Assessing Science Teacher Competencies for Educational Robotics Integration in Nigerian Unity Secondary Schools

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Abstract

This study investigates the determinants of science teacher quality crucial for effective educational robotics integration in Nigerian Unity Secondary Schools. Recognizing the transformative potential of robotics for STEM education, this research examines teacher qualifications, technical proficiencies, pedagogical competencies, and institutional support through a mixed-methods approach. Quantitative surveys administered to 183 science teachers, supplemented by qualitative focus groups, reveal significant deficiencies in formal robotics training, limited confidence in operating robotics kits, and inadequate curriculum-aligned pedagogical strategies. These deficiencies contribute to minimal classroom integration of robotics, characterized by low usage of robotics activities and a scarcity of hands-on projects. Principal challenges identified include insufficient training opportunities, limited access to robotics resources, time constraints, and a lack of clear curriculum guidelines. Based on these findings, the study recommends hands-on technical workshops, enhanced professional development initiatives, increased external funding, and supportive institutional policies to improve teacher competencies. While acknowledging limitations related to its scope, sample size, and reliance on self-reported data, this study offers actionable information for policymakers and educators seeking to bridge the divide between technology-driven educational policies and classroom realities, finally aiming to elevate STEM education in resource-constrained environments

Keywords: Educational Robotics, Science Teacher Quality, STEM Education, Professional Development, Nigeria

Introduction

The rapid globalization of technology and its transformative impact on education have indicated the imperative to equip learners with 21st-century skills, including critical thinking, creativity, and digital literacy (Wilson *et al.*, 2016). Educational robotics (ER), a dynamic interdisciplinary tool, has emerged as a pedagogical innovation with the potential to revolutionize science, technology, engineering, and mathematics (STEM) education by fostering hands-on, problem-based learning (Smakman *et al.*, 2022; Souza *et al.*, 2018). In Nigeria, where the Federal Government prioritizes STM education as a driver of national development (Bellanaija, 2017; Braun *et al.*, 2021; NAN, 2018; Vanguard, 2019), the integration of ER into Unity Secondary Schools—a network of institutions established to promote national cohesion and quality education—presents a strategic opportunity to bridge gaps in science education. However, the efficacy of ER hinges on the preparedness and competence of science teachers, who act as critical conduits for its implementation (Alekhuogie, 2021).

Globally, research affirms that teacher quality—encompassing pedagogical knowledge, technological proficiency, and positive attitudes—is the most significant school-based determinant of successful technology integration (Souza *et al.*, 2018). Yet, in Nigeria, systemic challenges such as inadequate teacher training, limited access to digital resources, and outdated curricula hinder the adoption of innovative pedagogies (Coronado *et al.*, 2020). For instance, a study by researchers revealed that 68% of Nigerian science teachers lack confidence in using advanced technologies, while Fidan & Debbag (2021) identified insufficient professional development programs as a barrier to ER adoption. These gaps raise critical questions about the readiness of science teachers in Unity Schools to leverage ER effectively, despite its potential to enhance student engagement and conceptual understanding in STEM (Id *et al.*, 2019).

Existing literature on ER in sub-Saharan Africa remains sparse, with few studies addressing teacher preparedness in resource-constrained contexts (Takacs *et al.*, 2013). In Nigeria, while initiatives like the Robotics and Artificial Intelligence Nigeria (RAIN) program aim to promote ER, empirical research on science teacher competencies for ER integration is notably absent (Roush, 2019). This study seeks to address this lacuna by investigating the determinants of science teacher quality—including knowledge, skills, attitudes, and institutional support—necessary for effective ER integration in Nigerian Unity Schools. Grounded in the Technological Pedagogical Content Knowledge (TPACK) framework (Braun *et al.*, 2021), the research employs a mixed-methods approach to evaluate teacher competencies and identify scalable strategies for professional development.

By elucidating the nexus between teacher quality and ER implementation, this study contributes to global discourse on STEM education equity while offering actionable insights for policymakers and educators in Nigeria. Its findings aim to inform teacher training programs, curriculum reforms, and resource allocation strategies to ensure that ER becomes a sustainable tool for advancing science education in alignment with Sustainable Development Goal 4 (SDG 4) (Gottsegen, 2021).

Problem Statement

The integration of educational robotics (ER) into science curricula has been globally recognized as a transformative approach to fostering STEM skills, creativity, and problem-solving abilities among students (Bikar *et al.*, 2020). In Nigeria, the Federal Government's emphasis on STEM education as a pillar of national development (Federal Ministry of Education, 2013) positions ER as a strategic tool to revitalize science instruction in Unity Secondary Schools. However, the adoption of ER in these schools remains nascent, hindered by systemic and pedagogical challenges. Central to these challenges is the quality of science teachers, whose competencies, attitudes, and training are critical determinants of successful technology integration (Braun *et al.*, 2021; Karalekas *et al.*, 2020).

