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Original Article

Roadmap: Empower Researchers in AI Skills in Developing Countries

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Abstract *- AI offers transformative potential in scientific research, enhancing access to data, collaboration, and analytical capabilities. However, researchers in developing countries face significant challenges in leveraging AI due to inadequate infrastructure, limited digital literacy, and resource constraints. This study explores these challenges and proposes a comprehensive roadmap to empower researchers with AI skills. The roadmap emphasizes cost-effective solutions, including cloud-based services, open-source tools, and strategic partnerships. By addressing barriers such as limited funding, digital skills gaps, and infrastructure deficits, the roadmap aims to promote sustainable development in scientific research. The plan is accompanied by proposals for tools and methods to monitor and track progress so that the outcomes of each stage are verified. The findings emphasize the need to integrate digital literacy into educational curricula, promote interdisciplinary research, and build international collaboration. Ultimately, this research contributes to a systematic and scalable approach to enhancing scientific innovation in resource-constrained environments through empowerment in AI skills and qualifies researchers in resource-constrained environments to leverage AI tools to improve and develop their research and academic careers and facilitate their communication with peers to exchange information and expertise.*

Keywords *- AI Skills, Developing Countries, Digital Empowerment, Scientific Research.*

1. Introduction

Artificial intelligence (AI) has become a transformative force across various fields, revolutionizing how knowledge is generated, analyzed, and applied. However, researchers in developing countries often face challenges in leveraging AI due to limited access to resources, infrastructure, and training. Bridging this gap is crucial for empowering researchers to harness AI effectively, contributing to global scientific advancements, and addressing local challenges in countries [1], [2].

Artificial intelligence (AI) has become a transformative force across various fields, revolutionizing how knowledge is generated, analyzed, and applied. However, researchers in developing countries often face challenges in leveraging AI due to limited access to resources, infrastructure, and training.

Bridging this gap is crucial for empowering researchers to harness AI effectively, contribute to global scientific advancements, and address local challenges [1], [2]. This study explores the challenges faced by researchers in developing countries when using AI and suggests a roadmap to empower researchers in AI skills.

AI is dramatically enhancing scientific research by improving efficiency, accuracy, and innovation. AI accelerates data analysis by quickly processing massive amounts of information, identifying patterns, and predicting things that would take humans much longer to discover. It also supports researchers in literature reviews by summarizing and organizing large collections of academic papers. AI-powered tools, such as natural language processing and machine learning algorithms, help automate repetitive tasks like coding, statistical analysis, and simulation, allowing researchers to focus on critical thinking and discovery. In addition, AI enhances collaboration by enabling advanced modelling and real-time hypothesis and insight generation across scientific disciplines, ultimately leading to more innovative and impactful research [3], [4], [5].

While researchers worldwide are increasingly leveraging digital tools, particularly those powered by artificial intelligence, many researchers in developing countries face significant challenges in adopting these technologies. This gap is particularly pronounced among researchers in non-IT-related disciplines, where access to and proficiency in digital tools remain limited. This study seeks to address these challenges by reviewing existing literature to identify key

barriers and proposing a practical roadmap for empowering researchers to effectively utilize digital tools. Recognizing the financial constraints prevalent in developing countries, the roadmap emphasizes affordable and accessible solutions to maximize impact while minimizing costs.

The current study aims to explore the challenges facing enhancing the efficiency of researchers in using artificial intelligence. It proposes a roadmap that can be adopted by the competent authorities to improve the efficiency of researchers in using artificial intelligence in developing countries. To achieve this goal, this research seeks to study the challenges by reviewing recent literature to identify the main barriers and then propose a practical roadmap to enable researchers to effectively benefit from digital tools and artificial intelligence tools. Recognizing the financial constraints prevailing in developing countries, the roadmap emphasizes affordable and available solutions to maximize impact while minimizing costs.

2. The State of Scientific Research in Developing Countries

Scientific research plays a crucial role in the development and progress of developing countries. It drives innovation and technological progress, which is essential for economic growth in developing countries. By investing in research and development, these countries can develop new products and industries, improve existing technologies and processes, and increase productivity and competitiveness in global markets. Scientific research also enables developing countries to address specific issues relevant to their populations and environments. This includes developing solutions to local health problems, improving agricultural productivity and food security, and addressing the region's unique environmental challenges. Participation in scientific research forums helps invest in and build comprehensive scientific capacity.

Digital empowerment is essential for fostering inclusive growth. Achieving this goal involves addressing challenges such as the digital divide, gender inequality, and infrastructure gaps. Key obstacles to digital empowerment include insufficient infrastructure, limited digital literacy, the digital divide, high costs, and security concerns [6]. Educational institutions play a critical role in preparing students for a digitally empowered future, as those lacking access to digital technology may experience notable disadvantages [1].

Students demonstrate limited familiarity with focus group discussions, suggesting minimal exposure to certain qualitative research methods. Additionally, tools like Google Forms and email are used less frequently for data collection, reflecting gaps in digital literacy with these platforms. Advanced tools such as NVIVO, STATA, and Activity Insight are also less commonly utilized, underscoring the need for expanded training in digital research resources [7].

Environmental and resource limitations significantly hamper scientific research in many developing countries. Numerous research laboratories face challenges such as outdated or malfunctioning equipment, with repairs often delayed. Moreover, research materials are frequently costly and difficult to acquire. Many developing regions lack access to modern computers, specialized software, and high-speed internet, limiting engagement with global research developments and hindering collaborative efforts [8].

Academic, social networking sites are valuable platforms for sharing research, building academic networks, and increasing visibility, yet their use remains limited in developing countries due to several factors, such as insufficient Internet access, limited awareness, and lack of digital literacy [9].

Health research is essential to address specific health challenges, promote equity, and support economic growth. However, many developing countries face barriers such as insufficient research funding, limited training resources, inadequate infrastructure, and weak ethical standards. In addition, health research is often given low priority, while access to vital health information is constrained by high publishing costs and limited internet access [10].

Among the constraints in the field of scientific research are limited funding, lack of infrastructure and equipment, and brain drain of talented scientists in developed countries [11].

