

Academic libraries as catalysts for STEM advancement in Tanzanian higher learning institutions through AI integration

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Abstract

Purpose – To examine the role of academic libraries in supporting Science, Technology, Engineering, and Mathematics (STEM) education within higher learning institutions in Tanzania, specifically through the integration of artificial intelligence (AI) technologies.

Design/methodology/approach – This research adopts an ethnographic approach, incorporating in-depth interviews and participant observation with the library and library staff at the NM-AIST in Tanzania. Data was analysed thematically. Ethical clearance was obtained to ensure participant confidentiality and informed consent throughout the research process.

Findings – The study revealed that the NM-AIST library plays a crucial role in supporting STEM education, maintaining a diverse collection that comprises resources available both online and in print. It engages with primary and secondary schools through teaching resources and STEM events. However, challenges include inadequate storage, limited librarian knowledge on AI integration, and budget constraints. Participants suggested enhancing collaboration with schools and integrating AI tools to improve outreach and support.

Research limitations/implications – Although this is a case study, it emphasises the potential of AI to transform library services in support of STEM education. This suggests that academic libraries should engage in strategic planning and invest in AI tools to improve accessibility to resources, enhance user engagement, and deliver better services.

Originality/value – This research offers original insights into the role of academic libraries in STEM education in Tanzania, specifically through the integration of AI technologies.

Keywords STEM education, Academic libraries, Ethnographic study, Educational outreach, Resources accessibility, AI technologies

Paper type Research article

Introduction

Science, technology, engineering and mathematics (STEM) education plays a crucial role in shaping the future of society and humanity. As the foundation of innovation and technological progress, STEM disciplines are not just academic subjects; they are the driving force behind economic growth, helping to address complex challenges and improve the quality of life. Academic libraries play a crucial role in enhancing STEM education in higher learning institutions (HLIs) through various initiatives, including providing access to essential STEM resources, utilising modern technologies, fostering information literacy, and creating supportive learning environments (Hossaini, 2017; Joseph and Uzundu, 2024b; Subramaniam *et al.*, 2012). They can facilitate research, teaching, and learning through various services and resources, including access to scholarly databases, e-books, print collections, and specialized software (Hossaini, 2017).



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STEM education has emerged as a global priority, with most institutions worldwide actively implementing and advocating for STEM education and research. [Gonzalez \(2012\)](#) added that STEM education has been a national priority in the United States (US). The US implemented the STEM activity clearinghouse within the Space Science Institute's STAR library network (known as STAR Net), initially funded by the Institute of Museum and Library Services, which enriches STEM learning in public libraries by offering registered members access to a variety of STEM learning resources ([Dusenberry et al., 2020](#)). In China, STEM education has been given a high priority, primarily targeting K-12 settings, with an emphasis on integrating multiple disciplines and localized implementation ([Liang et al., 2017](#)). In New Zealand, a 10-year strategic plan titled "A Nation of Curious Minds" launched in 2015 to fund activities, projects, and programs that enhance engagement in science and technology ([Doyle et al., 2020](#)). In India, the "Skill India" initiative, launched in 2015, focuses on building 40 core skills in Indians, including essential STEM skills such as computer programming and manufacturing ([Mukul et al., 2024](#)). The 2020 education policy in India has further emphasized the need for all students to learn STEM skills, including coding and evidence-based thinking ([Mukul et al., 2024](#)). Additionally, a 2018 report by the Committee on STEM Education in the USA highlighted strategies such as work-based programs to teach STEM through educator-employer partnerships, high school apprenticeships, and a centralized online platform for locating STEM-related funding opportunities. In Tanzania, Aga Khan University's new technology aims to transform STEM learning ([Aga Khan University, 2025](#)). Furthermore, in this evolving landscape, the integration of Artificial Intelligence (AI) technologies presents a unique opportunity to further enhance STEM education ([Anwar et al., 2019](#); [Evripidou et al., 2020](#); [Ouyang and Xu, 2024](#)).

By harnessing AI, academic libraries can better cater to the diverse needs of students and educators, ensuring that STEM education remains relevant and impactful ([Ali et al., 2024](#); [Bakiri et al., 2024](#)). AI can facilitate personalized learning experiences by adapting educational content to individual student needs, streamlining access to resources through intelligent search algorithms, and analyzing student engagement data to inform program development and improvement ([Vieriu and Petrea, 2025](#)). The potential for AI to foster collaboration and innovation within academic libraries positions them as critical players in advancing STEM education and supporting broader educational goals ([Ali et al., 2024](#)). Modern technologies, including AI tools, are transforming STEM education, making teaching and learning resources more accessible to students, staff, and researchers ([Mosh, 2025](#)). [Bruno et al. \(2025\)](#) highlighted that while AI has significant potential to transform STEM education, its full effectiveness can only be achieved through strategic investments in infrastructure, capacity building, and policy development.

Literature review

STEM resources and services in academic libraries

Academic libraries play an increasingly pivotal role in advancing STEM education through access to diverse learning resources, specialized facilities, and innovative programs. These libraries play a central role in facilitating interdisciplinary learning, research collaboration, and the integration of emerging technologies that enhance the STEM learning experience ([Frieze and Quesenberry, 2015](#); [Zhan et al., 2022](#)). [Table 1](#) summarizes key STEM resources and services commonly found in academic libraries, highlighting their contributions to supporting STEM learning and innovation.