Despite Nigeria's policy frameworks advocating technology-driven education, studies reveal persistent gaps in science teachers' preparedness to utilize advanced tools like ER. For instance, researchers found that 68% of Nigerian science teachers lack confidence in operating technological tools, while Fidan & Debbag (2021) attributed low ER adoption to inadequate professional development opportunities. Compounding this issue is the outdated teacher training curricula, which rarely incorporate emerging technologies (Coşkunserçe, 2021), and limited access to robotics kits and digital infrastructure in schools (Rao & Jalil, 2021). These barriers undermine the potential of ER to enhance student engagement and conceptual mastery, perpetuating disparities in STEM proficiency among Nigerian learners.

Globally, the Technological Pedagogical Content Knowledge (TPACK) framework emphasizes the necessity of teachers' synergistic mastery of technology, pedagogy, and subject matter for effective classroom innovation (Mishra & Koehler, 2006). However, in Nigeria, empirical research on science teachers' TPACK readiness for ER integration is virtually absent (Niyi, 2021).

Existing studies on ER in sub-Saharan Africa largely focus on technical implementation, neglecting teacher-centric factors such as attitudes, institutional support, and training needs. This gap is particularly acute in Unity Schools, which serve as models of national educational excellence but face unique logistical and socio-cultural challenges in adopting ER.

The consequences of inaction are profound. Without addressing science teacher quality, ER initiatives risk becoming superficial interventions, failing to achieve sustainable integration or improve learning outcomes. This exacerbates inequities in STEM education, disproportionately affecting students in resource-constrained environments and undermining Nigeria's progress toward Sustainable Development Goal 4 (SDG 4) on inclusive, quality education (Myhill, 2020). This study, therefore, seeks to investigate the determinants of science teacher quality—including knowledge, skills, attitudes, and institutional support systems—required for effective ER integration in Nigerian Unity Secondary Schools. By identifying these factors, the research aims to inform targeted interventions to bridge the gap between policy aspirations and classroom realities.

Objectives of the Study

The aim of this research is to determine the qualities and competencies of science teachers essential for the effective integration of educational robotics in Nigerian unity secondary schools. The study seeks to identify the factors influencing teacher readiness and capacity in adopting educational robotics as a tool for enhancing science teaching and learning outcomes. Specifically, the objectives of this research are:

1. To evaluate the current qualifications, technical skills, and pedagogical knowledge of science teachers in Unity Secondary Schools regarding educational robotics.

2. To evaluate the level of science teachers' knowledge and understanding of educational robotics in Nigerian unity secondary schools.

3. To identify the essential qualities and skills required for science teachers to effectively integrate educational robotics into their teaching practices.

4. To assess the current state of robotics integration in science education within Nigerian secondary schools.

5. To examine the challenges faced by science teachers in adopting educational robotics in their classrooms.

6. To recommend strategies for enhancing science teachers' professional development in the use of educational robotics.

Research Questions

The research questions guiding this study are

1. What are the existing qualifications, technical proficiencies, and pedagogical competencies of science teachers in Nigerian Unity Secondary Schools for teaching educational robotics?

2. What is the level of science teachers' knowledge and understanding of educational robotics in Nigerian unity secondary schools?

3. What specific qualities and skills are necessary for science teachers to effectively integrate educational robotics into science teaching in secondary schools?

4. To what extent is educational robotics currently integrated into science teaching practices in Nigerian unity secondary schools?

5. What are the major challenges faced by science teachers in incorporating educational robotics into their teaching?

6. What strategies can be recommended to improve science teachers' capacity for integrating educational robotics into their teaching practices?

Methodology

This study employs a mixed-methods explanatory sequential design, strategically combining quantitative surveys and qualitative focus group discussions to investigate the integration of educational robotics in Nigerian Unity Secondary Schools (NUSS). This approach facilitates triangulation, allowing quantitative data to reveal broader patterns and challenges while qualitative data provides richer, context-specific insights into potential improvement strategies. The use of both Likert scales and focus groups ensures a comprehensive understanding of teacher competencies, challenges, and the contextual factors influencing effective robotics integration.

The study's population comprises approximately 352 science teachers in NUSS. A stratified random sampling method was used to select 183 participants, ensuring representation across geographic zones and school sizes. This sample size was determined through power analysis. Inclusion criteria specified that participants must be active science teachers with at least one year of experience. Following the survey, a purposeful sample of 12 participants was selected for focus group discussions, aiming to capture diverse perspectives based on demographics and teaching experience.

