioner approve the white paper, it will proceed to the education board for further review, during which additional modifications and questions may be proposed. Ultimately, the board of education holds the authority to determine how to proceed based on the project findings. They may choose to implement all, some, or none of the recommendations outlined in the white paper. Additionally, they might request further research or a more extensive evaluation process for specific recommendations.

To assess the effectiveness of the suggested recommendations, a multipronged approach comprising of (a) a cover letter for stakeholder feedback, (b) stakeholder survey, or (c) focus group discussions can be adopted. A cover letter, collaboratively developed with key decision-makers, can be added to the white paper. This document provides stakeholders with the opportunity to note informal remarks, ideas, and feedback regarding the research findings and recommendations. An online survey, subject to approval by the state commissioner of education, can be administered to the board of education and other relevant stakeholders. This survey can be designed to gather quantitative and qualitative data on their perspectives concerning the implemented recommendations. Focused group discussions with teachers, administrators, and other key stakeholders can furnish insights into the effect of the implemented recommendations on ICT integration practices within secondary schools.

Throughout the review and evaluation process, the authors will maintain a supportive role. This includes answering questions from decision-makers, clarifying specific recommendations or findings within the white paper, contributing to the development of evaluation tools, and synthesizing the evaluation data. By employing these comprehensive evaluation methods, the project can achieve a nuanced understanding of the effectiveness of the implemented recommendations. This information can be used to refine future ICT integration initiatives within the secondary schools in the investigated state in Nigeria.

7.2 Project Implications

Information and communication technologies offer immense potential to revolutionize physics education, fostering deeper engagement and enhancing learning outcomes. This subsection explores the implications of the qualitative research study project investigating the challenges faced by secondary school physics teachers in a southwestern state of Nigeria, regarding ICT integration within their classrooms. The study's findings, presented in the accompanying white paper, offer valuable insights for stakeholders interested in promoting effective ICT integration in physics education across the state. This subsection also delves into the impact of the proposed recommendations on various educational aspects, highlighting potential benefits and considerations for successful implementation. The implications of this project study is discussed under four subheadings – implications for educational outcomes, implications for teachers, implications for educational policy and leadership, and implications for educational equity and accessibility.

7.2.1 Implications for Educational Outcomes

Effective ICT integration has the potential to significantly enhance student learning outcomes in physics education. The findings of the current study revealed that interactive simulations, visualizations, and online learning resources can bring abstract physics concepts to life, fostering deeper student engagement and comprehension. Effective adoption and execution of ICT-integrated pedagogies can facilitate personalized knowledge gaining experiences, facilitating students to explore physics content at their own pace and revisit challenging concepts as needed. The research also holds promise in motivating physics teachers to blend technology in their lesson plans, fostering avenues for developing vital skills such as critical thinking and problem-solving. By addressing the benefits of ICT-integrated teaching techniques, this study reinforces the notion that interactive learning environments created through technology can make physics more appealing and increase student motivation to learn.

7.2.2 Implications for Teachers

The proposed recommendations in the white paper can empower physics teachers and improve their professional development in ICT integration. Investing in professional development equips teachers with the necessary skills and confidence to utilize ICT effectively within their classrooms. Training programs on pedagogical approaches for ICT integration can introduce teachers to innovative ways to leverage technology for physics instruction. By addressing teacher workload concerns and exploring options for support staff, more time can be allocated for lesson planning and integrating ICT into existing curriculum. Providing opportunities for teachers to experiment with new technologies and share best practices can foster a sense of accomplishment and enhance professional satisfaction.

