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Libraries as Catalysts for STEM Engagement: A Strategy for Uganda's Educational Transformation

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Abstract: *This study investigated the role of libraries as catalysts for Science, Technology, Engineering, and Mathematics (STEM) engagement and examined their potential contribution to educational transformation in Uganda. The study was conducted against the backdrop of increasing national demand for scientific literacy, technological innovation, and a skilled workforce capable of supporting sustainable socio-economic development. Despite the growing importance of STEM education, many Ugandan students continued to face challenges related to inadequate access to learning resources, limited technological infrastructure, and insufficient opportunities for practical scientific exploration. Consequently, the study sought to establish how libraries could serve as alternative and complementary learning environments that enhanced STEM learning experiences and promoted student engagement. A quantitative cross-sectional research design was adopted to collect and analyze data from 400 respondents drawn from public and private secondary schools across selected districts in Uganda. Respondents were selected using a stratified random sampling technique to ensure adequate representation of different educational settings and demographic characteristics. Data were collected using structured questionnaires that measured perceptions of library infrastructure, availability of digital resources, librarian technical expertise, and student engagement in STEM-related activities. The collected data were analyzed using a combination of univariate descriptive statistics, bivariate correlation analysis, and Structural Equation Modeling (SEM) to establish relationships among the study variables and validate the proposed conceptual framework. The findings revealed that the quality and availability of library infrastructure significantly influenced students' interest and participation in STEM disciplines. Libraries that possessed modern technological facilities, reliable internet connectivity, and diverse STEM learning materials were associated with higher levels of student motivation, curiosity, and academic engagement. The study further established a strong positive correlation between library infrastructure quality and STEM interest, indicating that improvements in physical and digital learning environments contributed substantially to enhanced educational outcomes. Additionally, the results demonstrated that librarian technical expertise played a critical role in shaping students' learning experiences. Libraries staffed by technically competent and STEM-literate personnel recorded significantly higher levels of student engagement, suggesting that knowledgeable librarians served as effective facilitators of scientific inquiry and problem-solving skills development. The Structural Equation Model confirmed the existence of significant causal relationships among the key study variables and demonstrated an acceptable level of model fit. The findings provided empirical evidence that investments in digital resources, technological infrastructure, and librarian professional development collectively contributed to improved STEM engagement and proficiency among learners. The study therefore concluded that libraries represented a largely underutilized but highly strategic educational resource capable of supporting Uganda's broader goals of scientific advancement and technological development. Based on these findings, the study recommended increased government investment in modernizing library infrastructure, expanding access to digital learning technologies, and strengthening continuous professional development programs for librarians. It was further recommended that educational stakeholders establish strategic partnerships with technology firms, academic institutions, and development organizations to enhance the capacity of libraries to serve as innovative STEM learning centers. The study ultimately demonstrated that transforming libraries into dynamic, technology-driven educational hubs had the potential to significantly improve STEM participation, strengthen scientific literacy, and contribute to Uganda's long-term educational and economic transformation.*

Keywords: Libraries, STEM Education, Student Engagement, Digital Resources, Librarian Expertise, Educational Transformation, Uganda, Structural Equation Modeling.

Introduction

In the contemporary era of rapid technological advancement, the global shift toward knowledge-based economies necessitates a foundational and deeply rooted commitment to Science, Technology, Engineering, and Mathematics (STEM) education to ensure national competitiveness and societal progress. Within the Ugandan context, the national aspiration to attain middle-income status is heavily predicated upon the development of a scientifically literate, innovative, and technically adept youth population capable of navigating complex global challenges (Darussyamsu et al., 2021; Iffath Unnisa Begum, 2024; Veselinović et al., 2020). Traditionally viewed merely as passive repositories for literary and historical texts, libraries are currently experiencing a pivotal evolution, emerging as dynamic, multifunctional hubs for digital learning, information navigation, and community-driven innovation. This study explores the critical imperative of transforming these Ugandan library spaces into active, experiential STEM learning environments, positing that such a transformation serves as a potent, scalable strategy to effectively bridge the persistent gap between theoretical knowledge acquisition and the practical, experimental application required for meaningful scientific advancement (Abelha et al., 2020; Deepa et al., 2022; Ralston, 2021; Tulibaleka, 2022). Furthermore, the deliberate, strategic introduction of