Data collection was conducted using the Science Teacher Quality for Effective Integration of Educational Robotics Questionnaire (STQEIERQ), an instrument adapted from existing literature and research. The STQEIERQ consists of seven sections. Sections A through F collect quantitative data, while Section G gathers qualitative information. Section A collects demographic data. Section B, the Science Teacher Qualifications and Competency Assessment Survey for Educational Robotics Integration, uses a five-item Likert scale to assess existing qualifications, technical proficiencies, and pedagogical competencies related to educational robotics. Section C, the Science Teacher Knowledge and Understanding of Educational Robotics Questionnaire, also employs a five-item Likert scale to measure teachers' knowledge and understanding of the subject. Section D, the Essential Qualities and Skills for Effective Robotics Integration in Science Teaching Inventory, uses a four-point Likert scale of importance to identify key qualities and skills. Section E, the Educational Robotics Integration in Science Teaching Practices Evaluation Scale, uses a four-point Likert scale (from "Never to Always") to assess the current level of robotics integration. Section F, the Challenges in Educational Robotics Integration for Science Teachers Scale, uses a four-point Likert scale to identify challenges faced by teachers. Finally, Section G, the Strategies for Enhancing Science Teachers' Capacity in Educational Robotics Integration Focus Group Guide, contains five items designed to elicit insights and recommendations for improving teachers' capacity for effective robotics integration.

Surveys were administered electronically or in person, with informed consent obtained and anonymity assured. Data collection spanned 4–6 weeks. Focus groups were conducted virtually or in person, audio-recorded, and transcribed. Sessions lasted 60–90 minutes and were guided by a moderator. The STQEIERQ was developed through a comprehensive literature review and validated by three experts in STEM education and robotics. A pilot test with 20–30 teachers was conducted to refine wording and assess reliability. Cronbach's alpha ($\alpha > 0.7$) was reported for each scale. Descriptive statistics (mean, standard deviation) were used to analyze data from Sections B–F. Inferential statistics (e.g., ANOVA, regression) were used to explore relationships between demographics and competencies/challenges. Thematic analysis of focus group transcripts was conducted using NVivo software, and emerging themes were linked to the survey findings.

Result

The results of the study are presented in a comprehensive manner, detailing the current state of science teachers' preparedness in Nigerian Unity Secondary Schools regarding educational robotics. Each research question is addressed individually, with the findings directly derived from the analyzed data.

Research Question 1: What are the existing qualifications, technical proficiencies, and pedagogical competencies of science teachers in Nigerian Unity Secondary Schools for teaching educational robotics?

Table 1: Science Teacher Qualifications and Competency Assessment Scale

Sno.	Item	Mean	Standard Deviation
1	I possess formal training in robotics or related technical fields	1.2	0.31
2	I am confident in operating and troubleshooting educational robotics kits	1.09	0.22
3	My pedagogical training adequately prepares me to integrate robotics into science lessons	1.14	0.28
4	I can align robotics activities with the national science curriculum objectives	1.02	0.20
5	I regularly update my technical skills to stay relevant in robotics education	1.91	0.43

Table 2 reveal that respondents generally report very low levels of preparedness in educational robotics. Teachers' self-assessments for formal training in robotics (mean = 1.20), confidence in operating and troubleshooting robotics kits (mean = 1.09), and the adequacy of their pedagogical training to integrate robotics into science lessons (mean = 1.14) are all near the lowest end of the scale. Specifically, the ability to align robotics activities with national curriculum objectives received the lowest mean score (1.02), highlighting significant challenges in curriculum integration. While there is a relatively higher, though still low, level of engagement in regularly updating technical skills (mean = 1.91), this suggests that although teachers are somewhat proactive in self-improvement, substantial training and support in robotics remain critical needs.

Research Question 2: What is the level of science teachers' knowledge and understanding of educational robotics in Nigerian unity secondary schools?