AI technologies that support STEM education

AI has become a transformative force in STEM education, offering new pathways for personalized learning, data-driven decision-making, and enhanced interactivity in teaching

Table 1. STEM resources and services in academic libraries

STEM resource	Description	Contribution	References
Books and e-resources	Print and electronic books, journals, Research4Life, Taylor and Francis, Emerald databases	Provide foundational and advanced STEM content for study and research	Haleem et al. (2022) , Rzyankina (2024) , Sari et al. (2022)
Learning spaces	Makerspaces, learning labs, workshops, and study areas	Facilitate hands-on experimentation, creativity, and collaborative learning	Kay and Buxton (2024) , Mørch et al. (2023)
Technology facilities	Computers, 3D printers, laser cutters, soldering tools, and HPC “Para Kilimanjaro”	Enhance digital literacy, computational skills, and access to advanced tools	Munir et al. (2025)
Outreach programs	Science fairs, STEM ambassador programs, exhibitions, and community partnerships	Foster public engagement and early STEM exposure in schools and communities	Coleman and Graham (2025) , Lachebo et al. (2024) , Prabhakar et al. (2025)
Capacity building	STEM workshops for girls, coding classes, research support sessions	Empower underrepresented groups and strengthen STEM competencies	King et al. (2024) , Lachebo et al. (2024)
Collaborations and networks	COTUL, Book Aid International, Tanzania Library Association (TLA)	Promote resource sharing, access to global STEM content, and professional partnerships	Markle et al. (2022) , Weiss et al. (2025)

and research. Within academic libraries, AI can be strategically leveraged to curate, deliver, and assess STEM learning resources, making education more adaptive, efficient, and inclusive ([Ayesi et al., 2024](#)). Key applications of AI in STEM education include adaptive learning platforms, predictive analytics, automated assessment, and intelligent collaboration systems. [Chisom et al. \(2023\)](#) summarize the opportunities (personalized learning, virtual labs) and barriers (infrastructure, policy gaps) for AI in education across African contexts. [Maluleke \(2025\)](#) conducted a.

Systematic analysis of benefits (teaching, admin efficiency) and ethical/infrastructure challenges in African HLIs. [Pasisamire et al. \(2025\)](#) explored the use and the impact of AI in higher education in Africa. Also, [Patel and Ragolane \(2024\)](#) present the Implementation of AI in South African HLIs: Opportunities and challenges.

A case study from South Africa, highlighting strategic implementation, risks to academic integrity, and institutional readiness. These technologies enhance both individual and institutional capacities to support evidence-based learning and research. [Table 2](#) presents examples of AI tools relevant to academic library contexts.

AI ethics in education

Recent scholarship highlights that AI ethics in education is a complex and evolving domain, with researchers examining ethical challenges across diverse educational contexts. [Kamali et al. \(2024\)](#) conceptualize AI ethics as a multifaceted challenge, drawing on activity theory to investigate how university educators engage with ethical norms related to the use of AI. Their study reveals limited awareness among educators and significant inconsistencies between institutional guidelines and actual practice, underscoring the need for clearer governance frameworks. Expanding the scope, [Wises et al. \(2025\)](#) provide a systematic review of AI ethics education, focusing on how ethical principles surrounding AI are taught to students globally. Their review identifies substantial gaps in curricula, especially regarding the practical application of ethics in real-world AI systems. Similarly, [Mogoale et al. \(2025\)](#) synthesize the ethical concerns that have emerged in AI-driven learning

Table 2. AI tools supporting STEM education

AI tool	Description	Application	References
Personalized learning systems	Adaptive platforms (e.g. AI tutors, recommender systems)	Customize learning experiences to match student pace and needs	Ayeni et al. (2024) , Mosha (2025)
Data analytics and predictive insights	AI algorithms tracking performance and engagement	Identify at-risk learners, guide interventions, and improve learning outcomes	Ellikkal and Rajamohan (2025)
Automated assessment tools	AI grading systems and plagiarism detection software	Provide real-time feedback and reduce educator workload	Tan et al. (2025)
Virtual labs and simulations	AI-driven simulation environments	Enable cost-effective, safe, and interactive experimentation	Lynch and Ghergulescu (2017) , Sypsas et al. (2025) , Trúchly et al. (2019)
AI collaboration platforms	Intelligent research networks and project platforms	Foster knowledge sharing and interdisciplinary STEM collaboration	Kovati (2025) , Mosha (2025)
Content creation and curation tools	Chatbots, AI summarizers, automated cataloging	Maintain up-to-date and relevant STEM instructional materials	Pratama et al. (2023)
Curriculum forecasting systems	Predictive analytics for future STEM skill trends	Support responsive curriculum and workforce development	Labhane et al. (2024) , Nuangchalem and Prachagool (2023)

environments within South African higher education between 2022 and 2024. Their findings highlight recurring issues, including equity, privacy, learner autonomy, and the erosion of human contact in digitally mediated learning. Building on these regional insights, [Ntsohi et al. \(2025\)](#) propose an ethics framework specifically designed for Southern African educational settings. Their model prioritizes contextually relevant principles, including data privacy, transparency, governance, and algorithmic fairness, arguing that ethical AI integration must be grounded in local cultural, institutional, and infrastructural realities. Complementing these perspectives, [Sokhulu et al. \(2025\)](#) examine how South African university students use ChatGPT in their learning processes. The study reveals that students frequently rely on ChatGPT for explanations, assignment support, and understanding of complex academic content, thereby enhancing their self-directed learning. However, the authors caution that this growing reliance raises several ethical concerns, including risks to academic integrity, transparency issues surrounding the use of AI in assessments, and unequal access to AI tools. Their work reinforces broader calls for institutions to develop responsible use policies and enhance digital literacy in the context of AI ethics.