3. The Challenges of Scientific Research in Developing Countries

Scientific research in developing countries faces numerous, complex challenges that inhibit progress and stymie development. Overcoming these challenges is vital for developing countries to leverage scientific research as a catalyst for social and economic advancement.

In developing countries, scientific research faces critical obstacles across multiple dimensions, and many studies have discussed these challenges [8], [12], [13]. The main challenge is the limited infrastructure and resources, including outdated equipment, lack of functional laboratory spaces, and minimal access to modern research tools, severely restricting innovation. Insufficient training programs further limit skill-building, especially in health and biomedical research, where essential competencies like research methodology, critical thinking, and evaluation are often missing. Language barriers also pose a significant challenge.

Moreover, access to high-speed internet and research databases is crucial for staying connected with worldwide scientific developments, but researchers often lack these resources, preventing them from participating fully in the global scientific community. Financial constraints remain a

persistent barrier, limiting funding for laboratory maintenance, supplies, and research staff. This financial shortfall significantly narrows the scope and quality of research, impacting progress across scientific fields.

In addition, conducting research within diverse socio-political landscapes introduces ethical complexities, particularly in terms of cultural sensitivity and informed consent. Balancing ethical compliance with local values is essential for conducting impactful, respectful research. International collaborations often suffer from inequity, with foreign partners typically controlling project priorities, undermining local research capacity and sustainability. Establishing more balanced partnerships led by local researchers is crucial for aligning research with national needs.

4. AI Tools for Scientific Researchers

Many studies discussed the benefit of digital skills, including AI for scientific research, [14], [15], [16], [17], [18], [19], [20], [9], [21], [22], [23], [2], [24], which can be summarized as follows:

AI is revolutionizing scientific research by enhancing data access, collaboration, analysis, and security, enabling faster and more efficient discoveries. Key resources such as academic databases, open-access repositories, and specialized software allow researchers to collect, analyze, and share data more effectively. Online academic networks, collaborative tools, digital libraries, and remote sensing further support global communication and broaden access across various fields.

Artificial intelligence (AI) and machine learning (ML) accelerate research by automating complex data analysis, detecting patterns, and supporting predictive modeling, aiding in literature reviews and experimental designs. Cloud platforms add scalability and cost-effectiveness, facilitating large-scale data management, analyses, and global collaboration, while blockchain technology ensures data integrity and security through decentralized records, enhancing intellectual property protection and research reproducibility.

Collaboration platforms enable real-time data sharing, promoting interdisciplinary research, while academic networks and open data platforms drive transparency, reproducibility, and innovation. Strong cybersecurity and data privacy protections are essential, creating a secure environment for data sharing. Research management software also supports the research process by organizing data, managing projects, and facilitating collaboration. Together, these digital advancements and AI empower researchers to conduct, share, and validate work more effectively, fueling scientific innovation worldwide.

5. The Digital Empowerment and AI Skills Programs and Initiatives

A notable initiative that has been implemented to support researchers in developing countries is AuthorAID. Established in 2007 by the International Network for Advancing Science and Policy (INASP). AuthorAID aims to enhance the research capabilities of scientists in low- and middle-income nations by providing training, resources, and mentorship in research communication. The main components of AuthorAID are a mentorship program where AuthorAID connects early-career researchers with experienced mentors worldwide, facilitating guidance in research writing, publishing, and career development, workshops and training that organizes workshops on research writing and proposal development in various countries across Africa, South Asia, and Latin America, aiming to improve the quality and impact of research outputs. The second component is E-Resources and Grants, where AuthorAID offers a comprehensive library of free e-resources on research communication and provides grants to support researchers in attending conferences, organizing local workshops, and participating in intensive courses.

Since its inception, AuthorAID has contributed significantly to building research capacity in developing countries. By June 2012, the mentoring scheme had nearly 5,000 members from over 150 countries. The program's workshops and resources have empowered researchers to publish in peer-reviewed journals, enhancing the visibility and impact of research from these regions [25].

The Africa AI Accelerator program aims to enhance AI capabilities in developing countries. This initiative focuses on building AI skills and fostering workforce development across Africa, particularly within the public sector. The Africa AI Accelerator aims to cultivate a workforce proficient in creating, deploying, and managing AI products and systems. By providing training, resources, and support, the program seeks to bridge the AI skills gap prevalent in many African nations. The key components of this program are capacity building by training individuals and enhancing their technical expertise in AI and data science, resource provision by enabling participants to gain access to necessary tools and platforms and enabling them to develop and implement AI solutions effectively, support systems including ongoing mentorship and guidance are provided to ensure the successful application of acquired skills in real-world scenarios [26].

6. Literature Studies

[27] Mannuru et al., 2023 explored the transformative potential of generative artificial intelligence (AI) in developing countries, emphasizing its role in economic growth, education, healthcare, industry, and environmental management. While generative AI presents significant opportunities, such as improving accessibility, automating tasks, and fostering innovation, the study also highlights

critical challenges like infrastructure deficits, inequitable access, potential job displacement, and ethical concerns.

[2] Christou, 2023 examines the integration of artificial intelligence (AI), particularly deep learning models like GPT, into qualitative research. It highlights AI's potential to enhance literature reviews, data analysis, and theoretical conceptualization by automating complex tasks, identifying patterns, and generating insights. However, it emphasizes the need for ethical vigilance, transparency, and critical evaluation to avoid biases and misinformation inherent in AI-generated outputs.

[28] Shaqra, 2023 explores the role of artificial intelligence in enhancing leadership skills among academic leaders in public and private universities in the northern region, as perceived by faculty members. The findings indicated that, overall, the role of artificial intelligence in improving leadership skills was rated as moderate. Additionally, the results revealed statistically significant differences based on gender, favoring males, and university type, favoring public universities. However, no statistically significant differences were observed based on academic rank. The study recommended encouraging academic leaders in universities to integrate artificial intelligence programs into their practices.

[29] Darawsheh et al., 2023 explore the integration of artificial intelligence (AI) by academic leaders in Jordanian universities and its relationship to the teaching competencies of faculty members. Conducted during the 2022/2023 academic year, the study employed a descriptive relational approach and surveyed 350 faculty members from public and private universities in Jordan's northern region. The findings revealed that academic leaders use AI extensively, particularly in academic and human resource domains, and faculty members demonstrate high levels of technological teaching competencies, which are vital for modern educational environments.