Table 2: Science Teacher Knowledge and Understanding of Educational Robotics Scale

Sno.	Item	Mean	Standard Deviation
1	I am knowledgeable about the core principles of educational robotics	1.43	0.56
2	I understand how robotics can enhance students' problem-solving skills in science	2.11	0.62
3	I am familiar with common robotics platforms used in secondary education	1.13	0.41
4	I can explain the relevance of robotics to real-world scientific applications	1.99	0.30
5	I feel confident teaching robotics concepts (e.g., programming, sensors, mechanics)	1.23	0.28

Table 2 reveals significant gaps in science teachers' knowledge and confidence regarding educational robotics. With mean scores ranging from 1.13 to 2.11 (on a 1–4 scale), respondents reported the lowest familiarity with common robotics platforms (Item 3: M = 1.13, SD = 0.41) and confidence in teaching robotics concepts (Item 5: M = 1.23, SD = 0.28), indicating minimal practical exposure. While teachers demonstrated slightly higher awareness of robotics' relevance to real-world scientific applications (Item 4: M = 1.99, SD = 0.30) and its potential to enhance problem-solving skills (Item 2: M = 2.11, SD = 0.62), these scores still reflect only a basic understanding. Notably, the consistently low standard deviations (≤0.62) across all items suggest limited variability in responses, indicating a widespread deficiency in foundational robotics knowledge and technical proficiency. These findings highlight an urgent need for targeted training programs to improve teachers' familiarity with robotics tools, pedagogical strategies, and hands-on application in science education.

Research Question 3: What specific qualities and skills are necessary for science teachers to effectively integrate educational robotics into science teaching in secondary schools?

Table 3: Essential qualities and skills for effective robotics integration scale

Sno.	Item	Mean	Standard Deviation
1	Proficiency in basic programming languages (e.g., Scratch, Python)	1.10	0.25
2	Ability to design inquiry-based robotics activities for science topics	1.11	0.21
3	Skill to troubleshoot technical issues during robotics lessons	1.10	0.18
4	Creativity in linking robotics to cross-disciplinary science concepts	1.12	0.43
5	Competence in assessing student learning through robotics projects	1.44	0.67

Table 3 highlights severe deficiencies in science teachers' essential skills for integrating educational robotics, with mean scores ranging from 1.10 to 1.44 (on a 1–4 scale), reflecting minimal competency across all domains. Teachers reported critically low proficiency in basic programming languages (Item 1: M = 1.10, SD = 0.25), designing inquiry-based robotics activities (Item 2: M = 1.11, SD = 0.21), and troubleshooting technical issues (Item 3: M = 1.10, SD = 0.18), indicating a lack of foundational technical and pedagogical skills. Creativity in cross-disciplinary robotics integration (Item 4: M = 1.12, SD = 0.43) and competence in assessing student learning through robotics (Item 5: M = 1.44, SD = 0.67) were marginally higher but still fell far below acceptable thresholds. The uniformly low standard deviations (≤0.67) suggest minimal variability in responses, revealing systemic gaps in robotics-related skills among teachers. These findings emphasize the urgent need for comprehensive professional development programs to address technical, pedagogical, and evaluative competencies, ensuring teachers can effectively harness robotics to enhance science education.

Research Question 4: To what extent is educational robotics currently integrated into science teaching practices in Nigerian unity secondary schools?

Table 4: Educational Robotics Integration in Science Teaching Practices Evaluation Scale

Sno.	Item	Mean	Standard Deviation
1	I use robotics kits to demonstrate scientific concepts (e.g., motion, energy)	1.31	0.65
2	Robotics activities are included in my lesson plans for science classes	1.01	0.22
3	Students engage in hands-on robotics projects during science lessons	1.20	0.41
4	Robotics integration aligns with the termly syllabus objectives	1.01	0.28
5	My school provides adequate resources for robotics-based science instruction	1.01	0.31

Table 4 demonstrates a low level of robotics integration within science instruction. All mean values, ranging from 1.01 to 1.31 on a scale of 1 to 4, indicate infrequent use of robotics in the classroom. Specifically, robotics kits are rarely used to demonstrate scientific concepts (mean = 1.31), robotics activities are seldom included in lesson plans (mean = 1.01), and students infrequently participate in hands-on robotics projects (mean = 1.20). Furthermore, robotics integration is not aligned with termly syllabus objectives (mean = 1.01), and schools lack adequate resources to support robotics-based science instruction (mean = 1.01). The small standard deviations (ranging from 0.22 to 0.65) suggest a high degree of consensus among respondents regarding this limited integration. Clearly, significant improvements are needed in planning, resource allocation, and aligning robotics with science education objectives. ~

Research Question 5: What are the major challenges faced by science teachers in incorporating educational robotics into their teaching?

