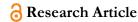
Journal of Research in Environmental and Science Education

ISSN 3062-8660 (online) & 3062-8431 (print) July 2025, Vol. 2, No. 2, pp. 68–80





Integrating Artificial Intelligence in STEM Education: Enhancing 21st Century Skills in Zimbabwean Universities

Doris Chasokela¹ [□]



¹Department of Technical and Engineering Education and Training, National University of Science and Technology, Zimbabwe

Abstract

In recent years, integrating Artificial Intelligence (AI) into STEM education has emerged as a critical focal point in Zimbabwean universities, aimed at enhancing essential 21st-century skills among students. As AI continues to exert transformative effects across various sectors, it becomes imperative for students to cultivate the competencies necessary to thrive in an increasingly AI-driven economy. This qualitative study investigates the nuances of AI integration within the STEM educational framework in Zimbabwe, emphasising the potential benefits, prevailing challenges, and strategic methodologies for successful implementation. To gather comprehensive insights, semi-structured interviews were conducted with 30 diverse participants, including students, lecturers, university administrators, and industry experts. Thematic analysis of the data collected unveiled three central themes: the urgent need for AI literacy and skill development, the significance of contextualised learning through industry partnerships, and the existing challenges related to infrastructure and resource limitations. Findings from this study underscore the necessity for a holistic approach toward AI integration in STEM education. It highlights the critical role of curriculum development that encompasses AI technologies, ongoing faculty training to keep lecturers abreast of evolving trends, and collaborative efforts with industry stakeholders to ensure relevant and up-to-date learning experiences. Furthermore, the recommendations derived from this research hold potential implications for educational policy and practice, not only within Zimbabwe but also for other developing nations grappling with similar challenges. By promoting an AI-enhanced educational framework, Zimbabwean universities can better prepare their students to meet the demands of the modern workforce and cultivate a generation equipped with the relevant skills needed for success in the complex landscape of the 21st century.

Keywords: Artificial Intelligence, Enhanced Learning Materials, STEM Education, 21st-Century Skills

☑ Correspondence Doris Chasokela dchasokela@gmail.com

Received November 17 2024 Accepted March 30, 2025 Published July 1, 2025

Citation: Chasokela, D. (2025). Integrating artificial intelligence in STEM education: Enhancing 21st century skills in Zimbabwean universities. Journal of Research in Environmental and Science Education, 2(2), 68-80.

DOI: 10.70232/jrese.v2i2.16

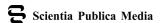
© 2025 The Author(s). Published by Scientia Publica Media



This is an open access article distributed under the terms of the Creative Commons Attribution-NonCommercial License.

1. INTRODUCTION

The world is experiencing a significant transformation in the way we live, work, and learn, driven by evolving advancements in Artificial Intelligence (AI) (Goralski & Tan, 2020; Makridakis, 2017). As AI continues to revolutionise various industries and sectors, the demand for professionals with AI-related skills and knowledge is increasing exponentially (Miailhe & Hodes, 2017; Sofia et al. 2023). In response, educational institutions, particularly universities, are faced with the challenge of preparing students for this AI-driven future. In Zimbabwe, where the government has prioritised Science and technology. Engineering and Mathematics (STEM) education is a key driver of economic development, universities are poised to play a critical role in developing the country's AI talent pool. However, AI integration in STEM education poses significant challenges, including inadequate infrastructure, limited resources, and a shortage of qualified lecturers (Moyo et al. 2022). Against this backdrop, this article explores the role of AI in enhancing 21st-century skills in Zimbabwean universities, with a specific focus on STEM education. The current state



of AI integration in Zimbabwean universities, the benefits and challenges of AI-enhanced learning, and the strategies and initiatives that can be implemented to support the development of AI-related skills and knowledge are examined. By investigating these issues, researchers aim to contribute to the conversation on the future of education in the AI era that is revolving and provide insights that can inform policy and practice in Zimbabwe and beyond.

Artificial Intelligence (AI) integration in Zimbabwean universities is crucial for developing 21st-century skills in STEM education, but the current lack of AI literacy and skills development among students, inadequate infrastructure and resources, and limited industry partnerships pose significant challenges to effective integration. As a result, Zimbabwean universities are failing to impart the necessary skills to students to succeed in an AI-driven economy, compromising their employability and competitiveness in the global market. The study is underpinned by the following research questions:

- 1. What are the current challenges and opportunities in integrating AI in STEM education in Zimbabwean universities?
- 2. How do students and lecturers perceive the effectiveness of AI-enhanced learning materials in STEM subjects?
- 3. What skills and competencies do STEM graduates need to develop to thrive in an AI-driven economy?