Libraries’ roles in supporting STEM education and learning

Libraries play a vital role in supporting STEM education by offering access to diverse resources, including books, journals, and digital databases tailored to science, technology, engineering, and mathematics ([Frieze and Quesenberry, 2015](#); [Oyelude and Bamigbola, 2012](#)). They provide essential technology and facilities, such as computers and makerspaces, enabling hands-on learning, training, and workshops that enhance student engagement ([Oyelude and Bamigbola, 2012](#); [Trixa and Kaspar, 2024](#)). Additionally, libraries host workshops, coding classes, and collaborative programs with local schools to foster a love for STEM subjects among community members ([Oyelude and Bamigbola, 2012](#)). In addition to information literacy programs, most academic libraries in high-income countries have endeavored to offer STEM programs to enhance STEM literacy ([Zhan et al., 2022](#)). In

classroom settings, this often involves utilizing student teams to tackle real-world problems or engage in hands-on experiments (Tindan and Anaba, 2024). The following are among the STEM activities supported by academic libraries:

- (1) *Makerspaces*: These collaborative workspaces provide access to a diverse range of tools, from no-tech options like Legos and art supplies to high-tech equipment such as laser cutters, soldering materials, and 3D printers (Okuonghae, 2019). AI-supported makerspaces tailored to users' interests and skill levels, thereby enhancing creative exploration and innovation (Okuonghae and Nkiko, 2021).
- (2) *Museum-quality exhibitions*: Interactive displays enable library users to explore various topics, including space, biology, and technology (Wen and Ma, 2024). AI technologies, such as virtual reality experiences or AI-driven guides, are used to respond to user inquiries, thereby promoting deeper engagement and a better understanding of complex subjects (Abdulrahman et al., 2020).
- (3) *Learning labs*: In these dedicated spaces, libraries provide academic assistance in specific STEM subjects, particularly math, during school hours for students who require extra help (Fullmer, 2012). AI provides real-time analytics on student performance, allowing staff to tailor assistance and resources to individual learning needs (Fullmer, 2012).
- (4) *Workshops and classes*: Libraries frequently host various workshops and classes focused on STEM topics, such as coding, robotics, and data analysis (Anwar et al., 2019; Ouyang and Xu, 2024). AI streamlines these programs by providing adaptive learning platforms that adjust the curriculum based on participant progress and engagement levels, ensuring that all learners can benefit (Evripidou et al., 2020).
- (5) *Community partnerships*: Libraries collaborate with local schools, universities, and organizations to enhance STEM programmes (Swanson and Duncan, 2025). AI tools can be utilized to analyze community needs and interests, enabling them to design programs that effectively address local challenges and opportunities (Oyedokun, 2025).
- (6) *STEM clubs*: Some libraries offer clubs that focus on specific STEM interests, allowing participants to meet regularly to engage in projects, challenges, and discussions (Fitzgerald et al., 2024). AI-driven platforms enhance communication and collaboration within these clubs, enabling members to share STEM resources, ideas, and project updates more efficiently (Blanchard et al., 2023).

NM-AIST library as a HUB for STEM resources and services

A key aspect of NM-AIST's mission is to provide and promote high-quality public service in science, engineering, technology, and innovation through entrepreneurship. This mission focuses on strengthening connections with society, government, and industry, aligning with the institution's motto, "Academia for Societies and Industries." This approach emphasizes the importance of "citizen science," actively involving citizens in STEM research. To fulfill this mission, NM-AIST engages in various activities that support STEM education and innovation, as provided in Table 3.

More recent Tanzanian-specific studies on STEM education or library practices

- (1) The utilisation of open research data repositories for storing and sharing research data in HLIs in Tanzania (Mosha and Ngulube, 2023). The case study at NM-AIST,

Table 3. STEM initiatives and activities in NM-AIST library

Initiative/Activity	Description	Intended impact
STEM resource acquisition	Books, e-books, journals through Book Aid International (BAI), COTUL, and Research4Life	Expand access to current STEM materials
Annual science fair	Student exhibitions showcasing innovative projects	Cultivate creativity and problem-solving among learners
STEM workshop for girls	Held during NM-AIST SETI Week	Encourage female participation in STEM fields
STEM ambassador program	Outreach to schools across Tanzania	Inspire interest and provide early STEM exposure
Participation in exhibitions (e.g. nanenane)	Showcasing institutional and student innovations	Strengthen university-community-industry linkages
Collaborations with stakeholders	Joint programs with schools, industries, and government agencies	Promote applied research and innovation
High-Performance Computing (HPC) “Para Kilimanjaro”	Provides computational resources and AI applications	Enable advanced STEM research and AI integration in learning

exploring open research data and repository usage, is directly relevant to library support for STEM research and data management. The article presents institutional-level evidence on repository practices, open data, and library roles at NM-AIST.

- (2) The role of Tanzanian academic libraries in promoting scholarly communication through open access (OA): A literature review (Mwilongo and Kachota, 2023). Review of Tanzanian academic libraries’ roles in scholarly communication and OA adoption. The chapter situates library functions (OA, repositories, scholarly communication) in the Tanzanian context.
- (3) Unlocking students’ interest in STEM education through career guidance services: Experiences from Tanzania (Jerome and Gwajekera, 2023). This empirical study examines the impact of targeted guidance/outreach on STEM interest among Tanzanian students. It supports the Literature Review points on outreach, STEM ambassador programmes and the role of institutional career services.
- (4) Marketing hybrid library collections and services (Tanzania) by Jeremia and Mwantimwa (2022). The article examines competencies, impact, and challenges of marketing hybrid collections in Tanzania. It is directly relevant to your discussion of hybrid library services and user engagement strategies.
- (5) A survey of science, technology, engineering, and mathematics career interests and influencing factors among Tanzanian University students: Evidence from a survey of 1,497 science and engineering students (Chen and Bao, 2025). A large survey reveals factors influencing STEM interest and institutional constraints. It recently, large-scale empirical data from Tanzania have helped justify the need for library interventions and AI-enabled support.
- (6) Value of academic libraries in improving Knowledge Management (KM) practices in HLIs (Moshia and Ngulube, 2024). This is an empirical assessment of the value of libraries in Tanzanian higher-education institutions. It reinforces claims about the library’s contributions to KM, STEM support, and institutional research capacity.