Table 5: Challenges in Educational Robotics Integration Scale

Sno.	Item	Mean	Standard Deviation
1	Limited access to robotics kits and tools hinders integration	3.21	0.33
2	Insufficient training opportunities for robotics pedagogy	3.45	0.27
3	Time constraints limit preparation for robotics-based lessons	3.01	0.53
4	Lack of technical support for maintaining robotics equipment	1.40	0.72
5	Inadequate curriculum guidelines for robotics in science education	3.81	0.23

Table 5 reveals several perceived challenges to robotics integration in science education. While access to robotics kits and tools (mean = 3.21), insufficient training opportunities for robotics pedagogy (mean = 3.45), and time constraints limiting lesson preparation (mean = 3.01) are identified as moderate to high hindrances, with teachers expressing considerable concern, inadequate curriculum guidelines for robotics in science education are perceived as a particularly significant obstacle (mean = 3.81). Conversely, the lack of technical support for maintaining robotics equipment is perceived as a less substantial, though still notable, challenge (mean = 1.40). The relatively small standard deviations across most items suggest a high degree of agreement among respondents regarding these challenges.

Research Question 6: What strategies can be recommended to improve science teachers' capacity for integrating educational robotics into their teaching practices?

To address this research question, an open-ended qualitative question for focus group including:

1. What type of training programs would best improve teachers' robotics skills?
2. How can schools address the shortage of robotics resources in science classes?
3. What institutional policies could support effective robotics integration?
4. How can collaboration among science teachers enhance robotics adoption?
5. What incentives would motivate teachers to adopt robotics in their teaching?

Table 6: What type of training programs would best improve teachers' robotics skills?

Sno.	Item	Freq	Percentage
1	Hands-On Technical Workshops	162	87.1
2	Curriculum Integration and Lesson Planning Workshops	18	9.7
3	Pedagogical Strategies and Classroom Management Training	44	23.7
4	Interdisciplinary Collaboration Workshops	26	14.0
5	Online Courses and Webinars on Emerging Robotics Trends	73	39.2

Table 6 indicated that hands-on technical workshops are strongly preferred by teachers (87.1%) as the most effective training program to improve their robotics skills. While other options are also valued, they are considerably less popular. Pedagogical strategies and classroom management training related to robotics (23.7%) and online courses and webinars on emerging robotics trends (39.2%) are seen as helpful by a notable portion of teachers. Curriculum integration and lesson planning workshops (9.7%) and interdisciplinary collaboration workshops (14.0%) are identified as beneficial by smaller percentages of respondents. This data strongly suggests that practical, hands-on experience with the technical aspects of robotics is considered the most critical training need.

Table 7: How can schools address the shortage of robotics resources in science classes?

Sno.	Item	Freq	Percentage
1	Seeking external funding	174	93.5
2	Forming partnerships	112	60.2
3	Resource sharing	32	17.2
4	Utilizing low-cost and open-source solutions	65	34.9
5	Investing in teacher training	181	97.3

To address the shortage of robotics resources in science classes, according to Table 7, schools should prioritize two key strategies: investing in teacher training (97.3%) and seeking external funding (93.5%). These are strongly identified as the most crucial approaches. Forming partnerships (60.2%) is also seen as a valuable strategy by a substantial portion of respondents. While utilizing low-cost and open-source solutions (34.9%) and resource sharing (17.2%) are suggested, they are considered less critical compared to the other options. This result indicates that securing funding and ensuring teachers are adequately trained to utilize robotics resources are perceived as the most effective ways to address the resource shortage.

Table 8: What institutional policies could support effective robotics integration?

Sno.	Item	Freq	Percentage
1	Curriculum integration policy	178	95.7
2	Professional development policy	184	98.9
3	Resource allocation policy	173	93.0
4	Technology infrastructure policy	179	96.2
5	Partnership and collaboration policy	132	71.0

Table 8 reveals that several institutional policies are identified as crucial for supporting effective robotics integration. Professional development policy (98.9%) and technology infrastructure policy (96.2%) emerge as particularly vital, with near-unanimous agreement on their importance. Curriculum integration policy (95.7%) and resource allocation policy (93.0%) are also seen as essential by a large majority of respondents. While still considered valuable, partnership and collaboration policy (71.0%) receives somewhat less emphasis compared to the other policy areas. This result suggests that prioritizing professional development, robust technology infrastructure, curriculum alignment, and adequate resource allocation are key to successful robotics integration.

Table 9: How can collaboration among science teachers enhance robotics adoption?

Sno.	Item	Freq	Percentage

1	Sharing best practices	186	100.0
2	Pooling resources	32	17.2
3	Professional development	11	5.9
4	Interdisciplinary integration	148	79.6
5	Supportive network	164	88.2

Table 9 shows that collaboration among science teachers can significantly enhance robotics adoption, primarily through sharing best practices (100%) and fostering a supportive network (88.2%). Interdisciplinary integration (79.6%) is also seen as a valuable benefit of collaboration. While pooling resources (17.2%) is identified as a potential advantage, it is considered less crucial compared to the other options. Professional development (5.9%), while important in general, is not perceived as a primary outcome of teacher collaboration in the context of robotics adoption. This result strongly suggests that creating opportunities for teachers to share expertise and build supportive relationships are key to maximizing the benefits of collaboration for robotics integration.