[1] Akkoyunlu et al., 2010 aim to create a reliable scale to measure digital empowerment among university students. The study developed a scale with 45 items, based on a seven-point Likert scale, aimed at assessing students' digital empowerment. The final scale, after refinement, includes four main components: Awareness, Motivation, Technical access, and Empowerment. The study emphasizes the role of educational institutions in preparing students for a digitally empowered life, arguing that those without access to digital technology may face significant disadvantages.

[6] Kumar, 2023 discusses the concept of digital empowerment in the context of India and highlights its significance within the Digital India initiative. Digital India Initiative was launched in 2015, and this program aims to transform India into a digitally empowered society. The initiative focuses on providing digital infrastructure, services, and resources to ensure equitable access, especially for underprivileged and marginalized populations. The primary goal of Digital India is to foster inclusive growth through digital services, products, and job opportunities. This includes offering high-speed internet, real-time governance platforms, and digital tools to rural communities, thereby promoting social and economic growth. The study lists some challenges in digital empowerment, such as lack of infrastructure, digital literacy, digital divide, cost, and security.

[8] Badr, 2018 explores the environmental and resource-related obstacles that hinder scientific research in developing countries. Many research labs in developing countries operate with outdated or non-functional equipment, facing delays in repairs due to dependence on foreign suppliers. Moreover, certain research materials, like chemicals and isotopes, are costly and hard to obtain, limiting research scope and timeliness. Developing countries often lack modern computers, specialized software, and high-speed internet, which hampers access to global research developments and impedes collaboration. In addition, laboratories frequently lack basic amenities, adequate workspace, and essential supplies, contrasting with facilities in developed nationsThe author concludes that despite these obstacles, prioritizing investment in scientific research could empower developing nations to address broader social and economic issues more effectively.

[7] Gbore et al. 2024 explore the awareness of final-year students at Adekunle Ajasin University, Nigeria, of various technological methods and tools for data collection and analysis. They discovered that students were familiar with common methods such as questionnaires and experiments but showed low awareness of focus group discussions, indicating limited exposure to some qualitative methods. However, tools such as computer-aided applications, social media, and audio-visual tools were well known. Google Forms and email were used less frequently for data collection, indicating gaps in digital literacy about these tools. There is less awareness of analytical tools, where SPSS and Microsoft Excel were the most popular tools for data analysis among students, while advanced tools such as NVIVO, STATA, and Activity Insight were less popular. The study concludes with recommendations for universities to enhance students' awareness and practical skills through workshops and training on various technology tools to better equip them for research tasks.

[3] Al-Shammari 2024 identifies several AI tools that support researchers, including tools for automated reference searches, text translation, statistical analysis, and data management. Specific AI applications mentioned include Google Scholar, Scalar, and Data Search, which help researchers find relevant studies, organize their references, and analyze large datasets. These tools improve the efficiency

of retrieving and processing research materials, making it easier for postgraduate students to conduct high-quality research. The study recommends the integration of AI applications into postgraduate studies by creating dedicated spaces within universities where students can access and learn to use these technologies. It also suggests that universities should provide training programs to help students effectively utilize AI in their research, thus enhancing their analytical and critical thinking skills. Additionally, it calls for increased investment in AI tools to ensure accessibility for all students, allowing them to benefit from AI's capabilities in literature review, statistical computations, and academic writing.

[4] Hazari 2024 outlines a structured roadmap for the impact of AI on academic integrity and higher education policy, divided into three levels. At the micro level, the focus is on teachers, ensuring academic quality and integrity while integrating AI ethically. It examines the role of AI in student assessments, the effectiveness of AI-generated feedback versus human feedback, and its impact on students' cognitive and interpersonal skills. The meso level addresses university administrators and faculty leaders, analyzing the cost-benefit of AI in education, its long-term impacts on student thinking and industry needs, and its potential to enhance equity in assessments. It also explores the role of AI in preparing students for the labor market and its impact on teacher-student relationships. At the macro level, policymakers assess the legal and ethical dimensions of AI in education, its impacts on employability and economic mobility, and how universities can balance autonomy with collaboration with technology companies. The study also highlights the need for global collaboration to ensure ethical AI practices.

[10] Rahman et al. 2020 examine the biomedical research landscape in developing countries, focusing on the challenges and opportunities inherent in these regions. Health research is critical to addressing unique health burdens, promoting equity, and fostering economic growth. However, many developing countries face barriers such as inadequate research funding, limited training facilities, lack of research infrastructure, and inadequate ethical standards. Furthermore, health research is often given low priority, and access to health information is restricted by high publishing costs and limited internet availability.

[14] Laar et al. 2017 emphasized the critical role of human capital and 21st-century digital skills in driving innovation and competitiveness in the knowledge economy. Although 21st-century skills are essential, their digital aspect remains underdeveloped. The research aimed to (1) explore the relationship between 21st-century and digital skills and (2) create a framework for 21st-century digital skills tailored to knowledge workers. After screening 1,592 articles, 75 met the criteria for analysis. Findings indicate that 21st-century skills are broader and more conceptual than digital skills, with the latter often relying on ICT. The proposed framework includes seven core skills (technical, information management, communication, collaboration, creativity, critical thinking, and problem-solving) and five contextual skills (ethical awareness, cultural awareness, flexibility, self-direction, and lifelong learning).

[20] Nath et al. 2019 highlight that cloud computing offers cost-effective and scalable resources, enabling researchers to access powerful computational tools without heavy investments in infrastructure. It enhances collaboration by allowing remote, real-time data sharing, which supports teamwork across locations. With robust data storage and security features, cloud computing ensures data safety and reliability while also reducing environmental impact by minimizing the need for individual data centers. Overall, cloud computing provides an accessible, efficient platform that accelerates scientific research progress.

[4] Sunil Hazari discusses the need for AI literacy courses in higher education. It highlights the ethical concerns, biases, and responsible use of AI while proposing a roadmap for integrating AI literacy into higher education curricula for implementing AI education. The study emphasizes that students must develop awareness, skills, and practical applications to navigate an AI-driven world effectively.