7.2.3 Implications for Educational Policy and Leadership

By documenting the challenges faced by physics teachers regarding ICT integration, the white paper sheds light on critical issues that may not have received sufficient attention from policymakers and school administrators. Recommendations requiring infrastructure upgrades and technology acquisition necessitate a commitment from the state ministry of education and district authorities to allocate adequate resources for ICT initiatives. The study reiterates on collaboration between curriculum developers and educational technology companies which is crucial to ensure that available technology tools are well-aligned with the defined learning objectives of the physics curriculum. The white paper project advocates for incorporating dedicated time within the school schedule for ICT-focused professional development, demonstrating a commitment from school administrators to supporting teachers in integrating technology effectively. Strong leadership support from school principals creates a positive environment and promotes collaboration in ICT integration efforts.

7.2.4 Implications for Educational Equity and Accessibility

The recommendations proposed in the project strive to promote ICT integration in a way that fosters educational equity and accessibility. Ensuring all schools have access to reliable internet connectivity and technology devices is crucial to prevent technology from becoming a barrier to learning for students from under-resourced communities. The white paper recommends developing curriculum-aligned technology resources which will ensure that students across the state benefit from ICT integration and engage in physics education with enhanced curiosity and engagement. The findings of this project study can also influence educators to invest in offline learning resources and create alternative solutions in situations where internet connectivity is unreliable, promoting universal access to physics educational materials.

7.3 Considerations for Implementation

While the proposed recommendations provide a clear path towards successful ICT integration, several considerations require careful attention during the implementation phase. Long-term funding has to be secured for ICT infrastructure upgrades such as internet connectivity, devices, etc., teacher training programs, and device replacement plans. Such funding is crucial for sustained ICT integration efforts. **Fostering a collaborative environment where educators can exchange best practices and navigate challenges can cultivate a sense of ownership among teachers**. This collaborative approach can significantly enhance the success of ICT integration initiatives. It is essential to ensure readily available technical support within schools for troubleshooting technical issues and assisting teachers in integrating technology seamlessly into their lessons. Regularly evaluating the effectiveness of ICT integration through data collected from student assessments, teacher feedback, and resource utilization data is crucial to determine the impact of these recommendations and make adjustments as needed.

8. Project Strengths and Limitations

This project study offers a valuable contribution to the effort of improving ICT integration in physics education in the secondary schools of a southwestern state in Nigeria. By recognizing the strengths, the transparency in the research process is demonstrated and the quality of the project study is highlighted. By acknowledging the limitations, overstating the significance of the findings is avoided and the credibility of the project study is maintained. Identifying limitations also may help other researchers determine avenues for future research and areas where further methodological improvements are needed.

8.1 Strengths

By utilizing a white paper format, this project study demonstrates a focus on practical solutions and an action-oriented approach. Semistructured interviews with 12 secondary school physics teachers of the state and further analysis of the interview data collected resulted in four recommendations presented in the white paper. The clear recommendations presented in the white paper will allow the state education department, policymakers, and stakeholders to readily grasp the proposed course of action for enhancing ICT integration within physics education in the state's secondary school classrooms. Additionally, the project targets a particular state and education system in Nigeria. This focus led to the recommendations being tailored to address the unique challenges faced by the physics teachers of this state, explore opportunities within the specific context of the secondary schools in the state, and enhance the prospects for successful implementation of ICT-integrated teaching practices.

By incorporating data collected through semistructured interviews with secondary school physics teachers, the current project prioritizes the perspectives and experiences of those who are directly involved in implementing ICT-integrated teaching and learning practices. Consequently, this study offers valuable insights into the real-world challenges and opportunities faced by teachers on the ground. Moreover, these data revealed crucial information about the factors that motivate or hinder teachers' use of technology in the classroom, resulting in the proposed recommendations to be more targeted and effective. The challenges and concerns identified by teachers through the interviews are directly addressed in the white paper. This makes the white paper more responsive to teachers' needs and enhances the feasibility of teacher buy-in.

The qualitative data gathered through the interviews can serve as a rich starting point for further research endeavors. Although the current project study focuses on proposing solutions through the white paper, the interviews and data analysis may reveal a wealth of nuanced experiences, challenges, and opportunities related to ICT integration in physics education. The analysis of the interview data may also likely reveal unexpected concerns or barriers faced by physics teachers that require further investigation. The insights gained from the thematic analysis of the interview data may be used to formulate focused research questions for future studies, delving deeper into the specific themes identified in the interviews.