Table 10: What incentives would motivate teachers to adopt robotics in their teaching?

Sno.	Item	Freq	Percentage
1	Professional development and certification	91	48.9
2	Financial rewards and grants	186	100.0
3	Access to quality resources	56	30.1
4	Recognition and career advancement opportunities	22	11.8
5	Enhanced student engagement and outcomes	7	3.8

Table 10 indicate that financial rewards and grants are overwhelmingly the most significant motivator for teachers to adopt robotics in their teaching (100%). Professional development and certification (48.9%) and access to quality resources (30.1%) are also identified as important incentives, though considerably less so than financial rewards. Recognition and career advancement opportunities (11.8%) and enhanced student engagement and outcomes (3.8%) are seen as motivators by a smaller percentage of teachers. This result clearly indicates that financial incentives are the primary driver for robotics adoption, followed by opportunities for professional growth and access to necessary resources.

Discussion

This study reveals significant competency gaps among science teachers, hindering the effective integration of educational robotics in Nigerian Unity Secondary Schools. The findings indicate that teachers generally lack formal training in robotics, possess limited technical proficiency, and are underprepared pedagogically to incorporate robotics into science lessons. For example, teachers report minimal confidence in operating and troubleshooting robotics kits, and their pedagogical training appears insufficient for aligning robotics activities with the national science curriculum. These findings align with Rao and Jalil (2021), who found that insufficient training and technical skills leave teachers unprepared to teach robotics. Similarly, Chootongchai et al. (2021) observed that educators often perceive robotics instruction as burdensome due to gaps in technical proficiency and confidence. Additionally, Coşkunserçe (2021) emphasizes that the absence of a systemic plan and institutional support further complicates the pedagogical integration of robotics, indicating the need for structured professional development and curriculum alignment.

Teachers exhibited only a foundational understanding of robotics principles, with notably low familiarity with common robotics platforms and limited confidence in teaching robotics-related concepts. As a result, classroom integration remains minimal—robotics kits are seldom utilized, and few lesson plans incorporate robotics activities. Jurado et al. (2020) attribute this gap to insufficient professional development, varying educational backgrounds, and the lack of structured robotics integration into curricula. Given these disparities in teacher knowledge and confidence, targeted training programs and deliberate curriculum alignment are critical for effective robotics education. Research supports this approach, demonstrating that intensive workshops can significantly enhance educators' robotics knowledge, programming skills, and self-efficacy (Rao and Jalil, 2021).

This study identifies key challenges hindering robotics integration in science education, including insufficient teacher training, limited access to robotics resources, and—most critically—a lack of clear curriculum guidelines for implementation. While time constraints pose a moderate barrier, the absence of technical support for equipment maintenance is perceived as less significant. These findings align with prior research. Carruth and Bethel (2017) highlight technical hurdles such as the lack of standardization and interoperability among robotics systems, which complicate large-scale adoption. Similarly, Pal (2024) emphasizes financial barriers, noting that high acquisition and maintenance costs—along with the expense of training personnel—often deter institutional investment. Additionally, the gap between simulation and real-world application, as well as reproducibility challenges, limits the utility of robotics simulators in educational settings (Carruth &

Bethel, 2017). Collectively, these obstacles span technical, economic, and operational dimensions. Addressing them is essential to developing actionable strategies for effective robotics integration in science education.

To address these challenges, this study recommends several strategic interventions. Teachers strongly prefer hands-on technical workshops to enhance their robotics skills. Furthermore, increased investment in teacher training and securing external funding are strongly advocated to improve resource availability. Crucially, institutional policies focused on professional development, technology infrastructure, curriculum integration, and resource allocation are essential for supporting effective robotics integration. Finally, fostering collaboration among science teachers through best practice sharing and supportive networks, coupled with financial incentives, could further motivate robotics adoption and integration. As found by Chalmers (2017), teachers strongly prefer hands-on technical workshops to enhance their robotics skills, as these workshops provide practical experience and build confidence in implementing robotics-based activities. The constructionist approach, which emphasizes learning through doing, is particularly effective in professional development for teachers. This method not only improves teachers' technical skills but also equips them with strategies to engage students in robotics activities. However, Chen & Faulkner (2014) reported that programs like BOTS provide ongoing support and professional development, allowing teachers to adapt and develop their own robotics activities, thereby increasing their self-efficacy in teaching robotics

These findings highlight the urgent need for systemic changes in teacher training and resource allocation to bridge the gap between policy goals and classroom realities. Such changes are essential to ensuring that educational robotics can realize its full potential to enhance STEM education in Nigeria. While these challenges are significant, they also present opportunities for innovation and improvement. Addressing these barriers requires a collaborative approach involving stakeholders from various sectors to develop standardized solutions, enhance training programs, and create supportive regulatory frameworks.