7. Research Methodology

This study employs a rigorous mixed-methods approach, as outlined by Dawadi 2021[30], to explore the integration of AI in scientific research within developing countries. An extensive review of existing literature examines the state of research in these regions, identifying critical challenges such as infrastructure limitations and gaps in digital literacy. Building on this foundation, the study highlights essential AI skills, including data literacy and collaborative AI tools, that researchers need to engage effectively in the global scientific community. Using these insights, it proposes a structured roadmap for empowering researchers with AI, emphasizing strategic technology integration to overcome financial and logistical barriers and enhance their contributions to scientific progress.

8. Analysis and Discussion

From the above studies, the challenges faced by researchers, especially in developing countries, can be categorized into four main areas: institutional support, access to references, technical skills and digital tools, and economic and environmental constraints. One of the main issues is the lack of institutional support, which is manifested in limited training opportunities and the absence of structured mentoring for researchers. Without institutional support, researchers struggle to access necessary resources and professional development programs, which hinders their ability to conduct high-quality research. Another significant challenge is access to references, especially paid academic resources. Many

researchers in developing countries cannot afford expensive journal subscriptions, which limits their exposure to the latest scientific developments. In addition, language barriers limit access to critical research, as much of the leading academic literature is published in English, making it difficult for non-native speakers to fully engage with the material. The lack of technical skills and digital tools is also a major obstacle. Many researchers face inadequate digital literacy, which limits their ability to use artificial intelligence tools, data analysis software, and online research platforms. Even when researchers have the necessary skills, they often face difficulty accessing basic tools, either due to high costs or their unavailability in their regions.

Furthermore, a lack of knowledge about AI applications in research prevents them from leveraging the technology to advance their work. Finally, economic and environmental constraints significantly impact research progress. Poor financial support limits researchers' ability to attend conferences, receive high-quality training or invest in specialized programs. In addition, infrastructure issues, such as unreliable internet access, outdated computer systems, and inadequate research facilities, limit opportunities for innovation and collaboration. Addressing these challenges requires a comprehensive approach, including increased institutional support, increased access to research resources, digital literacy training, and financial investment in research infrastructure. In an attempt to solve or mitigate these challenges, the researcher in the current study aimed to develop a roadmap that takes into account the financial constraints of developing countries.

Building on insights from previous studies that consider the challenges, the current research has developed a tailored roadmap designed to meet the unique challenges of developing countries with limited resources. Digital empowerment, including AI skills, represents a transformative opportunity for these nations to elevate scientific research, ultimately driving broader socio-economic development and national progress. Recognizing the economic constraints that many developing countries face, this study carefully integrated cost-effective implementation mechanisms into the roadmap. Additionally, robust monitoring and evaluation frameworks were incorporated to ensure the effectiveness and sustainability of the proposed initiatives, enabling measurable progress while optimizing resource use.

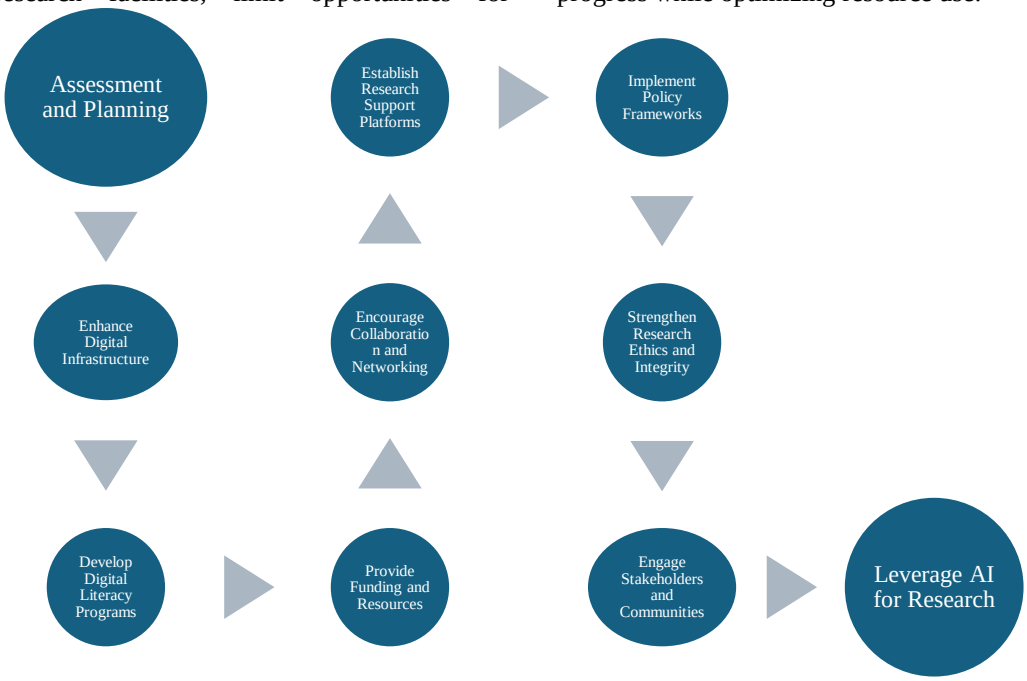

Fig. 1 Roadmap to empower researchers in AI skills [author]

9. Roadmap to Empower Researchers in AI Skills

The proposed roadmap relies on a specially trained local technical team to implement it, which significantly reduces costs compared to hiring external companies. This roadmap focuses primarily on empowering researchers in developing countries with AI skills, where financial and infrastructure constraints are the main challenges. To address these challenges, the roadmap relies on innovative technology-based solutions, often at a fraction of the cost of traditional approaches. By incorporating cost-effective AI tools and methods, the roadmap not only promotes the use of technology in achieving each milestone but also aligns with the ultimate goal of empowering researchers to adopt and use these tools independently. Therefore, it is imperative that the implementation team actively uses these AI tools, both to keep costs low and to demonstrate practical and scalable

applications that are consistent with the vision of sustainable solutions. This roadmap provides a structured approach for stakeholders in developing countries to empower researchers with AI skills in scientific research. Following these stages and steps can effectively address existing challenges and foster a more robust research environment for innovation and sustainable development. The roadmap can be described as follows:

Table 1. The foundation stage

Phases	steps	Process 1	Process 2	Technologies support to reduce cost & budget
Assessment and Planning	Conduct Needs Assessment	Identify specific digital skill gaps and infrastructure limitations in research institutions.	Gather input from stakeholders, including researchers, educators, and policymakers.	– Online surveys and automated data collection tools reduce costs compared to in-person assessments. – Leveraging AI can also help analyze data quickly, identifying key areas for digital empowerment.
	Develop Strategic Plan	Create a comprehensive plan outlining goals, objectives, and resources needed for digital empowerment in research.	Include timelines and measurable outcomes.	
Enhance Digital Infrastructure	Improve Connectivity	Invest in high-speed internet access in rural and underserved areas.	Collaborate with telecom companies to expand coverage.	– Rather than investing in expensive hardware, utilizing cloud services provides scalable, pay-as-you-go infrastructure. – Open-source software for research and collaboration can meet many needs without licensing fees. – Technology companies can offer subsidized or even free services as part of their social responsibility efforts, benefiting infrastructure development.
	Provide Access to Technology	Supply necessary hardware (computers, tablets).	Supply software (research tools, data analysis programs) to institutions.	
Develop Digital Literacy Programs	Curriculum Integration	Collaborate with universities to incorporate digital skills training into existing curricula.	Emphasize essential skills such as data analysis and programming.	– MOOCs and platforms like Coursera and edX offer free or low-cost training modules. – Tailoring these programs for researchers reduces the need for in-person training. – Virtual reality can provide immersive training experiences without physical travel costs, which is useful for laboratory training, complex equipment handling, and more.
	Organize Workshops and Training	Schedule regular training sessions for researchers, faculty, and students on AI tools and research methodologies.		

Table 2. The scientific research stage

Phases	steps	Process	Technologies support to reduce cost & budget
Establish Research Support Platforms	Create Online Research Hubs	Develop platforms for data sharing, collaboration, and access to research resources and facilitate networking opportunities among researchers.	– Centralized digital platforms that promote open-access journals and repositories enable cost-effective knowledge sharing. – ResearchGate and arXiv are prime examples. – AI chatbots can provide researchers with 24/7 assistance on common questions, document submission, and platform use, lowering the need for a large support staff.
	Foster Open Access Publishing	Promote open-access journals and repositories to increase the visibility and accessibility of research findings.	
Encourage Collaboration and Networking	Promote Interdisciplinary Research	Encourage collaboration across different disciplines to address complex research problems.	– Video conferencing (Zoom, Microsoft Teams) and virtual workspaces (Slack, Microsoft SharePoint) minimize the need for expensive conferences and travel. – Platforms like LinkedIn and ResearchGate facilitate mentorship, networking, and collaboration without geographical limitations, helping researchers build international connections.
	Build International Partnerships	Establish collaborations with foreign universities and research institutions to facilitate knowledge transfer.	
Provide Funding and Resources	Allocate Grants for Digital Projects	Offer targeted research grants for projects that incorporate digital technologies.	– Platforms like Experiment.com allow researchers to seek small amounts of funding from a wide audience, creating alternative funding pathways. – Blockchain technology can track and manage funds transparently and efficiently, reducing administrative costs associated with traditional funding disbursement.
	Support Startups and Innovation	Foster the development of startups focusing on digital solutions for research challenges through funding and mentorship.	
Implement Policy Frameworks	Create Supportive Policies	Develop and implement policies that promote digital empowerment in research.	Online policy management tools streamline the creation, tracking, and revision of digital policies, providing a low-cost and efficient alternative to physical documentation. AI can assist in reviewing policy compliance, identifying gaps, and proposing recommendations, which can help develop a robust digital framework.
	Regulate and Standardize Practices	Establish standards for digital research practices to ensure quality and consistency.	

Table 3. The final stage

Phases	steps	Process	Technologies support to reduce cost & budget
Strengthen Research Ethics and Integrity	Provide AI Ethics Training	Train researchers on ethical practices related to data privacy and responsible use of AI tools.	– Software like Turnitin and iThenticate detects plagiarism, while other tools evaluate ethical compliance, ensuring research quality and integrity at a lower cost than manual processes. – Blockchain technology can ensure that research data is tamper-proof and traceable, reinforcing trust in research outputs.
	Monitor Compliance	Implement monitoring systems to ensure adherence to ethical standards in digital research.	
Engage Stakeholders and Communities	Involve Local Communities	Engage communities in research projects to address relevant issues and foster local development.	– Using social media platforms and digital campaigns, research institutions can engage stakeholders at minimal costs, creating awareness and fostering community support. – Mobile platforms allow direct and continuous communication with communities, increasing engagement without the expense of physical meetings or events.
	Promote Public Awareness	Conduct awareness campaigns about the importance of scientific research and digital empowerment.	
Leverage AI for Research	Use Data Analytics	Encourage the use of data analytics in research to enhance research.	– Free or low-cost data analytics tools, like Google Analytics or Tableau Public, can be used to process and interpret large datasets for informed decision-making. – AI algorithms can identify trends and predict future research needs, enabling proactive decision-making and efficient resource allocation.
	Establish Data Repositories	Create national or regional repositories to facilitate data sharing and collaboration among researchers.	

Tables 1, 2, and 3 outline a comprehensive roadmap for enabling AI skills for researchers in developing countries. The approach begins with a baseline stage (table 1) of assessment and planning, with a focus on identifying digital skills gaps and infrastructure constraints in research institutions. Initial steps should include conducting needs assessments and gathering input from researchers, educators, and policymakers. This assessment informs a strategic plan, detailing goals, objectives, timelines, and resources needed to facilitate and enable the use of AI tools in scientific research. Improving digital infrastructure is also prioritized, with affordable solutions such as cloud services and open-source software recommended to reduce costs while expanding access. Emphasis is placed on basic digital literacy to enable AI skills, and emphasis is placed on integrating digital skills, including AI, into existing university curricula. This approach ensures that researchers acquire essential skills from an early stage. To support scalability, digital training tools such as massive open online courses and virtual reality provide immersive and cost-effective learning experiences that reduce the need for in-person training.