A thorough review of the existing literature on ICT integration in physics education was carried out to present the white paper project of the current study. Such a review ensured that the recommendations are grounded in a strong theoretical foundation. Furthermore, this strengthens the credibility and persuasiveness of the proposed solutions. The study site is one of the largest states in Nigeria, comprising six education districts providing education to over 200,000 senior secondary school students. An effective dissemination of this white paper has the likelihood to influence educational policies and practices not only across this state, but also in the neighboring smaller states, impacting numerous schools and ultimately benefiting a large number of senior secondary students.

8.2 Limitations

One of the major limitations for the implementation of the project's recommendations may be the funding required for significant investments in infrastructure upgrades, technology acquisition, and teacher training. Given the economic hardship faced by the country during the proposal of the recommendations, securing long-term funding for such initiatives may be difficult. Additionally, securing sustained funding for ICT infrastructure upgrades, teacher training programs, and ongoing maintenance across all 36 states in Nigeria, each with varying levels of development, will be crucial for successful scalability. Though the project study focuses on the challenges faced by physics teachers within a specific state, certain recommendations, particularly those pertaining to establishing consistent electric supply or providing alternative power sources alongside reliable internet connectivity, may necessitate intervention beyond the state government's capacity. The state government and relevant government agencies within the state may face limitations in implementing specific recommendations in the white paper due to budgetary constraints, lack of authority over federal infrastructure projects, or logistical challenges associated with large-scale infrastructure upgrades. The white paper, in its current form, may not be sufficiently persuasive to address these infrastructure-related issues directly with the federal government. Therefore, to effectively address these critical infrastructure needs, the project acknowledges the importance of gaining broader collaboration. This may involve engaging the federal government and exploring opportunities for public–private partnerships. By acknowledging the limitations of state-level implementation and advocating for multi-stakeholder collaboration, the project recognizes the need for a more comprehensive approach to addressing critical infrastructure challenges that hinder ICT integration efforts.

9. Conclusion

This qualitative project study examined the perspectives of secondary school physics teachers in a specific Nigerian state, aiming to uncover the challenges hindering effective ICT integration in their classrooms and to propose actionable recommendations. The findings highlighted significant barriers, including inadequate infrastructure, insufficient teacher training, and a lack of financial resources. To address these challenges and promote effective ICT integration, a comprehensive set of recommendations was formulated. These recommendations emphasize the importance of equitable access to technology, ongoing teacher professional development, sustainable funding, and a phased implementation approach. By prioritizing these areas, stakeholders can create a conducive environment for effective ICT integration, ultimately leading to improved student learning outcomes in physics education. The successful implementation of these recommendations requires a concerted effort from various stakeholders, including policymakers, school administrators, teachers, and technology providers. By working collaboratively and utilizing the potential of ICT, we can transform physics education, making it more engaging, interactive, and relevant to the needs of 21st-century learners.

References

Afzal, A., Khan, S., Daud, S., Ahmad, Z., & Butt, A. (2023). Addressing the digital divide: Access and use of technology in education. *Journal of Social Sciences Review*, *3*(2), 883–895. https://doi.org/10.54183/jssr.v3i2.326

Ali, H., Rafique, M., & Hussain, B. (2023). Effect of ICT integration on secondary school students' physics achievement and reasoning skills. *Voyage Journal of Educational Studies*, *3*(2), 383–398. https://doi.org/10.58622/vjes.v3i2.73

Al-khresheh, M. H., & Alkursheh, T. O. (2024). An integrated model exploring the relationship between self-efficacy, technology integration via Blackboard, English proficiency, and Saudi EFL students' academic achievement. *Humanities and Social Sciences Communications*, *11*(1), 1–12. https://doi.org/10.1057/s41599-024-02783-2