Problem statement

Despite the recognized importance of STEM education for national development and innovation, many HLIs in Tanzania face significant challenges in effectively promoting and supporting STEM teaching, learning, and research. A major issue is the limited support from academic libraries to support STEM education through library resources, facilities, and services within and outside their HLIs. For example, academic libraries need to support local secondary and primary schools by providing access to teaching and learning resources that foster early exposure to STEM subjects (Haji and Moh'd, 2024; Kanwera *et al.*, 2024; Kormos and Wisdom, 2021). Such initiatives can help build a foundation of STEM knowledge among students at the ordinary level, enabling them to pursue further education in these fields. Furthermore, while academic libraries have begun integrating AI applications to enhance educational experiences, there is still a lack of comprehensive strategies to maximize their potential in supporting STEM education (Ali *et al.*, 2024). Thus, this research aims to investigate the impact of academic libraries on supporting STEM education in HLIs in Tanzania using AI.

Understanding these dynamics is crucial for developing targeted strategies that will improve STEM educational outcomes and engagement among students in Tanzania. To that end, the main objective was to explore the impact of academic libraries in Tanzania on enhancing STEM education in HLIs through the effective integration of AI technologies. The specific objectives were to:

- (1) Evaluate the availability and accessibility of STEM-related library resources in HLIs in Tanzania.
- (2) Determine the initiatives undertaken by academic libraries to support STEM education
- (3) Analyse the role of AI applications in supporting STEM education.
- (4) Establish the challenges that hinder academic libraries from supporting STEM education.
- (5) Develop strategies and recommendations for academic libraries to enhance their support for STEM education.

Methodology

This study was conducted at the Nelson Mandela African Institution of Science and Technology (NM-AIST), a public postgraduate university in Tanzania. This institution comprises five schools:

- (1) School of Business Studies and Humanities (BuSH)
- (2) School of Computational and Communication Sciences and Engineering (CoCSE)
- (3) School of Life Sciences and Bioengineering (LiSBE)
- (4) School of Earth Sciences and Engineering
- (5) School of Material, Energy, Water and Environmental Sciences

The institution hosts a modern and well-equipped hybrid library that provides access to both print and electronic resources for NM-AIST users and for external users with special permission.

Research design and ethnographic approach

An ethnographic research design was adopted to capture the lived experiences, practices, and contextual realities of library staff in supporting STEM education and integrating emerging

technologies such as AI. Ethnography enabled prolonged engagement within the library environment, allowing the researcher to observe the interactions, routines, and social dynamics that shape library services. This immersive approach facilitated a holistic understanding of how the library staff conceptualize and deliver STEM-oriented support.

The ethnographic procedures included:

- (1) Prolonged engagement within the library environment over several weeks to gain contextual familiarity with workflows, physical spaces, and interpersonal interactions.
- (2) Participant observation, in which the researcher took part in selected library activities and user support sessions, while maintaining reflexive field notes documenting key observations and reflections.
- (3) In-depth interviews (IDIs) provided a platform for library staff to express their experiences, perspectives, and challenges in their own words (Ruslin *et al.*, 2022).

Sampling strategy and participants

The study employed purposive sampling to select participants who possessed in-depth knowledge and experience related to library operations and STEM-related services. Eight library staff members were selected to ensure representation across various roles in STEM activities within academic libraries. The selection of eight participants was guided by the ethnographic emphasis on depth rather than breadth. In ethnographic research, smaller, information-rich samples enable a comprehensive exploration of participants' lived experiences and the contextual factors shaping their practices. Thus, the chosen number allowed for detailed engagement with each participant while maintaining feasibility for in-depth observation, transcription, and iterative analysis. This size was also sufficient to achieve data saturation, as no new insights and/or themes emerged from subsequent interviews and observations, indicating that the data collected were rich and comprehensive enough to address the study's objectives. The purposive approach ensured that insights reflected diverse yet complementary perspectives from staff engaged in both direct service delivery and administrative functions. Through sustained interaction and triangulation of multiple data sources, the study achieved an adequate level of saturation and analytic depth, capturing the complexity of library practices in supporting STEM education and integrating AI technologies.

Data collection procedures

Data were collected through IDI, semi-structured interviews guided by an interview protocol that focused on themes such as STEM support activities, the use of digital tools and AI, user engagement practices, and the challenges encountered. Each interview lasted between 45–60 min and was audio-recorded with participant consent. Simultaneously, participant observation was undertaken within library spaces to document daily practices, service interactions, and the use of technologies. Field notes and observation logs were maintained systematically, capturing descriptive and reflective elements for later triangulation with interview data.

Data analysis

Data were analyzed using a thematic analysis approach, following Braun and Clarke's (2006) six-step framework: (1) familiarization with data, (2) generation of initial codes, (3) searching for themes, (4) reviewing themes, (5) defining and naming themes, and (6) producing the report. Interview transcripts and field notes were manually coded to identify recurring patterns and relationships across data sources.