1.1. Literature Review

1.1.1. AI-enhanced learning outcomes in higher education

According to Chen et al. (2020) and Algabri et al. (2021), artificial intelligence (AI) has the potential to transform the learning experience in higher education, leading to significant improvements in learning outcomes. By leveraging AI-powered tools and techniques, lecturers can create personalised learning experiences that cater to individual student's needs, abilities, and learning styles (Kaswan et al. 2024; Srinivasa et al. 2022). Personalised learning paths can be provided including adaptive assessments, and continuous real-time feedback, which can increase student engagement and retention rates. Additionally, students can cultivate essential 21st-century skills including critical thinking and problem-solving skills, through AI-driven problem-solving exercises and simulations (Jaramillo & Chiappe, 2024). AI-enhanced learning outcomes can also lead to increased student success, improved graduation rates, and better preparation for the workforce. In the context of STEM education, AI-enhanced learning outcomes can be particularly valuable, as they can equip students with the skills and competencies required to thrive in emerging industries and technologies (Ang et al. 2020; Pedro et al. 2019). To achieve these outcomes, lecturers can use AI-powered adaptive learning systems, AI-assisted assessments, data analytics, intelligent tutoring systems, and collaborative learning platforms. Implementing AI-enhanced learning outcomes requires a multi-faceted approach (Vashishth et al. 2024). To effectively integrate AI-powered tools into teaching and learning practices, there is a need for professional development opportunities for lecturers. Institutions must also invest in infrastructure development to ensure adequate hardware and software resources for AI-driven learning experiences. Additionally, high-quality educational content must be developed that is tailored to individual students' needs and abilities. Finally, a system for monitoring and evaluating the effectiveness of AI-enhanced learning outcomes must be established, making adjustments as needed. By implementing these strategies, AI can be leveraged by higher education institutions to enhance learning outcomes and improve student success, thus equipping them with 21st-century skills to thrive in a rapidly changing world workforce.

1.1.2. The current state and future directions of STEM education globally, with a focus on AI

The current state of STEM education globally is characterised by an increased focus on STEM subjects, with governments and lecturers recognising their importance for economic growth, innovation, and competitiveness. According to Chan (2023), the government therefore has a major task to fund and support the AI implementation and integration for effective teaching and learning to take place. The industry experts voice up on the need for AI policies to be put in place (Dwivedi, et al. 2021). However, despite efforts, many countries face a shortage of skilled STEM professionals, particularly in areas like AI, data science, and cybersecurity (De Zan, 2022; Mahboubi, 2022). Administrators are facing challenges in

securing funding and developing policy frameworks to support AI integration in the universities (Gumport & Sporn, 1999). Moreover, the digital divide persists, with disparities in access to quality STEM education and technology exacerbating existing inequalities. Furthermore, many countries have incorporated coding and programming into their curricula, starting from primary school levels (Bers, 2018; Webb et al. 2017). Looking ahead to the future of STEM education, AI is expected to play a pivotal role in enhancing teaching methods, personalizing learning, and developing intelligent tutoring systems (Ahmad et al. 2021; Hemachandran, et al. 2022; Mousavinasab et al. 2021). As a result, STEM education focuses on building skills in AI, machine learning, and data science to prepare students for the future workforce (Ilori & Ajagunna, 2020). Immersive technologies such as virtual and augmented reality will become more prevalent in STEM education, enabling experiential learning and simulation-based training (Chasokela, 2024). The emphasis will shift from traditional classroom teaching to lifelong learning and upskilling, as AI's rapid evolution demands continuous learning to address emerging challenges and opportunities. In this AI-driven future, global collaborations and knowledge sharing will become essential, enabling students and lecturers to share resources, best practices, and knowledge across borders (Abulibdeh et al., 2024). In addition to the potential benefits of AI, its development also raises pressing ethical concerns, such as bias, privacy, and explainability (Huang et al., 2022). For the students to be fully prepared to navigate this complex landscape, STEM education must prioritize these issues. The future of STEM education can be molded through fostering collaborative learning among all stakeholders involved. Students will be well-prepared to navigate the future of work, armed with the skills and knowledge needed to succeed in an AI-driven economy.

1.1.3. An overview of the current state and future directions of STEM education in southern Africa, with a focus on Zambia, South Africa, Botswana, and Namibia

The current state of STEM education in Southern Africa is marked by varying degrees of emphasis and initiatives in each country. In Zambia, the government has launched programs such as the Zambia Support to Science and Technology Education Project (SSTEP) to focus on science and math education (African Development Bank Group, 2024). In South Africa, the South African Department of Science and Innovation's (DSI) STEM initiative has been implemented to promote STEM education (Parliamentary Monitoring Group, 2023). Botswana has established initiatives like the Botswana Innovation Hub and the Ministry of Education's STEM program to encourage innovation and STEM education (Botswana Innovation Hub, 2024). Meanwhile, Namibia is working to improve STEM education through programs at the Namibia University of Science and Technology (NUST). However, despite these efforts, challenges persist such as limited resources and infrastructure, a shortage of qualified STEM lecturers, gender disparities in STEM fields, and limited access to technology and the internet are all hurdles that need to be addressed (Barakabitze et al. 2019; Mahboubi, 2022; Means & Neisler, 2020). To move forward, each country is planning to incorporate AI and technology into their education systems and train the lecturers so that they integrate it effectively. In Zambia, the Zambia AI Academy will integrate AI and robotics into education, while in South Africa, the South African AI Institute will focus on developing AI and data science skills. Botswana aims to leverage AI and technology to enhance STEM education and innovation, while Namibia is exploring AI applications in education and healthcare.