STEM-centric library services addresses the critical, long-standing need for equitable, widespread access to educational resources, particularly in underserved rural and peri-urban communities where school laboratory facilities are often nonexistent or severely dilapidated. By systematically integrating advanced Information and Communication Technology (ICT) tools, specialized laboratory kits, and structured mentorship programs into the existing library framework, these institutions have the potential to bridge the widening digital divide that currently hampers academic progress and innovation in many regions of the country (Marsh & Johnson, 2020; Rivaldo & Nabella, 2023; Schön et al., 2023). This research provides a exhaustive, multidimensional analysis of the current state of Ugandan library infrastructure, identifying actionable, evidence-based pathways for leveraging these spaces to ignite intellectual curiosity, bolster critical thinking, and sustain long-term engagement with STEM fields, thereby contributing substantively and effectively to the broader national educational reform agenda and the long-term vision of scientific prosperity (Chatterjee & Bhattacharjee, 2020; Joyce Ayikoru Asiimwe, 2021; Makumbi et al., 2025).

Background of the Study

The education sector in Uganda has historically grappled with profound and systemic challenges regarding the equitable allocation of resources, the provision of comprehensive teacher training, and the universal access to modern, technologically advanced teaching aids, especially within the critical STEM disciplines (Chaaban et al., 2025; Julius & Audrey, 2026; Julius & Gracious Kaazara, 2025a). Although the national curriculum explicitly emphasizes the necessity of scientific progress and technical competency, the practical implementation phase consistently faces significant hurdles stemming from inadequate school laboratory facilities, insufficient funding for technical equipment, and limited access to current, peer-reviewed scientific reference materials (Bhargava et al., 2018; Julius et al., 2026; Julius & Milly, 2025). Consequently, the library system in Uganda has largely remained in a state of stasis, predominantly focusing on traditional, humanities-oriented literary pursuits rather than facilitating the complex, equipment-dependent nature of modern scientific inquiry and experimentation. This historical underinvestment has widened the disconnect between the ambitious objectives outlined in the national curriculum and the actual, day-to-day experimental experiences of students, leading to a general decline in practical engagement with science-based subjects (Bozkurt et al., 2021; Julius & Kazaara, 2025; Ssegantebuka, 2019).

In recent years, the accelerating global digital revolution has necessitated a fundamental reevaluation of educational infrastructure, with libraries increasingly recognized as essential, non-traditional players in the provision of community-based STEM support and technical capacity building (Ministry of Education and Sports (MoES), 2019; THE EARLY CHILDHOOD CARE AND EDUCATION POLICY, 2018). In Uganda, while there is a growing, nascent awareness of the need to modernize these facilities, the current movement lacks the systematic, empirical research required to guide evidence-based policy decisions and effective resource allocation. This background underscores the absolute necessity of integrating libraries into the broader national STEM policy framework, ensuring that these institutions successfully transition from their current status as passive storage sites into active, vibrant hubs that systematically

Problem Statement

Despite the widely acknowledged and critical importance of STEM education for driving long-term national economic development and technological competitiveness, students in Uganda frequently demonstrate persistently low levels of engagement and proficiency in science-related subjects, a trend largely attributable to the acute lack of interactive, inquiry based learning environments and restricted access to necessary innovative technological tools (Faridah et al., 2023; John et al., 2023; Kazaara, 2023; Kibuuka, 2022; Qahmash et al., 2023). Traditional school-based settings, which are often constrained by overcrowded classrooms and a lack of laboratory space, frequently fail to provide the practical, exploratory, and experimental exposure that is fundamentally necessary to inspire a deep, lasting engagement with the complexities of STEM fields. Furthermore, existing library infrastructures, which hold immense potential as decentralized centers of learning, remain significantly underutilized, continuing to function as book archives rather than active sites of scientific discovery and technical skill development (Ariyo, Kazaara, Audrey, et al., 2024; Dr. Ariyo Gracious Kazaara & Musiimenta Nancy, 2025; Victoria et al., 2023).