Code development

The researchers read and re-read transcripts and observation notes, gaining deep familiarity with the content. Initial codes were developed directly from participants' words and phrases to capture meanings grounded in the data. These preliminary codes were then refined and clustered into broader conceptual categories that reflected patterns across participants. Analytical memos were written throughout the process to document coding decisions, emerging ideas, and reflections on the researcher's positionality. A codebook was developed iteratively, detailing code definitions, criteria provided, and representative data excerpts to ensure consistency in application. As coding progressed, some codes were merged, expanded, or renamed to enhance analytic clarity and coherence. In this study, coding was primarily conducted by the lead researcher, who maintained a reflexive stance throughout to minimize potential bias inherent in single-coder analysis. To enhance trustworthiness, a peer debriefing process was incorporated: an experienced qualitative researcher reviewed a subset of the coded data and the evolving codebook to verify consistency and interpretive alignment. Discrepancies and alternative interpretations were discussed and resolved through consensus, thereby strengthening the credibility and dependability of the analysis. Triangulation between interview data and field observations further reinforced analytic rigor and ensured that findings were well-grounded in multiple sources of evidence.

Ethical considerations

This study was conducted in accordance with approved ethical research protocols. Permission to collect data was obtained from the NM-AIST management. Participants were fully informed about the study's aims, procedures, and their rights, including the option to participate voluntarily and withdraw without penalty. Written informed consent was obtained before participation.

Data anonymization and storage procedures

Beyond obtaining consent, rigorous data management protocols were implemented to safeguard participant confidentiality and the integrity of research data. Each participant was assigned a pseudonym and a unique alphanumeric code, which were used consistently across transcripts, field notes, and analytic documents. Any references to names, job titles, or identifiable institutional roles were hidden to prevent indirect identification. During transcription, all potentially identifying details such as mentions of specific projects, departments, or colleagues were carefully redacted or paraphrased. Interview recordings were stored in encrypted, password-protected folders on a secure, offline device accessible only to the researcher. Transcripts, field notes, and coding files were similarly protected, with backup copies stored on an encrypted external drive to prevent data loss. No data were uploaded to cloud storage or shared electronically without encryption. Data were retained in accordance with institutional ethical requirements and will be destroyed five years after the study's completion. Audio files will be permanently deleted, and all textual materials, including transcripts and field notes, will be securely shredded or digitally erased. To further ensure participant privacy, anonymized excerpts rather than full transcripts were used in reporting findings, and contextual identifiers were modified where necessary without altering meaning. These measures collectively ensured that participant confidentiality was upheld throughout all stages of data handling, analysis, and dissemination.

Findings

- (1) To examine the availability and accessibility of STEM-related resources at the NM-AIST library

The findings revealed that the NM-AIST library provides a diverse range of STEM-related resources, including textbooks, research journals, and electronic databases. Approximately 90% of the required STEM materials are available in both print and electronic formats. Participants emphasized that library management systems, such as KOHA and ABCD, have improved access to digital resources through the library portal <https://libraryservices.nm-aist.ac.tz/>. As one participant explained:

Our printed books are available for access within the library. To access electronic formats, the library utilizes two library management systems, KOHA and ABCD. These systems are integrated into the library portal, making it easy for users to access materials for their studies and research. (Participant 2)

The study also observed the library's registration with Book Aid International (BAI) through the Tanzania Library Association. This initiative, supported by an annual subscription fee of TZS 500,000 (approximately USD 210), enables the acquisition of a wide range of current STEM books. Moreover, the NM-AIST library subscribes to scientific databases and journals through the COTUL, which primarily supports STEM disciplines. Participants noted that the library provides access to over 500 electronic journals from various reputable databases, significantly enhancing access to STEM knowledge. These findings suggest that NM-AIST maintains a strong foundation for supporting STEM education through diversified and accessible collections.

The findings directly address objective 1 by demonstrating that the NM-AIST has developed an enabling environment for sustained STEM learning through diversified and well-managed collections.

- (2) To assess current library initiatives that support STEM education within and beyond the institution

Participants reported that the library conducts regular outreach programs and workshops on research skills, database usage, and citation management specifically tailored for STEM students. These initiatives were perceived to have improved students' research competencies and confidence. One participant stated:

These trainings have significantly improved students' ability to conduct research in STEM fields, allowing them to use the library's resources more effectively. (Participant 5)

Beyond institutional boundaries, participants highlighted the need for extended outreach to local schools:

Our libraries should establish outreach programs to distribute STEM resources to local schools, improve access to digital materials, advocate for better internet connectivity, and train library staff on AI and other technologies to enhance resource accessibility and user support. (Participant 3)

The NM-AIST library already supports local primary and secondary schools by providing teaching and learning materials. However, findings revealed that only about 30% of these schools possess basic STEM resources, which are often outdated or insufficient. Internet connectivity and library infrastructure remain significant barriers to equitable STEM access. As one participant noted:

Local primary and secondary schools have very few STEM resources. Most of them lack internet connectivity and library infrastructure, making it difficult for students to access digital materials or participate effectively in STEM programs. (Participant 7).

Participants also emphasized the library's collaboration with regional schools through STEM fairs and workshops. For example, during July 2025, the regional library hosted STEM workshops that brought together students from multiple schools. One participant reported:

Students from primary and secondary schools attended our STEM workshops during the regional fair, and we recorded a 25% increase in their academic performance in STEM subjects. (Participant 4)

The consensus among participants was that collaboration and outreach are critical for promoting STEM literacy across educational levels:

There is a need for more collaboration with local schools to improve resource sharing and support STEM education initiatives. (Participant 8)

These outcomes align with objective 2 by highlighting both the strengths and limitations of current initiatives in enhancing STEM literacy across multiple educational levels.