Ambe, B. A., Agbor, C. E., Amalu, M. N., Ngban, A. N., Bekomson, A. N., Etan, M. O., Ephraim, I. E., Asuquo, E. E., Eyo, O. E., & Ogunjimi, J. O. (2024). Electronic media learning technologies and environmental education pedagogy in tertiary institutions in Nigeria. *Social Sciences & Humanities Open*, *9*, Article 100760. https://doi.org/10.1016/j.ssaho.2023.100760

Ameziane, N., Hassouni, T., Bentaleb, K. A., & Chahlaoui, A. (2023). Evaluation of integration of new ICTs in teaching-learning of school system. *International Journal on Technical and Physical Problems of Engineering*, *15*(1), 127–134. http://www.iotpe.com/IJTPE/IJTPE-2023/IJTPE-Issue54-Vol15-No1-Mar2023/19-IJTPE-Issue54-Vol15-No1-Mar2023-pp127-134.pdf

Banda, H. J., & Nzabahimana, J. (2023). The impact of physics education technology (PhET) interactive simulation-based learning on motivation and academic achievement among Malawian physics students. *Journal of Science Education and Technology*, *32*(1), 127–141. https://link.springer.com/article/10.1007/s10956-022-10010-3

Basu, S., Rutstein, D., & Tate, C. (2021). *Building teacher capacity in K-12 computer science by promoting formative assessment literacy* [White paper]. National Comprehensive Center. https://files.eric.ed.gov/fulltext/ED615714.pdf

Batuyong, C. T., & Antonio, V. V. (2018). Exploring the effect of PhET® interactive simulation-based activities on students' performance and learning experiences in electromagnetism. *Asia Pacific Journal of Multidisciplinary Research*, *6*(2), 121–131. https://www.academia.edu/download/62370679/APJMR-2017.6.2.1520200315-105751-17jqo3i.pdf

Bolaji, H. O., & Ajia, I. S. (2023). Information and communication technology (ICT) integration: A veritable technique for quality secondary education. *ASEAN Journal of Educational Research and Technology*, *2*(2), 137–144. https://ejournal.bumipublikasinusantara.id/index.php/ajert/article/view/183

Bolaji, H. O., & Jimoh, A. (2023). Usability and utilization of ICT among educational administrators in secondary students in public school. *Indonesian Journal of Educational Research and Technology, 3*(2), 97–104. https://doi.org/10.17509/ijert.v3i2.48244

Bowman, M. A., Vongkulluksn, V. W., Jiang, Z., & Xie, K. (2022). Teachers' exposure to professional development and the quality of their instructional technology use: The mediating role of teachers' value and ability beliefs. *Journal of Research on Technology in Education*, *54*(2), 188–204. https://doi.org/10.1080/15391523.2020.1830895

Dachraoui, S., Bentaleb, K. A., Taqi, A., Hassouni, T., & Al Ibrahmi, E. (2023). Integration of ICT in the resolution of differential equations by the Euler method in physics for second year science baccalaureate classes. *International Journal on Technical and Physical Problems of Engineering, 15*(54), 195–203. https://www.academia.edu/download/104854040/29_IJTPE_Issue54_Vol15_No1_Mar2023_pp195_203_1_.pdf

Dev, P. S. B., Koerner, L. W., Saad, S., Antusch, S., Askins, M., Babu, K. S., Barrow, J. L., Chakrabortty, J., de Gouvea, A., Djurcic, Z., Girmohanta, D., Gogoladze, I., Goodman, M. C., Higuera, A., Kalra, D., Karagiorgi, G., Kearns, E., Kudryavtsev., V. A., Kutter, T., … Zhou, Y. L. (2024). Searches for baryon number violation in neutrino experiments: A white paper. *Journal of Physics G: Nuclear and Particle Physics*, *51*(3), 033001. https://doi.org/10.1088/1361-6471/ad1658