This research specifically addresses the critical failure of the current educational model to leverage community-based, school, and public libraries as viable, accessible platforms for substantive STEM enrichment and technological skill-building. If these underutilized institutions continue to operate solely as passive repositories for printed media, the country faces a substantial risk of further stagnation in the realms of scientific innovation, industrial development, and human capital formation in technical sectors (Ariyo, Kazaara, Julius, et al., 2024; Gracious Kaazara & Audrey, 2025; Julius & Gracious Kaazara, 2025b). There is a pressing, urgent need to empirically evaluate exactly how the transformation of these existing spaces into interactive STEM centers can directly and positively influence student engagement, as the persistent absence of such a strategic, integrated intervention significantly limits the untapped potential of Uganda's youth to contribute effectively to the demands of an increasingly complex, technologically driven global market.

Objectives and Research Questions
Main Objective

To comprehensively investigate the role of libraries as catalysts for STEM engagement and to develop a strategic framework for Uganda's comprehensive

educational transformation.

Specific Objectives

1. To systematically examine the direct and indirect influence of physical and digital library infrastructure on the learning interest of students in STEM disciplines.
2. To assess the multidimensional effect of librarian technical expertise and pedagogical support on student engagement levels within STEM-oriented library programs
3. To evaluate the profound impact of the availability and accessibility of modern digital resources, software, and laboratory tools on the overall STEM proficiency of students.

Research Questions:

1. To what extent does the presence of modern, technologically integrated library infrastructure correlate with student interest and participation in STEMrelated activities?
2. How does the presence of technically proficient, STEM-literate librarians influence the student engagement levels and the overall quality of the learning experience?
3. What is the significant relationship between the accessibility of digital learning tools and the demonstrated improvement in student STEM proficiency and academic outcomes?

Methodology.

This research employed a rigorous, quantitative, cross-sectional research design, which was meticulously chosen to establish the precise nature and strength of the relationship between modernized library services and heightened STEM engagement among secondary school students. Data were systematically collected through the administration of highly structured, validated questionnaires distributed to a total of 400 respondents, who were carefully selected using a stratified random sampling technique from a diverse range of both public and private secondary schools located across five representative Ugandan districts. To ensure a comprehensive analysis of the collected data, the study utilized a tiered statistical approach: univariate analysis was employed to summarize the demographic characteristics and baseline perceptions of the respondents; bivariate analysis, specifically Pearson correlation coefficients, was utilized to examine the initial strength and direction of the relationships between the independent and dependent variables; and advanced Structural Equation Modeling (SEM) was performed to rigorously confirm the causal pathways, evaluate the fitness of the proposed conceptual framework, and account for potential mediating variables (Nelson et al., 2022, 2023). The data were processed using professional-grade statistical software, ensuring that the results were robust, statistically significant, and provided a highly reliable representation of the actual impact of library transformation on STEM interest in the Ugandan educational context.

Results and Discussion

Table 1: Descriptive Statistics of Library Infrastructure Components

Infrastructure Component	Mean Score (1-5)	Std. Deviation
Digital Laboratory Availability	3.24	0.85
Internet Connectivity Speed	2.78	1.12
Variety of STEM Resource Materials	3.52	0.74

The findings presented in Table 1 revealed varying levels of adequacy regarding the availability of library infrastructure components that supported STEM learning activities. The variety of STEM resource materials recorded the highest mean score ($M = 3.52$, $SD = 0.74$), indicating that respondents generally perceived their libraries as having a relatively satisfactory collection of STEM-related

books, reference materials, and learning resources. This finding suggested that considerable efforts had been made to provide learners with access to educational materials that could support scientific inquiry and academic development. The relatively low standard deviation further implied consistency in respondents' perceptions regarding the availability of these resources across the surveyed libraries.