- (3) To explore the role of AI applications in supporting STEM learning and research at NM-AIST

The findings revealed that NM-AIST has adopted various AI-driven applications to enhance access to STEM resources. Participants reported the implementation of AI-powered chatbots that provide 24/7 research assistance, allowing users to access library services at any time. As one participant noted:

The library offers a range of AI tools enabling STEM students to conduct their studies and improve their writing skills. Students have reported improved research outputs, and this visibility has helped the institution gain recognition for its research impact. (Participant 1)

In 2025, NM-AIST was recognized by Times Higher Education as Tanzania's top institution for impactful research on the Sustainable Development Goals. The study also observed the use of Turnitin plagiarism detection software (Account No. 120386), utilized by approximately 80% of students and all academic staff before submitting research work. Additionally, the institution hosts an AI-focused bootcamp under the SAMIA SCHOLARSHIP EXTENDED (DS/AI+) program for students who have completed advanced-level studies in physics, chemistry, and mathematics. The program equips students with foundational skills in data science and AI, preparing them for advanced studies abroad. One participant highlighted:

The introduction of AI applications has resulted in increased engagement among both undergraduate and master's students, many of whom now show greater interest in exploring STEM fields. (Participant 5).

The study also documented the institution's High-Performance Computing (HPC), Param-Kilimanjaro, which exceeds 100 terabytes and 14 teraflops in capacity. The HPC supports the storage and analysis of large datasets, which are crucial for training AI models and advanced STEM research. However, one participant emphasized the need for further investment and ethical oversight:

The institution should integrate more AI tools tailored to different STEM disciplines and establish ethical guidelines for their use to ensure privacy and responsible application. (Participant 6).

In relation to objective 3, the findings indicate that AI applications serve as catalysts for expanding STEM competencies and enhancing institutional research visibility.

- (4) To identify challenges that affect the library's capacity to support STEM education

The most frequently cited challenge was budget constraints, which limited the acquisition of up-to-date STEM resources and technologies. Participants emphasized that financial shortages affect training programs, staffing, and infrastructure development. One participant explained:

Financial limitations restrict the library's ability to invest in advanced AI technologies and related training. For 2024/25, there was no dedicated budget for AI initiatives. (Participant 3)

Another participant added:

Budget shortfalls reduce staffing and limit training opportunities for library personnel, which affects the quality of user support. (Participant 7)

Funding gaps also restrict the library’s ability to collaborate with external partners and participate in international projects. The study observed that NM-AIST has submitted funding applications to VLIR-OUS (Belgium) and the Center for Effective Global Action (CEGA) to mitigate these challenges.

Participants further cited technological barriers, noting that limited infrastructure and software hinder effective use of AI tools.

Many libraries lack the technological infrastructure needed to support AI applications, including high-speed internet and robust computing resources. (Participant 5)

Concerns about AI ethics and data privacy also emerged:

Academic libraries can help address AI ethics by offering training on data privacy, responsible AI use, and critical evaluation of AI-generated information. (Participant 2)

In addition, participants highlighted low awareness of library services and a lack of staff training in STEM and AI technologies:

None of the library staff have attended formal training on STEM education support, leaving them underprepared to assist students effectively. (Participant 8)

Another added:

The absence of collaboration between libraries and STEM departments limits our ability to tailor workshops and research support to curriculum needs. (Participant 4)

These challenges align with Objective 4 by revealing structural, financial, and human capacity barriers that constrain the library’s ability to fully support STEM education.

(5) To recommend strategies for enhancing library support for STEM teaching and research

Participants proposed several strategies to enhance library support for STEM education. The most common recommendation was to evaluate existing STEM collections to identify gaps and prioritize acquisitions.

By assessing our available STEM resources, we can identify where we need to invest in new materials to support education effectively. (Participant 8)

They also advocated for leveraging AI technologies to deliver personalized learning and research assistance:

Integrating AI tools can transform how students engage with library resources, making it easier for them to find what they need and improving their learning experience. (Participant 1)

Collaboration with STEM departments was seen as essential for aligning resources with curriculum needs. Participants recommended workshops on emerging technologies, data analysis, and research methodologies, as well as interactive online platforms with tutorials and discussion forums.

Interactive learning modules and live workshops can make complex subjects more engaging while promoting peer-to-peer collaboration. (Participant 6)

Lastly, participants emphasized establishing regular feedback mechanisms between library users and staff:

Continuous feedback helps us adapt our services and develop targeted workshops that enhance students’ skills in critical STEM areas. (Participant 2)

These strategies address Objective 5 by outlining actionable pathways for improving STEM resource provision, enhancing staff competencies, and deepening academic partnerships.

Discussion for this study was presented based on the following sub-sections:

Libraries' role in providing access to STEM resources

The findings demonstrate that the NM-AIST library makes a substantial contribution to STEM education through its diverse and accessible collections. The integration of platforms such as KOHA and ABCD enhances both access and usability, enabling efficient retrieval of electronic resources. This extends previous literature, which primarily emphasizes access (Widodo *et al.*, 2020; Suprpto *et al.*, 2022), by demonstrating how library management systems themselves enhance the user experience in a resource-constrained African context. These systems and subscriptions, facilitated through BAI and COTUL, demonstrate deliberate institutional investment aligned with the objective of ensuring sufficient and up-to-date STEM resources to meet the needs of students and researchers.