For the research-focused stage (table 2), the roadmap calls for the creation of online platforms to support data exchange and collaboration and to encourage open publishing and interdisciplinary research. Tools such as ResearchGate and others facilitate communication and knowledge exchange, reducing reliance on physical resources. Collaboration is also

supported through video conferencing and virtual workspaces, which help overcome geographical barriers and enable international partnerships. Building networks is essential to developing interdisciplinary solutions to complex research problems and fostering a culture of cross-border collaboration. Funding and resource allocation are handled through alternative channels, such as platforms that enable crowdfunding of digital projects. Blockchain technology is proposed to transparently manage and track funding, reducing the administrative costs often associated with grant disbursements. A supporting policy framework is also essential; establishing policies for digital research practices and standards ensures quality and consistency. AI tools help manage policies by identifying compliance gaps and streamlining reviews.

The final stage (table 3) of the roadmap focuses on ethical research practices. Training researchers in digital ethics is essential to maintaining integrity, and technologies such as plagiarism detection software and blockchain ensure adherence to ethical standards. Community engagement is enhanced through local participation in research projects, ensuring that work addresses relevant issues and benefits local development. Digital campaigns and mobile platforms enable low-cost connectivity, enhancing stakeholder engagement and awareness. Data analytics is a critical tool for informed decision-making, enabling researchers to process and interpret large datasets, identify trends, and predict future needs. The creation of regional data repositories further supports data sharing and collaboration, enabling researchers to access valuable information to enhance their research.

At all stages, the roadmap emphasizes the use of affordable technology solutions—such as AI, cloud services, and open-source software to reduce costs while maximizing research capacity and outreach. This structured approach provides a robust path to empower researchers and elevate the role of AI tools in advancing sustainable research.

10. Monitoring and Evaluation Methods

Table 4 below shows several tools and methods to monitor and evaluate the progress of the roadmap. Surveys and questionnaires gather feedback on researchers' skill development and challenges, while performance analytics offer objective insights into their adoption and use of AI tools. Workshops and focus groups provide platforms for hands-on learning and in-depth discussions to refine the roadmap, whereas an LMS centralizes training resources, tracks progress and evaluates engagement. Finally, KPIs set measurable goals to monitor progress and ensure accountability, aligning outcomes with strategic objectives [31], [32], [33], [34]

Table 4. Methods and tools to monitor and evaluation the progress of the roadmap

Tool	Purpose	Application	Example
Surveys and Questionnaires	Gather feedback to assess progress and identify challenges.	Conduct pre- and post-implementation surveys to measure changes in skills and collect qualitative data.	Include questions on familiarity with AI tools, practical application, and satisfaction with training.
Performance Analytics	Measure the usage and success of AI tools and techniques.	Track metrics like tool usage frequency, AI-integrated projects, or publications using analytics tools.	Monitor usage of an AI training portal or contributions to AI-driven research.
Workshops and Focus Groups	Provide real-time insights and adjust strategies as needed.	Host workshops and focus groups to observe skill application and gather live feedback.	Evaluate engagement and identify gaps during hands-on AI tool sessions.
Digital Learning Management Systems (LMS)	Centralize training resources and track progress.	Use LMS platforms to assign training modules, track completion, and analyze engagement.	Platforms like Moodle or Blackboard can host content and provide detailed analytics.
Key Performance Indicators (KPIs)	Provide measurable benchmarks to evaluate success.	Define KPIs (e.g., number of researchers trained, AI-based project outcomes) and review regularly.	Achieve a 50% increase in AI-related publications within two years.

11. Comparison Study

The roadmap in the current research was compared with the roadmap in other research with a similar objective to the current research objective as follows:

Several studies have adopted the research roadmap approach to address different aspects of AI and higher education. However, they differ in focus, scope, and implementation strategies compared to the current study, which aims to empower researchers in developing countries with AI skills while ensuring cost-effective and sustainable implementation.

1. The roadmap proposed by Castelló-Sirvent [5] focuses on enhancing academic integrity in scientific research through four key areas: education, attitudes, machine learning, and technology design. This roadmap provides guidance for policymakers, university leaders, and educators to address the ethical and practical challenges of AI while maintaining research integrity.

   Key Difference: While Castelló-Sirvent's [5] roadmap centers on academic integrity and ethical AI use in research, the current study emphasizes empowering researchers in developing countries with AI skills, equipping them to overcome financial and infrastructure barriers.

2. [4] Hazari's roadmap outlines a three-stage process for integrating AI knowledge into higher education: AI Awareness – Introduction to AI concepts, terminology, and ethical considerations; practical AI Applications – Hands-on experience with AI tools in research and industry, AI in Real-World Scenarios – Applying AI to academic writing, research, and professional tasks. While this roadmap offers a structured but simplified integration of AI into higher education, the current study's roadmap is more detailed and includes cost-reduction mechanisms and monitoring tools, making it more comprehensive and suitable for resource-limited settings.

   Key Difference: Hazari's [4] roadmap primarily focuses on student AI education, whereas the current study prioritizes researchers' empowerment in developing countries by providing practical AI skills and addressing cost constraints through localized technical teams.

3. [35] Holmes et al. propose a roadmap structured around three dimensions:

   Learning with AI (AI-powered tools in education), Learning about AI (teaching AI concepts), and Readiness for AI (addressing ethical and societal impacts).

   This roadmap also introduces a timeframe-based approach—now, next, and later—highlighting AI developments, challenges, and enablers to support higher education in European countries (Denmark, Portugal, and the UK).

   Key Difference: The current study diverges by focusing on empowering researchers in developing countries rather than general AI adoption in European higher education. It also integrates cost-effective implementation strategies, ensuring accessibility in resource-constrained environments.

4. [36] Anh's roadmap emphasizes the role of technology in making higher education more accessible and engaging. It explores the potential of AI-powered tools such as adaptive learning systems, intelligent tutoring, and data-driven assessments to enhance education.

   Key Difference: Unlike [36] Anh's roadmap, which broadly discusses technology's impact on education, the current study is centered on AI-driven researcher empowerment, particularly in developing countries where financial and infrastructure limitations exist.