The availability of digital laboratories recorded a moderate mean score of 3.24 (SD = 0.85), indicating that although some libraries had begun integrating technological facilities into their service delivery, access to digital laboratory resources remained limited in many institutions. This finding implied that students were not consistently exposed to practical digital tools that could facilitate experimentation, simulations, and hands-on STEM learning experiences. The moderate variability observed among respondents further suggested disparities in infrastructure provision across different schools and library settings. Internet connectivity speed recorded the lowest mean score (M = 2.78, SD = 1.12), reflecting considerable dissatisfaction among respondents regarding the quality and reliability of internet services available in libraries. This finding indicated that many students experienced challenges in accessing online educational platforms, scientific databases, virtual laboratories, and other digital resources necessary for effective STEM learning. The relatively high standard deviation suggested substantial differences in internet accessibility across the sampled libraries, highlighting inequalities in technological infrastructure. Overall, the findings demonstrated that although foundational STEM resources were available in many libraries, technological limitations continued to constrain the full realization of libraries as modern centers for STEM education and innovation.**Table 2: Bivariate Correlation Analysis between Infrastructure and Interest**

Variables	STEM Interest	Infrastructure Quality
STEM Interest	1.00	0.68**
Infrastructure Quality	0.68**	1.00

The results presented in Table 2 demonstrated a strong and statistically significant positive relationship between library infrastructure quality and students' interest in STEM disciplines ($r = 0.68$, $p < 0.01$). The correlation coefficient indicated that improvements in library infrastructure were associated with corresponding increases in students' enthusiasm, participation, and commitment to STEM-related learning activities. The strength of the relationship suggested that infrastructure quality constituted a major determinant of student engagement within library-based STEM programs. The findings implied that libraries equipped with modern facilities, adequate digital resources, reliable internet connectivity, and conducive learning environments were more effective in stimulating students' curiosity and interest in science and technology-related subjects. Students who had access to well-resourced libraries were more likely to explore scientific concepts independently, participate in STEM activities, and develop positive attitudes toward scientific learning. Conversely, inadequate infrastructure appeared to limit opportunities for experiential learning and reduced the attractiveness of STEM disciplines among learners. The statistically significant relationship further demonstrated that library modernization initiatives could serve as effective interventions for increasing STEM participation among students. The results supported educational theories emphasizing the importance of learning environments in shaping academic motivation and engagement. Therefore, the findings suggested that strategic investments in library infrastructure could contribute significantly to improving STEM education outcomes and fostering a stronger culture of scientific inquiry among Ugandan students.

Table 3: Impact of Librarian Technical Expertise on Engagement

Structural Path	Path Coefficient (β)	p-value
Expertise -> Student Engagement	0.45	0.001

The results of the Structural Equation Model presented in Table 3 revealed that librarian technical expertise exerted a significant positive influence on student engagement in STEM activities ($\beta = 0.45$, $p = 0.001$). The positive path coefficient indicated that increases in the technical competence and pedagogical skills of librarians were associated with higher levels of student participation, interest, and involvement in STEM learning programs. The highly significant p-value confirmed that this relationship was statistically reliable and unlikely to have occurred by chance.

These findings suggested that librarians played a critical role beyond their traditional responsibility of managing information resources. Librarians who possessed strong STEM knowledge and technical skills were better positioned to guide students in accessing digital resources, conducting research, utilizing technological tools, and developing problem-solving capabilities. Their expertise enabled them to facilitate meaningful learning experiences that encouraged active participation and intellectual curiosity among learners.

The findings further indicated that the effectiveness of library-based STEM initiatives depended not only on the availability of physical and digital resources but also on the quality of human support provided within the library environment. Students appeared more likely to engage with STEM resources when librarians offered mentorship, technical assistance, and instructional guidance. Consequently, the study demonstrated that investments in professional development and STEM-related training for librarians could yield substantial benefits in enhancing student engagement and learning outcomes. The results emphasized the importance of strengthening librarian capacity as a strategic component of efforts aimed at transforming libraries into dynamic centers for STEM education and innovation in Uganda.