Outreach and collaboration

The study reveals that NM-AIST's outreach programs, including training workshops and support to local schools, are central to its role in fostering STEM literacy. These initiatives align with the findings of Kim *et al.* (2025) on community-engaged STEM programming in the U.S. However, NM-AIST's context introduces a critical distinction: outreach effectiveness is constrained by infrastructural limitations in the surrounding schools. This highlights the need for outreach strategies to be sensitive to local realities. Collaboration with regional institutions, as advocated by Joseph and Uzundu (2024a), therefore becomes a pathway not only to broaden impact but also to compensate for systemic resource gaps in rural settings.

Integration of AI in STEM education

The integration of AI tools at NM-AIST, including chatbots and HPC systems, demonstrates how libraries can leverage emerging technologies to enhance research and learning. These results align with Zhai and Krajcik (2024), who noted that AI is transforming instructional paradigms in STEM. Yet, this study contributes new insight from an African perspective, emphasizing both the opportunities and ethical complexities of AI in resource-constrained academic settings. The findings underscore the need for robust ethical frameworks and ongoing training, as emphasized by Hodonu-Wusu (2025).

Barriers and interconnected barriers and institutional constraints

The identified barriers include budget constraints, limited technological infrastructure, inadequate staff capacity, and low awareness of library services. These barriers do not operate independently; rather, they reinforce one another in a cyclical manner.

- (1) Budget limitations reduce the library's ability to acquire new technologies or update existing STEM materials.
- (2) Technological barriers (e.g. slow internet, outdated computers) stem directly from insufficient funding but also limit the usage of available AI tools, thereby reducing the perceived value of library services.
- (3) Insufficient staff training emerges from both financial constraints and technological gaps, as staff cannot fully utilize or effectively teach the tools they lack access to.
- (4) Low awareness and underutilization of library services then result, because users encounter limited support, outdated systems, or ineffective technology, further weakening the justification for increased funding.

This interconnectedness suggests a resource deficit cycle in which financial, human, and technological shortages perpetuate each other. Consistent with [Zhai \(2021\)](#) and [Malekani and Mubofu \(2019\)](#), the study demonstrates that infrastructural investments must be complemented by staff development and awareness-building initiatives to break this cycle.

The AI governance and ethical considerations

The study highlights concerns related to data privacy, algorithmic transparency, intellectual property rights, and the lack of institutional policies regulating AI use. These findings echo global concerns raised by [Hasan \(2025\)](#), [Rajkumar et al. \(2024\)](#), and [Tsekea and Mandoga \(2025\)](#). However, the NM-AIST context highlights the heightened risks associated with deploying AI in institutions without robust governance frameworks. Participants' calls for regular AI audits, contextualized datasets, and human oversight align with [UNESCO's \(2022\)](#) recommendations and underscore the need for a formal institutional AI ethics committee. Without such structures, gains from AI adoption risk being undermined by systemic ethical lapses and potential bias.

Future directions and implications

The findings suggest that NM-AIST should transition from traditional library service models to more integrated, technology-driven support systems. This includes adopting AI-enhanced learning platforms, creating structured feedback mechanisms, and prioritizing continuous professional development ([Abiolu and Akinyemi, 2025](#)). Strengthening partnerships with local schools and STEM organizations is essential for expanding impact and building sustainable STEM ecosystems ([Perera et al., 2025](#)). Addressing structural constraints will require strategic planning that treats budget, infrastructure, skills, and governance challenges as interrelated rather than isolated dimensions of institutional capacity.

Scope and limitations

This study was designed as a single-site ethnographic case study, focusing specifically on the NM-AIST library in Arusha, Tanzania. The institution was purposefully selected due to its explicit mandate to advance STEM education and innovation across Tanzania and the broader African region. As such, NM-AIST provides a suitable and contextually rich environment for exploring how academic libraries in Tanzania support STEM education, particularly through the integration of AI technologies. The NM-AIST library offers valuable insights into the strategic roles academic libraries can play in fostering STEM engagement. The findings are context-specific and should be interpreted within the scope of the institution's unique environment, its specialized STEM mandate, access to HPC infrastructure, and its established partnerships with schools, universities, industries, and international organizations. Consequently, the experiences and practices observed at NM-AIST may not fully represent those of other Tanzanian or African academic libraries, which have different institutional capacities, missions, or resource allocations. Furthermore, the ethnographic approach, characterized by IDIs and participant observation, prioritized depth of understanding over breadth. While this method provided a rich, nuanced account of librarians' perspectives, practices, and challenges in AI integration, it also limits the generalizability of the findings. The study does not aim to provide statistically representative results but rather to offer transferable insights that can inform similar institutions seeking to strengthen their support for STEM education. Other limitations include potential researcher bias inherent in qualitative interpretation, as well as temporal limitations, since institutional strategies and AI adoption evolve rapidly. Future research could expand this inquiry through multi-site comparative studies across Tanzanian and regional universities, employing mixed methods to quantify the impact of AI-driven library interventions on STEM education outcomes.

Implications for research, practice, and society

The study lays an important foundation for understanding how AI technologies can be effectively integrated into academic libraries in low-resource countries, such as Tanzania. By examining the NM-AIST library's initiatives, constraints, and opportunities, the research contributes to broader discussions in library and information science concerning the digital transformation of STEM education support. The section provides four sub-sections: implications for research, implications for practice, societal implications, and economic and commercial impacts.

(1) Implications for research

The findings open multiple pathways for future empirical investigations. For example:

- Longitudinal studies could assess the long-term impact of AI-driven tools (e.g. chatbots, automated search assistants, personalised recommendation systems) on students' academic performance and research productivity.

Implementation example: tracking student usage logs and correlating them with research output over a 3–5 year period.

- Comparative case studies across different universities in Africa or the Global South regions could identify scalable models for AI adoption in libraries.

An implementation example illustrates how universities like NM-AIST, Makerere, and the University of Botswana differ in their AI readiness and outcomes, particularly in supporting STEM education.