The roadmap proposed in this study differs significantly from previous research in several ways:

- Target Audience: Focuses on empowering researchers in developing countries rather than academic integrity, student learning, or AI policy in developed nations.
- Implementation Strategy: Relies on a specially trained local technical team, reducing costs compared to hiring external companies.
- Sustainability & Cost-Effectiveness: Suggests low-cost AI tools and scalable solutions to overcome financial and infrastructure constraints.
- Monitoring & Evaluation: Includes follow-up tools to ensure effective implementation and impact measurement.
- Scalability: Designed to be replicable and adaptable across various developing regions.

By following this roadmap, stakeholders in developing countries can empower researchers with AI skills for scientific research, fostering innovation and sustainable development despite financial and infrastructural limitations.

12. Conclusion

This paper highlights the transformative potential of AI to enable researchers in developing countries to advance their research despite the significant challenges they face. The findings of the current study are consistent with the study of Al-Shammari, R. (2024) by identifying the most important challenges and also recommending the importance of AI skills to support research, which was the same recommendations of [7] and [3].

A structured roadmap is proposed that focuses on effective and cost-effective solutions by leveraging digital and AI tools, which also help track the implementation of the

roadmap and assess progress. Ultimately, this approach not only enhances the capacity of researchers but also drives broader social and economic development and innovation in resource-constrained environments.

The researcher in this study possesses a deep understanding of the challenges faced by researchers in developing countries, particularly the obstacles that hinder universities and other institutions from equipping scholars with artificial intelligence skills. Drawing on this expertise, the study presents a roadmap tailored to the realities of developing nations, ensuring practical implementation while emphasizing cost-effective solutions to maximize accessibility and impact.

Recommendations

Strengthening digital skills to advance scientific research in developing countries requires collaboration between governments, universities, scientific institutes, and individuals. Each plays a critical role:

- Governments: Develop and implement a comprehensive roadmap that prioritizes digital literacy in education and allocates resources to improve digital infrastructure, such as internet connectivity and access to technology, especially in remote areas.
- Universities and scientific institutes: Update curricula to integrate AI skills training and encourage interdisciplinary research using AI tools to address local and global challenges. Provide and enhance digital resources, such as databases, software, and online platforms, to support scientific research.
- Individuals (researchers and students): Actively pursue lifelong learning through online courses, workshops, and self-study. Participate in local digital literacy programs and build professional networks through conferences, seminars, and social media to foster collaboration and skills development.

References

[1] Buket Akkoyunlu, Meryem Yilmaz Soylu, and Mehmet Caglar, "A Study on Developing "Digital Empowerment Scale" for University Students," *Hacettepe University Journal of Education*, vol. 39, pp. 10-19, 2010. [Google Scholar] [Publisher Link]

[2] Prokopis A. Christou, "How to Use Artificial Intelligence (AI) as a Resource, Methodological, and Analysis Tool in Qualitative Research?," *The Qualitative Report*, vol. 28, no. 7, pp. 1968–1980, 2023. [CrossRef] [Google Scholar] [Publisher Link]

[3] Radi Turkaa Eadhbi Al-Shammari, "The Extent to which Artificial Intelligence Applications Contribute to Developing Research Skills Among Postgraduate Students at The University of Hafr Al-Batin," *Journal of the College of Education*, vol. 40, no. 10.2, pp. 254-277, 2024. [CrossRef] [Google Scholar] [Publisher Link]

[4] Sunil Hazari, "Justification and Roadmap for Artificial Intelligence (AI) Literacy Courses in Higher Education," *Journal of Educational Research and Practice*, vol. 14, no. 1, pp. 106-118, 2024. [CrossRef] [Google Scholar] [Publisher Link]

[5] Fernando Castelló-Sirvent, Vanessa Roger-Monzó, and Ricardo Gouveia-Rodrigues, "Quo Vadis, University? A Roadmap for AI and Ethics in Higher Education," *Electronic Journal of e-Learning*, vol. 22, no. 6, pp. 35-51, 2024. [CrossRef] [Google Scholar] [Publisher Link]

[6] Sanjay Kumar, "Digital Empowerment: Need and Challenges in 2023," *IOSR Journal of Business and Management*, vol. 25, no. 5, pp. 44–49, 2023. [Publisher Link]

[7] Oladele Stephen Gbore, Peter Joy Abosede, and Onasanya Samuel Adebisi, "Undergraduates' Awareness of the use of Technological Tools for Information Collection and Analysis," *Indonesian Journal of Educational Research and Technology*, vol. 4, no. 2, pp. 105–112, 2024. [Google Scholar]

[8] Mostafa Z. Badr, "Challenges Facing Scientific Research in Developing Countries: 1. Environment and Resources," *Egyptian Journal of Basic and Clinical Pharmacology*, vol. 8, pp. 1-3, 2018. [Google Scholar]

[9] Mumtazimah Mohammad, Yuzarimi M. Lazim, and Suharmili Rosle, "Academic Social Network Sites: Opportunities and Challenges," *International Journal of Engineering & Technology*, vol. 7, no. 3.13, pp. 133-136, 2018. [Google Scholar]

[10] M. Masudur Rahman et al., "Biomedical Research in Developing Countries: Opportunities, Methods, and Challenges," *Indian Journal of Gastroenterology*, vol. 39, pp. 292–302, 2020. [CrossRef] [Google Scholar] [Publisher Link]

[11] Eva Harris, "Building Scientific Capacity in Developing Countries," *EMBO Reports*, vol. 5, no. 1, pp. 7–11, 2004. [CrossRef] [Google Scholar] [Publisher Link]

[12] Fikri M. Abu-Zidan, and Diaa E.E. Rizk, "Research in Developing Countries: Problems and Solutions," *International Urogynecology Journal*, vol. 16, pp. 174–175, 2005. [CrossRef] [Google Scholar] [Publisher Link]

[13] Leo Tan Wee Hin, and Ramanathan Subramaniam, *Challenges Facing Developing Countries in Communicating Science to the Public*, Communicating Science to the Public, Springer, Dordrecht, pp. 213-222, 2014. [CrossRef] [Google Scholar] [Publisher Link]