Table 4: Summary of Structural Equation Model (SEM) Fit Indices

Fit Index	**Resulting Value**	**Recommended Threshold**
Chi-Square/df (CMIN/DF)	2.15	< 3.0
Comparative Fit Index (CFI)	0.94	> 0.90
Root Mean Square Error of Approximation (RMSEA)	0.06	< 0.08

The results presented in Table 4 demonstrated that the proposed Structural Equation Model provided an acceptable and statistically sound representation of the relationships among library infrastructure, librarian technical expertise, digital resource accessibility, and student STEM engagement. The model fit indices were evaluated against internationally accepted thresholds to determine the extent to which the theoretical framework aligned with the observed data collected from respondents. The Chi-Square to Degrees of Freedom ratio (CMIN/DF) was reported as 2.15, which fell below the recommended threshold of 3.0. This finding indicated that the discrepancy between the observed covariance matrix and the covariance matrix predicted by the model was relatively small. Consequently, the model was considered to have achieved an acceptable level of fit, suggesting that the hypothesized relationships among the study variables adequately reflected the actual patterns observed in the data. The Comparative Fit Index (CFI) recorded a value of 0.94, which exceeded the recommended minimum threshold of 0.90. This result indicated that the proposed model provided a substantially better fit to the data compared to a null model in which no relationships existed among the variables. The high CFI value suggested that the conceptual framework successfully captured the underlying relationships between library transformation factors and STEM engagement outcomes. Furthermore, the result demonstrated that the inclusion of infrastructure quality, librarian expertise, and digital resource accessibility significantly improved the explanatory power of the model. Similarly, the Root Mean Square Error of Approximation (RMSEA) was reported as 0.06, which was below the recommended maximum value of 0.08. This finding indicated that the model exhibited a low level of approximation error and adequately represented the population covariance structure. The RMSEA value suggested that the model achieved a close fit to the data and that the estimated relationships among the latent constructs were both reliable and valid. Collectively, the fit indices provided strong empirical evidence that the Structural Equation Model was statistically robust and theoretically appropriate for explaining STEM engagement within the library context. The results confirmed that the proposed conceptual framework accurately represented the complex interactions among infrastructural resources, librarian competencies, and student learning outcomes. The satisfactory model fit further strengthened the credibility of the study findings and supported the conclusion that investments in modern library infrastructure and human resource capacity development could significantly enhance STEM engagement among students in Uganda. Therefore, the SEM results provided a solid foundation for policy recommendations aimed at transforming libraries into dynamic centers for scientific learning, technological innovation, and educational advancement.

Conclusion.

This study comprehensively examined the role of libraries as catalysts for STEM engagement and their potential contribution to educational transformation in Uganda. The findings demonstrated that libraries possessed significant untapped potential to serve as effective platforms for promoting scientific literacy, technological competence, and student participation in STEM-related learning activities. Through the analysis of library infrastructure, digital resource accessibility, and librarian technical expertise, the study established that libraries could play a crucial role in complementing formal classroom instruction and addressing existing challenges associated with limited access to quality STEM learning opportunities. The results revealed that modern and well-equipped library infrastructure significantly influenced students' interest in STEM disciplines. Libraries that provided access to digital laboratories, diverse STEM learning materials, and reliable internet connectivity were associated with higher levels of student motivation, curiosity, and academic engagement. These findings highlighted the importance of creating conducive learning environments that

encourage exploration, innovation, and independent knowledge acquisition. The study further established a strong positive relationship between infrastructure quality and STEM interest, emphasizing that investments in educational facilities remain fundamental to improving learning outcomes and fostering scientific inquiry among students.

Furthermore, the study confirmed that librarian technical expertise significantly contributed to student engagement in STEM activities. Librarians who possessed relevant technological knowledge and pedagogical skills were more effective in supporting students' learning needs, facilitating access to educational resources, and guiding learners through scientific exploration processes. This finding underscored the importance of human capital development within library systems and demonstrated that the effectiveness of STEM-focused library services depended not only on physical resources but also on the competence and preparedness of library personnel. The Structural Equation Modeling results further validated the proposed conceptual framework and confirmed the existence of meaningful relationships among the study variables. The acceptable model fit indices provided strong empirical evidence that improvements in library infrastructure, digital resource accessibility, and librarian expertise collectively enhanced STEM engagement among students. These findings reinforced the argument that libraries should no longer be viewed solely as repositories of information but rather as dynamic educational centers capable of supporting innovation, critical thinking, and lifelong learning. Overall, the study concluded that the transformation of libraries into modern, technology-enabled STEM learning hubs represented a viable and sustainable strategy for strengthening science and technology education in Uganda. By prioritizing infrastructure development, expanding digital resource accessibility, enhancing librarian competencies, and fostering strategic partnerships, educational stakeholders could maximize the contribution of libraries toward national educational goals.