Dier, M., & Asrizal, A. (2023). Development of ICT-based worksheet on STEM-integrated to increase knowledge, data literacy, and technology literacy of high school students. *Pillar of Physics Education*, *15*(4), 287–295. https://ejournal.unp.ac.id/students/index.php/pfis/article/view/13542

Dong, Y., Xu, C., Chai, C. S., & Zhai, X. (2020). Exploring the structural relationship among teachers' techno stress, technological pedagogical content knowledge (TPACK), computer self-efficacy and school support. *The Asia-Pacific Education Researcher*, *29*, 147–157. https://doi.org/10.1007/s40299-019-00461-5

Education.org. (2021). *Calling for an education knowledge bridge: A white paper to advance evidence use in education* [White paper]. https://whitepaper.education.org/download/white_paper.pdf

Fawns, T. (2022). An entangled pedagogy: Looking beyond the pedagogy—technology dichotomy. *Postdigital Science and Education*, *4*(3), 711–728. https://link.springer.com/article/10.1007/s42438-022-00302-7

Federal Ministry of Education. (2013). *National policy on education* (6th ed.). Nigerian Educational Research and Development Council. https://educatetolead.files.wordpress.com/2016/02/national-education-policy-2013.pdf

Federal Ministry of Education. (2019). *National implementation guidelines for ICT in education.* https://education.gov.ng/wp-content/uploads/2019/07/NATIONAL-IMPLEMENTATION-GUIDELINES-FOR-ICT-IN-EDUCATION-2019.pdf

Francom, G. M. (2020). Barriers to technology integration: A time-series survey study. *Journal of Research on Technology in Education*, *52*(1), 1–16. https://doi.org/10.1080/15391523.2019.1679055

Gurevych, R., Silveistr, A., Mokliuk, M., Shaposhnikova, I., Gordiichuk, G., & Saiapina, S. (2021). Using augmented reality technology in higher education institutions. *Postmodern Openings*, *12*(2), 109–132. https://doi.org/10.18662/po/12.2/299

Haley, U. C. V. & Jack, A. (2023). *Measuring societal impact in business and management research: From challenges to change* [White paper]. London: SAGE. https://dx.doi.org/10.2139/ssrn.4306589

Hamadan, N., McKnight, P., McKnight, K., & Arfstorm, K. M. (2013). *A white paper based on the literature review titled a review of flipped learning* [White paper]. Flipped Learning Network. https://flippedlearning.org/wp-content/uploads/2016/07/WhitePaper_FlippedLearning.pdf

Hasas, A., Enayat, W., Hakimi, M., & Ahmady, E. (2024). A comprehensive review of ICT integration in enhancing physics education. *MAGNETON: Jurnal Inovasi Pembelajaran Fisika*, *2*(1), 36-44. https://doi.org/10.30822/magneton.v2i1.3106

Hassan, M. M., & Ahmed, A. R. (2024). Examining internal factors impacting higher education institutions readiness for implementing public–private partnerships to foster a knowledge economy in post-conflict Somalia. *Innovative Higher Education*, 1-15. https://doi.org/10.1007/s10755-024-09715-7

Hayes, A. (2023, December 22). *What is a white paper? Types, purpose, and how to write one.* Investopedia. https://www.investopedia.com/terms/w/whitepaper.asp

Hershkovitz, A., Daniel, E., Klein, Y., & Shacham, M. (2023). Technology integration in emergency remote teaching: Teachers' self-efficacy and sense of success. *Education and Information Technologies*, *28*(10), 12433–12464. https://link.springer.com/article/10.1007/s10639-023-11688-7

Huang, C. K. (2023). Coaching for change: Preparing mathematics teachers for technology integration in differentiated classrooms. *Education and Information Technologies*, *28*(11), 13913–13941. https://link.springer.com/article/10.1007/s10639-023-11684-x