Initiatives such as the Southern African Development Community (SADC) STEM program and the African Union's Science, Technology, and Innovation Strategy for Africa (STISA) are driving forward a collaborative approach to STEM education. Looking ahead, it is clear that future directions for STEM education in Southern Africa will include an increased focus on AI, data science, and digital skills. Regional collaborations and knowledge sharing will be essential for addressing gender and geographical disparities in STEM education and developing education that aligns with industry needs. These countries are working to improve STEM education and leverage AI to drive innovation and economic growth. However, challenges persist, and addressing them will be crucial to unlocking the region's full potential.

1.1.4. Zimbabwe STEM education: Current state & AI-driven future

Chitate (2016) and Gweshe & Chiware (2023) cite that STEM education in the current state of Zimbabwe is marked by various initiatives to promote Science, Technology, Engineering, and Mathematics (STEM) education. The government has taken steps to encourage students to take science subjects by

offering free education, including school and boarding fees, to those who take science subjects at their Advanced levels (Gambanga, 2016).

The long-term objective is to boost enrollment rates in STEM degree programs at national universities by providing students with the skills and knowledge necessary to succeed in an AI-driven world, ultimately fostering a highly educated and competitive workforce that can drive innovation and economic growth. In terms of AI-powered tools, they are being used globally to enhance teaching and learning in STEM subjects by accelerating students' holistic development, transforming education systems, and automating routine administrative tasks (Jamro & Jamro, 2023). There is a need for lecturer staff development in the integration of AI in teaching and learning situations (Reuben & Kabilan, 2024). Assessment of University Lecturers' Readiness to Adopt Artificial Intelligence (AI) Technology in North-East of Nigeria. International Journal of Advanced Research in Education and Society, 6(2), 482-490.In Southern Africa, AI technology is being harnessed to revolutionise education, with applications including the assessment of children's literacy skills, pinpointing areas of struggle, and tailoring learning experiences to individual needs. In Zimbabwe, AI-powered tools are also being leveraged to streamline teaching practices, encompassing tasks such as lesson planning and adaptation, grading and feedback provision, teacher-student communication, and professional development opportunities. Online platforms and digital resources play a significant role in promoting collaborative learning and problem-solving skills globally, in Southern Africa, and in Zimbabwe. They facilitate global connections and collaborations, provide access to diverse perspectives and expertise, and offer virtual spaces for teamwork and knowledge sharing. In Southern Africa, they bridge geographical gaps and foster regional collaborations, provide access to inclusive, diverse, and cutting-edge learning materials and expertise, and enhance digital skills and literacy in the region. In Zimbabwe, they enhance access to inclusive, diverse, and cutting-edge learning materials and opportunities, support blended learning and flipped classroom models, foster collaborations and knowledge sharing among students and lecturers, and develop digital skills and literacy in line with the country's education goals. Examples of online platforms and digital resources that promote collaborative learning and problem-solving skills include learning management systems like Moodle and Canvas, collaboration tools like Google Workspace and Microsoft Teams, online communities and forums like Reddit and Stack Overflow, virtual reality and gamification platforms like Unity and Minecraft, and open educational resources like Khan Academy and OpenStax. By leveraging these platforms, students can cultivate crucial skills such as effective communication, critical thinking, and problem-solving, thereby equipping themselves to thrive in a rapidly evolving, interconnected, and digitally driven global environment.

1.1.5. How university lecturers use AI-driven analytics to personalise student learning experiences and improve student outcomes

University lecturers are revolutionising the way they teach and support students by harnessing the power of AI-driven analytics. These innovative tools are being used to personalise student learning experiences and improve outcomes in various ways. For instance, predictive modeling uses AI algorithms to analyze student data, identifying at-risk students and enabling early interventions. Moreover, AI-powered tools offer immediate, instant feedback on assignments and assessments, enabling students to receive timely guidance and insights that facilitate continuous improvement and accelerated learning. This then enables students to adjust their learning strategies. AI-driven assessments adapt their level of difficulty and content in response to student performance, providing a more accurate measure of knowledge. Furthermore, AI helps lecturers group students by learning needs, enabling targeted interventions and resource allocation, while natural language processing provides personalised support and answers to students' queries. The technology also analyses student feedback and sentiment, helping lecturers identify areas for improvement. Moreover, AI-driven tools provide students with personalised career guidance and job market insights, as well as support for faculty members in identifying effective teaching strategies and recommending professional development opportunities. By leveraging AI-driven analytics, university lecturers can create more effective, personalised, and data-driven learning environments that ultimately improve student outcomes and academic success.

2. METHODS

This study employed qualitative research as the primary methodology to delve into the intricate and multifaceted experiences and viewpoints of stakeholders involved in AI integration. A total of 30 participants, comprising students, lecturers, administrators, and industry experts, were interviewed using semi-structured interviews to gather in-depth insights into their perceptions and experiences. The interviews were digitally recorded and transcribed verbatim, allowing for a meticulous analysis of the data. The utilization of qualitative methods enabled a comprehensive and nuanced understanding of the participants' perspectives, which is crucial for informing policy and practice reforms in Zimbabwean universities.