Recommendations

Infrastructural Investment

The study recommended that the Government of Uganda, through the Ministry of Education and Sports and other relevant stakeholders, should substantially increase investment in the modernization of library infrastructure to support STEM education initiatives. The findings demonstrated that the quality of library infrastructure significantly influenced students' interest and engagement in STEM disciplines. Therefore, efforts should be directed toward equipping libraries with modern digital laboratories, reliable high-speed internet connectivity, computer facilities, multimedia learning resources, and specialized STEM learning materials. Such investments would create conducive learning environments that promote experimentation, innovation, and independent scientific inquiry among learners. Furthermore, improving infrastructure across both urban and rural libraries would help reduce disparities in access to quality STEM learning resources and contribute to greater educational equity throughout the country.

Capacity Building for Librarians: The study further recommended the implementation of comprehensive and continuous professional development programs aimed at enhancing the technical competencies of librarians in STEM-related fields. The findings established that librarian expertise had a significant positive effect on student engagement, highlighting the critical role played by library personnel in facilitating meaningful learning experiences. Consequently, librarians should receive specialized training in emerging technologies, digital literacy, STEM pedagogy, information management systems, and the use of scientific learning tools. Such training would enable them to effectively guide students in accessing and utilizing STEM resources while fostering critical thinking, problem-solving skills, and scientific curiosity. Additionally, establishing professional certification programs and periodic refresher courses would ensure that librarians remain knowledgeable about advancements in science and technology, thereby enhancing the quality of support provided to library users.

Strategic Partnerships and Collaboration: The study also recommended the establishment of strong partnerships between libraries, educational institutions, government agencies, private sector organizations, and international development partners. The findings suggested that achieving sustainable library transformation would require collaborative efforts that extend beyond government funding alone. Strategic partnerships could facilitate the provision of modern technological equipment, digital learning platforms, STEM kits, internet services, and mentorship opportunities for students. Collaboration with universities, research institutions, and technology companies could further expose students to real-world scientific applications and career pathways in STEM fields. Such partnerships would strengthen the capacity of libraries to function as community-based innovation hubs and enhance their contribution to national educational development.

Expansion of Digital Resource Accessibility: The study recommended that educational stakeholders prioritize the expansion of digital resource accessibility within libraries to support contemporary learning needs. The results indicated that access to digital resources was strongly associated with improved STEM engagement and proficiency among students. Therefore, libraries should invest in electronic databases, digital textbooks, online scientific journals, virtual laboratories, and interactive learning platforms that provide learners with access to up-to-date scientific information. Expanding digital access would enable students to engage with

global knowledge networks, improve research skills, and remain informed about emerging developments in science and technology. Such initiatives would also support self-directed learning and enhance students' preparedness for participation in the digital economy.

Integration of STEM Programs into Library Services: The study further recommended the deliberate integration of structured STEM programs into routine library operations. Libraries should organize science clubs, robotics workshops, coding boot camps, innovation competitions, science exhibitions, and mentorship programs to stimulate student interest in STEM disciplines. These activities would provide practical learning opportunities that complement classroom instruction and encourage active participation in scientific exploration. By transforming libraries into vibrant centers for experiential learning, students would be able to develop hands-on skills and gain confidence in applying theoretical knowledge to real-world challenges. Such programs would contribute significantly to nurturing a culture of innovation and lifelong learning among young people.

Policy Development and Institutional Support: Finally, the study recommended the formulation and implementation of a comprehensive national policy framework that formally recognizes libraries as strategic contributors to STEM education and educational transformation. Policymakers should incorporate library development into broader national STEM and digital transformation strategies to ensure sustained support and funding. Clear policy guidelines would facilitate coordinated planning, monitoring, and evaluation of library-based STEM initiatives across the country. Furthermore, institutional support mechanisms should be established to ensure the effective implementation of modernization programs and to promote accountability in resource utilization. Such policy interventions would strengthen the role of libraries in advancing Uganda's scientific capacity, technological innovation, and long-term socio-economic development.

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