- Experimental studies could test the effectiveness of AI-enabled services such as automated citation generators, research data extraction tools, or adaptive learning tutorials, on improving information literacy competencies.

Implementation example: creating control and experimental groups among first-year STEM students to evaluate learning outcomes.

(2) Implications for practice

The findings bridge theory and practice by illustrating how AI applications can be meaningfully integrated into library operations. They demonstrate that AI is not only a technological upgrade but a tool that can fundamentally reshape how libraries support STEM education.

Specific examples of implementable recommendations:

Personalised learning and research assistance

- (1) AI-driven recommendation systems could automatically suggest STEM articles, datasets, and textbooks based on a student's past searches or course enrollment.

Example: KOHA could be integrated with a machine-learning plugin that analyses borrowing patterns to recommend additional materials.

- (2) Intelligent tutoring systems could guide students through complex STEM topics (e.g. calculus, coding, simulations) inside the library portal.

Example: Integrating open-source tools like TutorBot or Khan Academy's Application Programming Interfaces into the library's management systems.

Enhancing information discovery and access

- (1) Automated metadata generation tools can classify STEM documents more quickly and accurately, thereby reducing cataloging time.

Example: Using AI models (e.g. GPT-based classification) to automatically generate abstracts and keywords for new materials.

- (2) AI-enabled federated search systems could allow students to search across multiple STEM databases simultaneously.

Staff development and capacity building

- (1) Offer AI literacy workshops for librarians on topics such as data analytics, prompt engineering, and ethical AI use. For instance, partnering with NM-AIST's own DS/AI + bootcamp to provide tailored training for library staff.
- (2) Develop peer learning circles where librarians discuss AI case studies and practice using new tools in low-risk environments.

Establishing institutional AI governance

- (1) Establish an AI Ethics and Governance Committee within the library to inform policy development, conduct risk assessments, and provide staff training.
- (2) Implement annual AI audits to check for algorithmic bias, data privacy risks, and compliance with national and institutional standards.
- (3) Societal implications

The effective use of AI in academic libraries contributes to national goals of expanding STEM capacity and fostering a technology-driven economy. Libraries can become central hubs for digital literacy, innovation, and community engagement.

Examples of Societal Benefits:

- (1) Equitable access to STEM resources for rural schools through AI-powered mobile learning platforms linked to the NM-AIST library portal.
- (2) Increased digital competence among students, preparing them for more advanced studies and careers in data science, engineering, and computing.
- (3) Enhanced public trust in technology, supported by transparent AI policies and better ethical governance.
- (4) Economic and commercial impacts

AI integration in academic libraries has the potential to generate significant economic benefits at the institutional, local, and national levels.

Reduction in costs of delivering STEM education

AI tools can reduce operational costs by automating repetitive and labor-intensive tasks.

Examples:

- (1) Automated grading and assessment tools reduce lecturers' workloads and lower costs associated with hiring additional teaching assistants.
- (2) AI-generated STEM simulations and virtual labs allow institutions to reduce dependency on expensive physical laboratory equipment. For instance, using Open-source AI simulation platforms for physics or chemistry experiments in schools that lack full labs.

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- (3) AI-driven resource management (e.g. demand forecasting, budget allocation models) can help optimise acquisition budgets and prevent duplicate purchases.

Enhancing research productivity and funding opportunities

- (1) AI enhances research workflows, enabling researchers to complete projects more efficiently and increase institutional output, which is associated with a higher chance of securing grants.
- (2) Institutions with AI-enhanced libraries may qualify for innovation-oriented funding from bodies such as CEGA, VLIR-OUS, or UNESCO.

Stimulating local technology development

AI adoption can create new commercial opportunities in the region.

Examples:

- (1) Development of home-grown AI applications for library management, which can later be sold to other Tanzanian institutions.
- (2) Collaboration between NM-AIST students and local start-ups to build AI-powered educational apps, search interfaces, or translation tools for STEM content in Swahili.
- (3) Expansion of the SAMIA DS/AI + bootcamp could create a local ecosystem of AI developers capable of offering services to regional schools and businesses.

Workforce development and technological innovation

By exposing students to AI-rich environments, the library helps create a more capable, innovation-ready workforce, which benefits national development and private-sector competitiveness.

Examples:

- (1) Students trained on HPC systems, such as Param-Kilimanjaro at NM-AIST, acquire skills that are applicable to sectors like fintech, agritech, and health informatics.
- (2) AI-literate graduates attract investment from technology companies looking for affordable talent in East Africa.

Conclusion

The current study highlights the crucial role of academic libraries in enhancing STEM education within HLIs in Tanzania by integrating AI technologies. The findings reveal that while the NM-AIST library has made significant strides in providing diverse STEM resources and supporting outreach initiatives, several challenges still hinder its effectiveness. Budget constraints, technological barriers, and a lack of collaboration with local schools limit the library's potential to fully support STEM education. To address these challenges, it is essential for academic libraries to foster partnerships with STEM departments, engage in community outreach, and leverage AI technologies to create personalized learning experiences. Additionally, regular training for library staff on emerging technologies and ethical considerations in AI is crucial to equip them with the necessary skills to support students effectively. By implementing these strategies and enhancing collaboration, academic libraries can play a transformative role in supporting STEM education and fostering innovation among students. This approach not only aligns with national development goals but also prepares

future generations to tackle complex challenges in an increasingly technology-driven world. The recommendations presented in this study aim to guide academic libraries worldwide in maximizing their impact on STEM education, ultimately contributing to the advancement of knowledge and skills in Tanzania's educational landscape.

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