2.1. Research Design

A case study approach was employed for this research, focusing on a single university to gain an indepth understanding of the complex dynamics surrounding AI integration. While this allowed for a rich and detailed examination of the university's AI integration initiatives, it also posed a limitation, as it may not be representative of all Zimbabwean universities. This singularity may limit the generalisability of the findings, making it essential to consider future studies that explore multiple case studies or adopt a more diverse sampling strategy. Despite this limitation, the case study design enabled a comprehensive examination of the specific context and stakeholders involved in AI integration at the selected university.

2.2. Participants

The population of the study was all STEM students, lecturers' administrators, and industry experts. A total of 31 participants were selected for the study, including 15 students, 10 lecturers, 3 administrators, and 3 industry experts. Random sampling was employed depending on the availability of the participants from electrical, mechanical, civil, and construction disciplines. Students were placed in 3 focus groups electrical (EEE), mechanical (MIE), civil, and construction (CCE) for coded as (FG1EEE, FG2MIE, and FG3CCE) with 5 students in each group, lecturers were coded as L1, L2, L3, L4, L5, L6, L7, L8, L9, and L10. The administrators were coded as ADM1, ADM2, ADM 3. The industry experts were coded as IE1, IE2, IE3.

2.3. Research Instruments

In-depth, semi-structured face-to-face interviews were conducted with participants to gain a profound understanding of their experiences and perceptions of AI integration in STEM education. The conversations were recorded as text, providing a precise and detailed record of the information gathered.

2.4. Procedures and Data Analysis

Thematic analysis was employed to identify key themes and patterns in the data. Three major themes emerged from the data: AI Literacy and Skills Development: The need for students, lecturers, and industry professionals to develop AI literacy and skills to effectively integrate AI in STEM education. Contextualized Learning and Industry Partnerships: The importance of contextualized learning experiences and industry partnerships in promoting AI adoption and innovation in STEM education. Infrastructure and Resource Constraints: The challenges faced by universities in providing adequate infrastructure and resources to support AI integration in STEM education.

2.5. Ethical Consideration

The researchers were cleared by the university under study to collect data. Participants received a transparent and straightforward informed consent form, clearly outlining the study's objectives, methods, and potential risks. They are also notified of their ability to withdraw from the study at any point without penalty or loss of benefits. Participation was completely voluntary, and individuals were free to decline or

discontinue their involvement without any coercion, incentives, or negative consequences. All data collected was anonymized and stored securely to protect participant privacy. Care was taken to ensure that vulnerable populations, such as students or individuals with disabilities, were not disproportionately represented or disadvantaged in the study. Participants were treated with respect and dignity throughout the research process, and their autonomy was respected in terms of their ability to provide or withhold information. Every effort was made to minimize potential harm or discomfort to participants, including the use of sensitive topics or emotional triggers. Participants were provided with a debriefing session after the interview, where they were offered feedback on the findings and any potential impact on their experiences. By taking these ethical considerations into account, this study aimed to ensure a high level of integrity and respect for all participants involved.

3. RESULTS

3.1. Integrating AI in STEM Education: Challenges and Opportunities in Zimbabwean Universities

The students in focus groups, lecturers, administrators, and industry experts were asked about the challenges and opportunities in integrating AI into STEM education. The focus groups replied as follows:

FG1EEE: "We believe that integrating Artificial Intelligence in our classes could change how we learn. However, I've noticed that many of my classmates are frustrated with the poor internet and constant power outages. We also struggle with outdated computers, which makes it hard to engage with new AI tools. It would be great if we could have more training sessions on AI applications, as I think it would help us."

FG2MIE: "We share the excitement about AI's potential in education. It can make learning more interactive and tailored to our needs. But we need better resources, like access to modern software. Sometimes we feel hesitant since I've heard of privacy issues with data if we use AI extensively. Plus, with limited exposure to AI in our labs, we are worried we won't be prepared for the job market."

FG3CCE: "AI can revolutionize our education, and we see its benefits, especially in how it can support lecturers. However, it's frustrating when classes are interrupted due to poor infrastructure. If universities invested properly in technology, it would make a huge difference in our learning experience."

The lecturers shared their sentiments as follows:

- L1: "I recognize the transformative power of AI in education. We can create richer learning environments and tailor our teaching methods. But I have to admit that the infrastructure challenges, like the lack of technical support and outdated technology, make it difficult to adopt these innovations fully."
- I.2: "While I am excited about AI's potential, I must express concern about job security. The rapid pace of technological change is daunting, and I am resistant to some extent because it feels overwhelming to keep up. Furthermore, without proper training and resources, implementing AI effectively in my teaching is a challenge."
- L3: "As someone in the education sector, I see both the opportunities and the challenges of incorporating AI into our curriculum. We need a strategic approach that addresses our current limitations, like power outages and insufficient training on AI technologies."
- L4: "There are significant barriers to AI adoption in our schools. Our classrooms lack proper infrastructure, and we face constant budget constraints that limit our ability to upgrade equipment and obtain new software. We need to tackle these hurdles head-on if we want to utilize AI effectively."
- L5: "AI can indeed enhance content creation and assessment methods. However, I worry about the privacy implications of utilizing student data in AI systems. We need clearer guidelines and policies around this to feel secure in moving forward."

Administrator shared their sentiments as follows:

ADM1: "I am aware of the potential AI has to improve educational outcomes but implementing these initiatives is tough. Our limitations in funding and infrastructure make it challenging to create policies that support AI integration effectively. We need to find a way to overcome these institutional challenges."