Hunduma, C. M., & Mekuria, Y. S. (2023). Constraints hindering ICT integration in Ethiopian public secondary schools: A literature review. *Online Submission*, *10*(2), 691–702. https://files.eric.ed.gov/fulltext/ED628816.pdf

Ifinedo, E., Rikala, J., & Hämäläinen, T. (2020). Factors affecting Nigerian teacher educators' technology integration: Considering characteristics, knowledge constructs, ICT practices and beliefs. *Computers & Education*, *146*, 103760. https://doi.org/10.1016/j.compedu.2019.103760

Ifinedo, E., & Kankaanranta, M. (2021). Understanding the influence of context in technology integration from teacher educators' perspective. *Technology, Pedagogy and Education, 30*(2), 201–215. https://doi.org/10.1080/1475939X.2020.1867231

Jimoh, A. S., Bamiro, N. B., Akapo, T. A., Ibrahim, D. A., & Ismaila, M. A. (2020). Survey of determinants of the utilization of ICT facilities for instruction in Lagos State secondary schools [PDF]. *Al-Hikmah Journal of Education, 7*(2), 42–53. https://www.alhikmah.edu.ng/ajhir/index.php/aje_path/article/view/135/136

Karim, S., & Zoker, E. M. (2023). Technology in mathematics teaching and learning: An impact evaluation in selected senior schools in Masingbi town. *Assyfa Learning Journal*, *1*(2), 60–72. https://doi.org/10.61650/alj.v1i1.63

Kiarie, C., & Jones, N. J. (2024). Towards learning excellence in Universities: A critical review of information and communication technology policies in education in Kenya. *Scholarship of Teaching and Learning in the South*, *8*(1), 162-182. https://journals.uj.ac.za/SOTL/index.php/sotls/article/download/293/177

Kilag, O. K. T., Malbas, M. H., Miñoza, J. R., Ledesma, M. M. R., Vestal, A. B. E., & Sasan, J. M. V. (2024). The views of the faculty on the effectiveness of teacher education programs in developing lifelong learning competence. *European Journal of Higher Education and Academic Advancement*, *1*(2), 92–102. https://journal.silkroad-science.com/index.php/EJHEAA/article/view/106

Korea Ministry of Education. (2017). *White paper on ICT in education Korea* [White paper]. KERIS. https://keris.or.kr/main/cf/fileDownload.do?fileKey=0c906615b9fcaa2d5e1810d61d3a2674

Kucuk, T. (2023). Technology integrated teaching and its positive and negative impacts on education. *International Journal of Social Sciences & Educational Studies*, *10*(1), 46–55. https://doi.org/10.23918/ijsses.v10i1p46

Laila, A., Nihal, B., Aziz, A., & Abderrahman, M. (2024). Exploring the possibilities of augmented reality in physics education. In Khalidi, M (Ed.), *E-Learning and Smart Engineering Systems (ELSES 2023)* (pp. 480–489). Atlantis Press. https://doi.org/10.2991/978-94-6463-360-3_45

Manu, J., Ampomah, R., Akyina, K. O., & Antwi, S. (2024). Education and technology in Ghana: Understanding the centrality of technology integration in the classroom and beyond. *American Journal of Educational Research*, *12*(10), 402-412. https://www.academia.edu/download/119573935/Education_and_Technology_12_10_2.pdf

Manubag, M., Kilag, O. K., Peñalosa, B., Timtim, J. M., Padilla, J. B., & Abendan, C. F. (2023). Empowering skills development: Exploring the role of technology management in technical vocational education enhancement. *Excellencia: International Multi-disciplinary Journal of Education, 1*(5), 195–208. https://multijournals.org/index.php/excellencia-imje/article/view/112

Merriam, S. B., & Tisdell, E. J. (2016). *Qualitative research: A guide to design and implementation* (4th ed.). San Francisco, CA: Jossey-Bass.