[14] Ester Van Laar et al., "The Relation between 21st-Century Skills and Digital Skills: A Systematic Literature Review," *Computers in Human Behavior*, vol. 72, pp. 577–588, 2017. [CrossRef] [Google Scholar] [Publisher Link]

[15] Rosario Ruvi et al., "Digital Competence in Scientific Research in Higher Education," *International Journal of Health Sciences*, vol. 6, no. S5, pp. 5778-5787, 2022. [CrossRef] [Google Scholar] [Publisher Link]

[16] Pilar Colás-Bravo, Jesus Conde-Jiménez, and Salvador Reyes-de-Cózar, "Sustainability and Digital Teaching Competence in Higher Education," *Sustainability*, vol. 13, no. 22, pp. 1-17, 2021. [CrossRef] [Google Scholar] [Publisher Link]

[17] Oleksandra Patriak, "Digital Skills in Modern Business Models," *Digital Platform: Information Technologies in Socio-Cultural Sphere*, vol. 6, no. 2, pp. 419-430, 2023. [CrossRef] [Publisher Link]

[18] Kim N. Blankendaal-Tran, Ralph F.G. Meulenbroeks, and Wouter R. Van Joolingen, "Digital Research Skills in Secondary Science Education: A Guiding Framework and University Teachers' Perception," *European Journal of STEM Education*, vol. 8, no. 1, pp. 1-14, 2023. [CrossRef] [Google Scholar] [Publisher Link]

[19] Ilya Zulaikha Zulkifli et al., "Examining Digital Literacy Towards ICT Among Students Based on Demographic Profile: A Descriptive Analysis Approach," *International Journal of Academic Research in Progressive Education and Development*, vol. 12, no. 2, pp. 1049-1060, 2023. [CrossRef] [Publisher Link]

[20] Mahendra Prasad Nath et al., "Cloud Computing: An Overview, Benefits, Issues & Research Challenges," *International Journal of Research and Scientific Innovations*, vol. 6, no. 2, pp. 25-35, 2019. [Google Scholar] [Publisher Link]

[21] Fusheng Wang et al., "Web-Based Collaborative Information Integration for Scientific Research," *2007 IEEE 23rd International Conference on Data Engineering*, Istanbul, Turkey, pp. 1232-1241, 2007. [CrossRef] [Google Scholar] [Publisher Link]

[22] Attipa Julpisit, and Vatcharaporn Esichaikul, "A Collaborative System to Improve Knowledge Sharing in Scientific Research Projects," *Information Development*, vol. 35, no. 4, pp. 624–638, 2019. [CrossRef] [Google Scholar] [Publisher Link]

[23] Iqbal H. Sarker et al., "Cybersecurity Data Science: An Overview from Machine Learning Perspective," *Journal of Big Data*, vol. 7, pp. 1-29, 2020. [CrossRef] [Google Scholar] [Publisher Link]

[24] Avner Barnea, "How will AI Change Intelligence and Decision-Making?," *Journal of Intelligence Studies in Business*, vol. 10, no. 1, pp. 75–80, 2020. [CrossRef] [Google Scholar] [Publisher Link]

[25] A Global Network of Researchers, AuthorAID. [Online]. Available: https://www.authoraid.info/en/

[26] The Africa AI Accelerator. [Online]. Available: https://africaai2.netlify.app/#/

[27] Nishith Reddy Mannuru et al., "Artificial Intelligence in Developing Countries: The Impact of Generative Artificial Intelligence (AI) Technologies for Development," *Information Development*, 2023. [CrossRef] [Google Scholar] [Publisher Link]

[28] Rawan Khader Abu Shaqra, "The Role of Artificial Intelligence in Enhancing the Leadership Skills of Academic Leaders in Public and Private Universities in the Northern Region from the Point of View of Faculty Members," *Journal of Namibian Studies: History Politics Culture*, vol. 37, pp. 290–320, 2023. [CrossRef] [Publisher Link]

[29] Najwa Abdel Hamid Darawsheh et al., "The Degree of Using Artificial Intelligence Among Academic Leaders in Jordanian Universities and its Relationship to Teaching Competencies of Faculty Members," *Journal of Namibian Studies: History Politics Culture*, vol. 34, pp. 4904–4926, 2023. [CrossRef] [Google Scholar] [Publisher Link]

[30] Saraswati Dawadi, Sagun Shrestha, and Ram A. Giri, "Mixed-Methods Research: A Discussion on its Types, Challenges, and Criticisms," *Journal of Practical Studies in Education*, vol. 2, no. 2, pp. 25–36, 2021. [CrossRef] [Google Scholar] [Publisher Link]

[31] David A. Bishop, "Key Performance Indicators: Ideation to Creation," *IEEE Engineering Management Review*, vol. 46, no. 1, pp. 13–15, 2018. [CrossRef] [Google Scholar] [Publisher Link]

[32] Tony Johnstone Young, *Questionnaires and Surveys*, Research Methods in Intercultural Communication: A Practical Guide, Oxford: Wiley, 2015. [CrossRef] [Google Scholar] [Publisher Link]

[33] Waleed Akhtar M. Sultan, "Key Performance Indicators (KPIs), Key Result Indicator (KRIs), and Objectives and Key Results (OKRs): A New Key Incorporated Results (KIRs) Approach," *Information and Knowledge Management*, vol. 13, no. 2, pp. 1-13, 2023. [CrossRef] [Google Scholar] [Publisher Link]

[34] Anna Raffoni et al., "Business Performance Analytics: Exploring the Potential for Performance Management Systems," *Production Planning & Control*, vol. 29, no. 1, pp. 51–67, 2018. [CrossRef] [Google Scholar] [Publisher Link]

[35] W. Holmes, J. Bidarra, and H. Køhler Simonsen, *Artificial Intelligence in Higher Education: A Roadmap and Future Perspectives*, Smart Learning: Copenhagen, Denmark, pp. 121-138, 2021. [Google Scholar] [Publisher Link]

[36] Vo Thi Kim Anh, "Reimagining Higher Education: A Roadmap for the 21st Century," *Vinh University Journal of Science*, vol. 53, no. 2, pp. 221-232, 2024. [CrossRef] [Google Scholar] [Publisher Link]