ADM2 & ADM3: "Our primary concern is the lack of a coherent policy framework regarding AI in education. We need more structured guidelines and support to not only implement AI but to ensure it is done in a way that is beneficial and sustainable for our universities."

Industrial experts shared their sentiments as follows:

IE1: "I see immense potential for AI to not only transform education but also to enhance employability for students. We need to work closely with educational institutions to ensure they have the support they need to integrate AI effectively into their programs, thus ensuring students are competitive in the job market."

IE2: "The key benefits of AI in STEM education include improved learning outcomes and adaptability to the needs of both educators and students. However, overcoming the barriers that institutions face, such as funding and infrastructure, is crucial for these benefits to materialize."

IE3: "AI holds the promise of enhancing both teaching and learning experiences. By collaborating with universities, we can develop tailored solutions that not only improve efficiency but also engage students in a way that prepares them for the challenges of the future job market."

The lecturers and students share the same sentiments that the integration of Artificial Intelligence (AI) in STEM education has the potential to revolutionize the way students learn and lecturers teach. However, the lecturers noted several challenges and opportunities that need to be addressed in Zimbabwean universities. Lecturers and students mentioned poor internet connectivity, rapid power outages, obsolete computers in the laboratories, privacy concerns of data, lack of learning software, and lack of AI training. Other lecturers came out in the open and said that they are resistant to change as technology is evolving rapidly and they cannot afford to keep abreast with it because of the massive challenges they are facing. The lecturers also mentioned lack of technical support, inadequate infrastructure, and concerns about job replacement are some of the barriers lecturers face in adopting AI in teaching practices. Administrators mentioned limited funding, inadequate infrastructure, and lack of policy frameworks as some of the institutional challenges they face in implementing AI initiatives. On a positive note, the lecturers and students said that there are opportunities for AI integration such as enhancing the student experience, lecturer support, content creation, assessment, and evaluation. Industry experts mentioned that enhanced learning outcomes, improved employability, and competitiveness in the job market are some of the opportunities for AI adoption in STEM education.

3.2. Perceptions of AI-Enhanced Learning Materials

Students perceived AI enhances learning materials as follows:

FG1EEE: "We appreciate how AI-powered learning materials help me grasp complex concepts. The interactive simulations make difficult topics much easier to understand, and we love the personalised explanations they offer. It feels like having a tutor available 24/7."

FG2MIE: "Using AI tools in our studies has been a game changer. We feel more engaged in group projects when we can leverage AI for collaboration, and it brings a whole new level of understanding to our subjects. We can't imagine studying without these resources now!"

FG3CCE: "The AI materials we use in class have made learning so much more dynamic. They adapt to my pace and highlight areas where we need improvement. We believe that if more people had access to this kind of technology, their understanding would greatly improve."

Lecturers also shared their personal perceptions as follows:

- L1: "I have noticed a significant improvement in student performance with the use of AI-enhanced materials. They not only facilitate more efficient grading but also help me provide timely feedback. I believe the curriculum could benefit immensely by embedding AI content throughout."
- L2: "AI-powered materials have streamlined the grading process for me, which allows me to give focused and constructive feedback to students. However, I think we need to proactively develop our curriculum to incorporate AI more thoroughly, as well as establish clear AI policies."
- L3: "Integrating AI into our coursework has revealed knowledge gaps in students that I might have otherwise missed. These insights allow me to tailor my teaching approach for better outcomes. Looking ahead, updating the curriculum to embed AI content is essential."
- L4: "I wholeheartedly believe that AI can revolutionize the educational experience for both students and lecturers. We need to ensure that our curriculum reflects the importance of AI and that we have policies set in place to guide its integration in a responsible manner."
- L5: "Having access to AI-enhanced learning materials enables me to engage with students on a deeper level. I can provide more personalized feedback, and it allows me to focus on those areas where students struggle the most. Curriculum redevelopment is essential for fully embracing this technology."
- L6: 'The use of AI in my lectures has transformed how I identify and address student misconceptions. I think reworking our curriculum to integrate AI content while also putting forward robust policies is crucial for maximizing the benefits of these technologies."

Administrators also shared their perceptions on AI-enhanced learning materials as follows:

ADM1: "We recognize the importance of AI in modern education and how it can enhance both teaching and learning. However, we also need to focus on developing policies that support the safe and effective use of AI technologies within the curriculum."

ADM2 & ADM3: "We are committed to facilitating the integration of these technologies by supporting curriculum adjustments and ensuring that policies are in place for their use."

Industry Expert shared their perceptions as:

- IE1: "The benefits of AI-powered learning resources are clear, particularly in how they enhance learning outcomes. Collaborating with educational institutions to help redesign curricula to include AI content will ensure that students are well-equipped for the future."
- IE2: "Seeing students thrive using AI-enhanced materials is inspiring. It's crucial that educational institutions also focus on embedding AI into their teaching frameworks while establishing policies that support such integration. This will lead to more competitive graduates."
- IE3: "The integration of AI in education has immense potential for improving student engagement and learning outcomes. Developing a curriculum that incorporates AI is essential, as is ensuring that educators have the right policies and support to implement these changes effectively."