Munje, P. N., & Jita, T. (2020). The impact of the lack of ICT resources on teaching and learning in selected South African primary schools. *International Journal of Learning, Teaching and Educational Research*, *19*(7), 263–279. https://doi.org/10.26803/ijlter.19.7.15

Moro, K. C., & Billote, W. J. S. M. (2023). Integrating Ivatan indigenous games to learning module in Physics: Its effect to student understanding, motivation, attitude, and scientific sublime [PDF]. *Science Education International*, *34*(1), 3–14. https://icaseonline.net/journal/index.php/sei/article/view/475

Muzari, T., Shava, G. N., & Shonhiwa, S. (2022). Qualitative research paradigm, a key research design for educational researchers, processes, and procedures: A theoretical overview. *Indiana Journal of Humanities and Social Sciences*, *3*(1), 14–20. https://indianapublications.com/articles/IJHSS_3(1)_14-20_61f38990115064.95135470.pdf

Novitra, F., Festiyed, Yohandri, & Asrizal. (2021). Development of online-based inquiry learning model to improve 21st-century skills of physics students in senior high school. *Eurasia Journal of Mathematics, Science and Technology Education*, *17*(9), 1–20. https://files.eric.ed.gov/fulltext/EJ1311539.pdf

Neroni, M. A., Oti, A., & Crilly, N. (2021). Virtual reality design-build-test games with physics simulation: Opportunities for researching design cognition. *International Journal of Design Creativity and Innovation*, *9*(3), 139–173. https://doi.org/10.1080/21650349.2021.1929500

Opeyemi, D. A., Ayodele, V., Alufa, O., Anderson, E., Strachan, R., & Emembolu, I. (2019, April). Barriers and identified solutions to the integration of digital technologies in the classroom: A case study of teachers in Nigeria. In *2019 IEEE Global Engineering Education Conference (EDUCON)* (pp. 953–958). IEEE. https://ieeexplore.ieee.org/abstract/document/8725160/

Pappa, C. I., Georgiou, D., & Pittich, D. (2023). Technology education in primary schools: Addressing teachers' perceptions, perceived barriers, and needs. *International Journal of Technology and Design Education,* 1–19. https://doi.org/10.1007/s10798-023-09828-8

Phillippi, J., & Lauderdale, J. (2018). A guide to field notes for qualitative research: Context and conversation. *Qualitative Health Research, 28*(3), 381–388. https://doi.org/10.1177/1049732317697102

Rahmat, A. D., Kuswanto, H., Wilujeng, I., & Perdana, R. (2023). Implementation of mobile augmented reality on physics learning in junior high school students. *Journal of Education and E-Learning Research*, *10*(2), 132–140. https://files.eric.ed.gov/fulltext/EJ1396351.pdf

Rana, K., & Rana, K. (2020). ICT integration in teaching and learning activities in higher education: A case study of Nepal's teacher education. *Malaysian Online Journal of Educational Technology*, *8*(1), 36–47. https://files.eric.ed.gov/fulltext/EJ1239982.pdf

Rapanta, C., Botturi, L., Goodyear, P., Guàrdia, L., & Koole, M. (2021). Balancing technology, pedagogy and the new normal: Post-pandemic challenges for higher education. *Postdigital Science and Education*, *3*(3), 715–742. https://link.springer.com/article/10.1007/s42438-021-00249-1

Rintaningrum, R. (2023). Technology integration in English language teaching and learning: Benefits and challenges. *Cogent Education*, *10*(1), 2164690. https://doi.org/10.1080/2331186X.2022.2164690

Saldaña, J. (2021). *The coding manual for qualitative researchers* (4th ed.). Sage Publications.