Conclusion

This study identifies critical deficiencies in science teacher competencies and preparedness for integrating educational robotics within Nigerian Unity

Secondary Schools, and proposes a roadmap for transformative improvements. The research demonstrates that teachers report significant deficits in formal robotics training, limited technical proficiency, and insufficient pedagogical strategies for effectively incorporating robotics into science curricula. The minimal classroom utilization of robotics indicates the disparity between its potential to enhance STEM education and current instructional practices. These challenges are exacerbated by inadequate training opportunities, restricted access to robotics resources, and a lack of clear curriculum guidelines. However, the findings also suggest promising solutions. Teachers express a strong preference for hands-on technical workshops, and financial incentives are identified as a key motivator for robotics adoption. Therefore, targeted professional development initiatives, improved resource allocation, and supportive institutional policies are imperative. Implementing these recommendations will enhance teacher competencies, promote innovative instructional practices, and ultimately improve student engagement and learning outcomes in science education throughout Nigeria. Future research should investigate the longitudinal impact of these interventions to ensure sustained improvement and equitable access to educational robotics for all science teachers.

Limitations of the study

The study has several limitations. First, its scope is confined to Nigerian Unity Secondary Schools, which may limit the generalizability of the findings to other educational contexts or regions. The sample size, though determined through power analysis, is relatively small and based primarily on self-reported data, which could introduce bias and affect the accuracy of the results. Moreover, the cross-sectional design offers only a snapshot of teacher competencies and challenges at a single point in time, thereby failing to capture how these factors may evolve with ongoing professional development or changes in educational policy.

Additionally, while the mixed-methods approach enriches the study, the qualitative component involved a very limited number of participants in the focus groups, potentially overlooking diverse perspectives among science teachers. The measurement tool (STQEIERQ), although adapted and validated by experts, might not fully capture the complex interplay of skills, attitudes, and institutional factors that influence the integration of educational robotics. Finally, external factors such as infrastructural support and broader policy implications were only partially explored, suggesting that there may be other critical variables affecting robotics integration that were not addressed.

Recommendation

For further study, researchers should consider a longitudinal design to assess the long-term impact of targeted interventions on teacher competencies. Expanding the sample to include various school types and regions could enhance generalizability. Future research might also integrate classroom observations and student performance metrics to provide a more comprehensive evaluation of educational robotics integration. Finally, refining the assessment tools and exploring additional contextual and institutional factors would help to better understand and address the barriers to effective robotics integration in science education.

Reference

Alekhuogie, N. (2021, June). Nigerian Students Shine at Robotics Challenge. *Thisdaylive*, 1–2. https://www.thisdaylive.com/index.php/2021/06/17/nigerian-students-shine-at-robotics-challenge/

Bellanaija. (2017, July). The Teens who made Nigeria proud at the First Global Robot Olympics. *BellaNaija.Com*, 7–10. https://www.bellanaija.com/2017/07/nigerians-first-global-challenge-2017/

Bikar, S. S., Sharif, S., Rathakrishnan, B., & Talin, R. (2020). Students' Perceptions about the Use of Minimalist Robotic Games in Geography Education. *Review of International Geographical Education Online*, *10*(4), 584–595. https://doi.org/10.33403/rigeo.739383

Braun, J. von, Archer, M. S., Reichberg, G. M., & Sorondo, M. S. (2021). Robotics, AI, and Humanity: Science, Ethics, and Policy. In *Robotics, AI, and Humanity*. Springer. https://doi.org/10.1007/978-3-030-54173-6_19

Carruth, D. W., & Bethel, C. L. (2017). Challenges with the integration of robotics into tactical team operations. In 2017 IEEE 15th International

Symposium on Applied Machine Intelligence and Informatics (SAMI) (pp. 000027-000032). IEEE.

Chalmers, C. (2017). Preparing teachers to teach STEM through robotics. *International Journal of Innovation in Science and Mathematics Education*, *25*(4), 17.