Students find AI-powered learning materials to be very effective in enhancing understanding, and collaboration, providing personalised explanations and interactive simulations. Lecturers mentioned that AI-enhanced materials enable more efficient grading, feedback, and identification of knowledge gaps. The lecturers also said that it would be wise to re-develop the curriculum imbed the AI content and also have AI policies in place.

3.3. Skills and Competencies for STEM Graduates

Lecturers, administrators, and industrial experts were asked about the skills and competencies needed for students and they replied as follows:

- L1: "In today's job market, STEM graduates must be equipped with essential skills like data analysis and programming. We need to prioritize these skills in our curriculum. The integration of AI in education presents us with opportunities to cultivate these competencies, but we also face challenges that need to be addressed to make this effective."
- L2: "I see the potential of AI to enhance our teaching methods and improve student outcomes. However, we must recognize the challenges our students encounter. Workshops and awareness sessions on AI can help both lecturing staff and students to understand its relevance and practical application in their fields."
- L3 & L9: "To prepare our students for an AI-driven economy, we must instill critical thinking, creativity, and collaboration skills. While there are clear opportunities presented by AI integration, we must also work on overcoming the obstacles faced at various institutional levels. Creating a unified approach is essential for success."
- L4 & L7: "AI can significantly enhance STEM education, but we cannot ignore the challenges. We need comprehensive workshops on AI that involve all stakeholders from lecturers to policymakers to ensure everyone understands both AI's capabilities and challenges. This will ensure our students receive the best possible education."
- L5: "I advocate for a curriculum that blends traditional STEM disciplines with emerging technologies like AI, focusing on relevant skills such as programming and analysis. However, we must first address the practical barriers we face in implementation, including a lack of resources and training for faculty."
- L6, L8 & L10: "Integrating AI in our teaching can indeed provide a rich environment for students to develop 21st-century skills. Yet, we need meaningful workshops and forums for awareness. Only then can we effectively prepare our students for the demands of the modern workforce."

Administrators shared their sentiments as follows:

ADM1 & ADM3: "As administrators, we recognise the pressing need for STEM graduates to possess a unique skill set for today's job market. However, we must collaborate with lecturers and industry experts to create workshops and training programs focusing on the necessary skills in AI and STEM education."

ADM2: "The integration of AI in education is a step forward, but we must proactively tackle the challenges that come with it. Ensuring that our faculty and students are well-versed in AI technologies will not only benefit their careers but will also enhance the overall educational environment."

Industry experts also shared the skills and competencies needed for students as follows:

- IE1: "Employers today seek STEM graduates who are not just technically proficient but also possess critical soft skills like communication, creativity, and collaboration. Strengthening these competencies through a blended curriculum that incorporates AI is essential for student success in the workforce."
- IE2: "The emphasis on 21st-century skills in our rapidly evolving economy cannot be overstated. There are great opportunities for collaboration between universities and industry to foster these skills in students, and AI could catalyse this transformation."
- IE3: "Preparing STEM graduates for the future involves more than just technical skills. It is crucial to incorporate skills like critical thinking and collaboration into their education. I recommend that universities hold workshops to increase awareness about the importance of these skills in the context of AI and other emerging technologies."

In today's AI-driven economy, industry experts emphasise that STEM graduates require a unique combination of 21st-century skills, including data analysis, programming, communication, critical thinking, creativity, and collaboration, to excel. Lecturers said that in Zimbabwean universities, the integration of AI in STEM education presents a dual scenario: both opportunities and challenges abound. To capitalize on the benefits of AI, lecturers cited that it is crucial to address the hurdles faced by students, lecturers, administrators, policymakers, and AI researchers. The lecturers also said that they need awareness and workshops on AI so that everyone is on the same boat as learning is taking place. Therefore, by doing so,

Zimbabwean students can receive a superior education that prepares them for success in an increasingly AI-dependent world.

The results of the study on integrating AI in STEM education within Zimbabwean universities significantly contribute to the existing body of knowledge and hold the potential to impact future research and practical applications in multiple ways. The study provides a comprehensive overview of both the challenges and opportunities that come with AI integration in the STEM curriculum. By collating perspectives from students, lecturers, administrators, and industry experts, the research highlights critical issues such as infrastructure limitations, resistance to change, and the need for training. This dual perspective enriches the ongoing discourse about AI in education, particularly in regions facing economic constraints.

The varied feedback from focus groups underscores the significance of stakeholder engagement in educational reform. By exposing the differing concerns and hopes of students, lecturers, and industry experts, the research informs policymakers about the diverse dimensions of the issue, emphasizing the need for inclusive and multidisciplinary approaches in education reform.

The responses illuminate the specific skills and competencies that STEM graduates require in an AI-driven economy. This focused examination of 21st-century skills encompassing data analysis, programming, critical thinking, and adaptability shapes academic curricula and aligns them with the evolving job market. The insights gathered from lecturers and administrators regarding the necessity of coherent policy frameworks and curriculum redesign provide empirical evidence to advocate for changes in educational structures. This research acts as a foundation for future policy recommendations aimed at integrating AI into educational systems sustainably.