Schmitz, M. L., Antonietti, C., Consoli, T., Cattaneo, A., Gonon, P., & Petko, D. (2023). Transformational leadership for technology integration in schools: Empowering teachers to use technology in a more demanding way. *Computers & Education*, *204*, 104880. https://doi.org/10.1016/j.compedu.2023.104880

Shih, Y., Chen, S., & Ye, Y. (2020). Taiwan's white paper on teacher education: Vision and strategies. *Universal Journal of Educational Research, 8*(11), 5257–5264. https://doi.org/10.13189/ujer.2020.081126

Shin, M., Yoo, H., & Jang, J. (2023). Barriers and solutions of Edtech integration in schools: Focused on leading teachers' perceptions. *Journal of Educational Technology*, *39*(1), 219–250. http://dx.doi.org/10.17232/KSET.39.1.219

Srinivasan, H., McCraney, M., Penny, R., Panesar-Aguilar, S., Cale, C., Luster, S., & Harris, L. (2024). Nigerian secondary physics teachers' perceptions of factors that challenge information and communication technology. *Journal of Education and Practice, 15*(11), 55–64. https://www.iiste.org/Journals/index.php/JEP/article/view/62677

Starks, A. C., & Reich, S. M. (2023). What about special ed? Barriers and enablers for teaching with technology in special education. *Computers & Education*, *193*, 104665. https://doi.org/10.1016/j.compedu.2022.104665

Stelzner, M. A. (2006). *Writing white papers: How to capture readers and keep them engaged.* WhitePaperSource Publishing.

Trikoilis, D. (2021). ICT implementation to improve rural students' achievement in physics. *European Journal of Physics Education*, *12*(2), 22–33. https://files.eric.ed.gov/fulltext/EJ1413984.pdf

Tuyizere, G., & Yadav, L. L. (2023). Effect of interactive computer simulations on academic performance and learning motivation of Rwandan students in atomic physics. *International Journal of Evaluation and Research in Education, 12*(1), 252–259. http://doi.org/10.11591/ijere.v12i1.23617

UNESCO Global Education Monitoring Report. (2020). *Inclusion and education: All means all* (3rd ed.). UNESCO. https://doi.org/10.54676/JJNK6989

Venkatesh, V., Morris, M. G., Davis, G. B., & Davis, F. D. (2003). User acceptance information technology: Toward a unified view. *Management Information Systems Quarterly, 27*(3), 425–478. https://doi.org/10.2307/30036540

Warr, M., Driskell, S. O., Langran, E., Mouza, C., & Schmidt-Crawford, D. (2023). Curriculum design for technology infusion: A continuous collaborative process. *Contemporary Issues in Technology and Teacher Education*, *23*(1), 124–150. https://www.learntechlib.org/primary/p/221547/

Wibowo, F. C. (2023). Effects of augmented reality integration (ARI) based model physics independent learning (MPIL) for facilitating 21st-century skills (21-Cs). *Journal of Technology and Science Education*, *13*(1), 178–192. https://files.eric.ed.gov/fulltext/EJ1391888.pdf

Williams, M. K., Christensen, R., McElroy, D., & Rutledge, D. (2023). Teacher self-efficacy in technology integration as a critical component in designing technology-infused teacher preparation programs. *Contemporary Issues in Technology and Teacher Education*, *23*(1), 228–259. https://www.learntechlib.org/primary/p/221546/

Wong, J. T., Bui, N. N., Fields, D. T., & Hughes, B. S. (2023). A learning experience design approach to online professional development for teaching science through the arts: Evaluation of teacher content knowledge, self-efficacy and STEAM perceptions. *Journal of Science Teacher Education*, *34*(6), 593–623. https://doi.org/10.1080/1046560X.2022.2112552

Yurtseven Avci, Z., O'Dwyer, L. M., & Lawson, J. (2020). Designing effective professional development for technology integration in schools. *Journal of Computer Assisted Learning*, *36*(2), 160–177. https://doi.org/10.1111/jcal.12394

Żadkowska, M., Dowgiałło, B., Gajewska, M., Herzberg-Kurasz, M., & Kostecka, M. (2022). The sociological confessional: A reflexive process in the transformation from face-to-face to online interview. *International Journal of Qualitative Methods*, *21*, 1–12. https://doi.org/10.1177/16094069221084785