Chen, Y., & Faulkner, G. (2014). Robotics Education in Primary Schools : a Tasmanian Case. *In 25th Annual Conference of the Australasian Association for Engineering Education: Engineering the Knowledge Economy: Collaboration, Engagement & Employability: Collaboration, Engagement & Employability (Pp. 21-29). Barton, ACT: School of Engineering & .*

Chootongchai, S., Songkram, N., & Piromsopa, K. (2021). Dimensions of robotic education quality: teachers' perspectives as teaching assistants in Thai elementary schools. *Education and Information Technologies*, *26*(2), 1387–1407. https://doi.org/10.1007/s10639-019-10041-1

Coronado, E., Mastrogiovanni, F., Indurkhya, B., & Venture, G. (2020). Visual Programming Environments for End-User Development of intelligent and social robots , a systematic review. *Journal of Computer Languages*, *58*, 100970. https://doi.org/10.1016/j.cola.2020.100970

Coşkunserçe, O. (2021). Implementing teacher-centered robotics activities in science lessons: The effect on motivation, satisfaction and science skills. *Journal of Pedagogical Research*, *5*(1), 50–64. https://doi.org/10.33902/JPR.2021067231

Fidan, M., & Debbag, M. (2021). Metaphoric perceptions of pre- service teachers about' LEGO Robotic Instructional Practices,' ' Augmented Reality' and' Flipped Classroom' concepts. *Research in Comparative & International Education*, *16*(1), 83 –99. https://doi.org/10.1177/1745499920982761

Gottsegen, G. (2021). *Classroom robots are infiltraing the education industry, but teachers are safe - for now*. Built In. https://builtin.com/robotics/robotics-in-the-classroom

Id, P., Jones, A., Engineering, S., Ph, S. E., Straub, J., Education, C. S., & Science, C. (2019). Robotic Competition Teams : Assessing the Experiential Education Value of Participation. *2019 ASEE Annual Conference & Exposition*, 1–14.

Jurado, E., Fonseca, D., Coderch, J., & Canaleta, X. (2020). Social steam learning at an early age with robotic platforms: A case study in four schools in Spain. *Sensors (Switzerland)*, *20*(13), 1–23. https://doi.org/10.3390/s20133698

Karalekas, G., Vologiannidis, S., & Kalomiros, J. (2020). EUROPA: A Case Study for Teaching Sensors, Data Acquisition and Robotics via a ROS-Based Educational Robot. *Sensors*, *20*(9), 1–8.

Myhill, R. (2020). *What is STEM education?* LIYSF. https://doi.org/10.1126/science.1194998

NAN. (2018). Nigerian students soar at World Adolescent Robotics competition. In *News Agency of Nigeria*. https://youtu.be/Fynjxqaf4xo

Niyi, F. (2021). *Nigerian students apply research, robotics in FIRST LEGO League challenge*. Coderina EdTech. https://coderina.org/nigerian-students-apply-research-robotics-in-first-lego-league-challenge/

Pal, H. H. (2024). Advancements and limitations in integrating robotics into medicine: A comprehensive review. *Multidisciplinary Reviews*, *7*(11). https://doi.org/10.31893/multirev.2024248

Rao, L. N., & Jalil, H. A. (2021). A Survey on Acceptance and Readiness to Use Robot Teaching Technology Among Primary School Science Teachers. *Asian Social Science*, *17*(11), 115. https://doi.org/10.5539/ass.v17n11p115

Roush, M. (2019). *Team from Ghana wins Robofest at Lawrence Tech*. TechCentury. https://www.techcentury.com/2019/05/20/team-from-ghana-wins-robofest-at-lawrence-tech/

Smakman, M. H. J., Konijn, E. A., & Vogt, P. A. (2022). Do Robotic Tutor Comprimise the Social-Emotional Development of Children. *Frontiers in Robotics and AI*, *9*, 1–12. https://doi.org/10.3389/frobt.2022.734955

Souza, I. M. L., Andrade, W. L., Sampaio, L. M. R., & Araujo, A. L. S. O. (2018). A Systematic Review on the use of LEGO Robotics in Education. *IEEE Frontiers in Education Conference (FIE)*, 1–9.

Takacs, A., Eigner, G., Kovács, L., Rudas, I. J., & Haidegger, T. (2013). Development, Usability and Communities of Modular Robotic Kits for Classroom Education. *IEEE Robotics & Automation Magazine*, *23*(2), 30–39.

Vanguard. (2019, July). Five students to represent Nigeria at Global Robotics Olympics. *Vanguard*, 1–3. https://www.vanguardngr.com/2019/07/five-students-to-represent-nigeria-at-global-robotics-olympics/

Wilson, S., Gameros, R., Sheely, M., Lin, M., Dover, K., Gevorkyan, R., Haberland, M., Bertozzi, A., & Berman, S. (2016). Pheeno, A Versatile Swarm Robotic Research and Education Platform. *IEEE Robotics and Automation Letters*, *1*(2), 884–891. https://doi.org/10.1109/LRA.2016.2524987