On the potential impact on future research, the identified challenges such as technology access, funding, and the need for training workshops serve as focal points for future research. Scholars can delve deeper into each challenge to propose targeted interventions, explore innovative funding models, or identify efficient methods for training educators. Given the transformative potential of AI in education, there is scope for longitudinal studies to track the effectiveness of implemented strategies over time. Researchers could assess how integration endeavors impact teaching methodologies, student learning outcomes, and workplace readiness. The findings can also pave the way for comparative studies within other African nations or developing countries. Assessing how different contexts deal with similar challenges could yield valuable insights and foster regional collaboration in educational reform.

In practical applications, the results indicate a pressing need to develop curricula that reflect the necessities of a rapidly evolving job market. Academic institutions may use this data to reform their programs, ensuring they incorporate critical 21st-century skills and AI technologies to equip students for future careers. Evidence from students regarding inadequate infrastructure and resources can inform university leaders and policymakers about where to prioritize funding and investments. Data-driven decisions can help create more equitable and effective learning environments, optimizing the benefits of AI integration. The call for more training and awareness workshops for both students and educators highlights a practical opportunity for universities to develop initiatives that ensure everyone is knowledgeable and skilled in AI tools. Tailored professional development programs would empower faculty and facilitate smoother AI adoption in educational practices. The emphasis from industry experts on the employability benefits of AI integration in education signals a need for closer ties between universities and industry. Collaborative projects could drive innovation in teaching practices and ensure students are receiving an education aligned with current workforce demands.

In summary, the study's results not only enhance our understanding of the challenges and opportunities relating to AI in STEM education but also lay the groundwork for transformative changes in curricula, teaching practices, and policy frameworks. Future research can build upon these findings to create actionable solutions and innovative educational strategies.

4. DISCUSSION

The findings of this study highlight the need for infrastructure development and resource allocation to address the challenges faced by students and lecturers in accessing AI-powered learning resources as

alluded to in the literature (Barakabitze et al. 2019; Mahboubi, 2022; Means & Neisler, 2020). Implications are that policymakers and administrators should prioritize investments in digital infrastructure and provide training for students to develop AI literacy. Moreover, the study highlights the need for lecturers to receive targeted training and support to effectively incorporate AI into their teaching methodologies. This is also highlighted in the literature by (Reuben & Kabilan, 2024). It is recommended that institutions proactively provide lecturers with professional development opportunities to enhance their expertise in AI-powered education. The implication is that the lecturers' adoption of AI in teaching practices is crucial for the effective implementation of AI-powered education. Furthermore, the findings indicate that administrators face challenges in securing funding and developing policy frameworks to support AI integration as cited by (Gumport & Sporn, 1999). The government and funding agencies should provide resources and support for AI initiatives in higher education. Administrators' implementation of AI initiatives is critical for the successful integration of AI in higher education. The students find AI-powered learning materials effective in enhancing their understanding of STEM subjects. Lecturers and policymakers should therefore prioritise the development and adoption of AI-powered learning materials in STEM education. The government and policymakers should invest in developing AI-powered teaching tools and provide training for lecturers to effectively integrate them into their practice. The study also highlighted the importance of skills such as data analysis, programming, critical thinking, creativity, and collaboration for STEM graduates to thrive in an AI-driven economy as cited by (Abulibdeh et al. 2024; Bers, 2018; Webb et al. 2017). Industry experts recognise the need for policies that support the development of these skills in STEM education as cited by (Dwivedi, et al. 2021). Governments and funding agencies should provide resources and support for AIfocused programs in higher education.

5. CONCLUSION

In conclusion, the integration of AI in STEM education in Zimbabwean universities is crucial for preparing students for the demands of an AI-driven economy. This study was based on integrating artificial intelligence in STEM education, enhancing 21st-century skills in Zimbabwean Universities. While there are challenges to be addressed, the opportunities presented by AI-powered education are significant. By prioritizing investments in digital infrastructure, providing training and support for lecturers, developing policy frameworks, and emphasising AI-related skills, Zimbabwean universities can harness the potential of AI to improve STEM education. Industry partnerships, continuous research, and ethical considerations are also essential for ensuring that AI-powered education is effective and responsible. By working together, lecturers, policymakers, and industry experts can leverage AI to enhance student learning outcomes, improve employability, and drive innovation in Zimbabwe's STEM fields. As AI continues to transform the education landscape, Zimbabwean universities must proactively embrace this technology to remain competitive and relevant. By doing so, they can unlock new possibilities for student success, economic growth, and societal impact. The future of STEM education in Zimbabwe depends on it.

6. RECOMMENDATIONS

Based on these findings, to fully leverage the benefits of AI in STEM education, it is recommended that governments and administrators in institutions invest in digital infrastructure to ensure students have access to AI-powered learning resources. Additionally, institutions should provide training and support for lecturers to develop their skills in AI-powered education, while governments and institutions should develop policy frameworks to support AI integration in higher education. Furthermore, lecturers and policymakers should prioritize the development and adoption of AI-powered learning materials in STEM education and emphasize the importance of AI-related skills such as data analysis, programming, critical thinking, creativity, and collaboration. Establishing partnerships with industry experts can also provide students with practical experience and exposure to AI applications in the workforce. Moreover, sustained research efforts are crucial to tackling the challenges and seizing the opportunities arising from AI's integration into STEM education. Furthermore, developers and users of AI-powered educational systems must prioritize ethical considerations, including transparency, accountability, and fairness, to ensure the responsible deployment of these technologies. By implementing these recommendations, Zimbabwean universities can harness the potential of AI to improve STEM education and prepare students for success in an AI-driven economy. The study's findings are limited by the sample size and the fact that it only

focused on one Zimbabwean university. Future studies should aim to include a larger sample size and explore AI integration in comparative studies of universities and other educational settings.

Acknowledgment. I thank the National University of Science and Technology for providing the necessary facilities and resources to conduct my research. I would also like to thank the students, lecturers, university administrators, and industry experts who allowed me to collect data from them.

Research Ethics. This study received ethics approval on 9 September 2024 (reference number: IRB/2024/54).

Data Availability Statement. All data can be obtained from the corresponding author.

Conflicts of Interest. The author declares no conflicts of interest for this study.

Funding. This research received no external funding.

REFERENCES

- Abulibdeh, A., Zaidan, E., & Abulibdeh, R. (2024). Navigating the confluence of artificial intelligence and education for sustainable development in the era of industry 4.0: Challenges, opportunities, and ethical dimensions. *Journal of Cleaner Production*, 140527. https://doi.org/10.1016/j.jclepro.2023.140527
- African Development Bank Group. (2024). Zambia Support to Science and Technology Education Project. https://mapafrica.afdb.org/en/projects/46002-P-ZM-IA0-005
- Ahmad, S. F., Rahmat, M. K., Mubarik, M. S., Alam, M. M., & Hyder, S. I. (2021). Artificial intelligence and its role in education. *Sustainability*, 13(22), 12902.
- Algabri, H. K., Kharade, K., & Kamat, R. (2021). Promise, threats, and personalization in higher education with artificial intelligence. *Webology*, 18(6).
- Ang, S. M. O., & Aragon, M. J. D. (2020). Development of AI-Enhanced Information Technology Program: Preparing Today's Students in AI Era (No. 4049). EasyChair.
- Barakabitze, A. A., William-Andey Lazaro, A., Ainea, N., Mkwizu, M. H., Maziku, H., Matofali, A. X., Iddi, A. & Sanga, C. (2019). Transforming African education systems in science, technology, engineering, and mathematics (STEM) using ICTs: Challenges and opportunities. *Education Research International*, 2019(1), 6946809.
- Bers, M. U. (2018). Coding and computational thinking in early childhood: The impact of ScratchJr in Europe. European Journal of STEM Education, 3(3), 8.18.
- Botswana Innovation Hub. (2024). Defining the Future of Innovation. https://www.bih.co.bw/
- Chan, C. K. Y. (2023). A comprehensive AI policy education framework for university teaching and learning. International Journal of Educational Technology in Higher Education, 20(1), 38.
- Chasokela, D. (2024). Exploring the Virtual Frontier: AR and VR for Engineering Skills Development. In R. Siva Subramanian, M. Nalini, & J. Aswini (Eds.), Navigating the Augmented and Virtual Frontiers in Engineering (pp. 62-81). IGI Global. https://doi.org/10.4018/979-8-3693-5613-5.ch004
- Chen, L., Chen, P., & Lin, Z. (2020). Artificial intelligence in education: A review. IEEE Access, 8, 75264-75278.
- Chitate, H. (2016). Science, Technology, Engineering and Mathematics (STEM): A Case Study of Zimbabwe's Educational Approach to Industrialisation. *World Journal of Education*, 6(5), 27-35.
- De Zan, T. (2022). Mitigating the cyber security skills shortage: The influence of national skills competitions on cyber security interest (Doctoral dissertation, University of Oxford).
- Dwivedi, Y. K., Hughes, L., Ismagilova, E., Aarts, G., Coombs, C., Crick, T., ... & Williams, M. D. (2021). Artificial Intelligence (AI): Multidisciplinary perspectives on emerging challenges, opportunities, and agenda for research, practice and policy. *International Journal of Information Management*, 57, 101994.
- Gambanga, N. (2016). STEM students at public schools in Zimbabwe offered free education. Teckzim. https://www.techzim.co.zw/2016/01/stem-students-public-schools-zimbabwe-offered-free-education/
- Goralski, M. A., & Tan, T. K. (2020). Artificial intelligence and sustainable development. *The International Journal of Management Education*, 18(1), 100330.

- Gumport, P. J., & Sporn, B. (1999). Institutional adaptation: Demands for management reform and university administration. In *Higher education: Handbook of theory and research* (pp. 103-145). Springer Netherlands.
- Gweshe, G. T., & Chiware, M. (2023). Gender-inclusive education in science, technology, engineering, and mathematics (STEM) fields in post-independence Zimbabwe. In *Economic Inclusion in Post-Independence Africa: An Inclusive Approach to Economic Development* (pp. 295-310). Springer Nature Switzerland.
- Hemachandran, K., Verma, P., Pareek, P., Arora, N., Rajesh Kumar, K. V., Ahanger, T. A., Pise, A. A. & Ratna, R. (2022). Artificial intelligence: A universal virtual tool to augment tutoring in higher education. *Computational Intelligence and Neuroscience*, 2022(1), 1410448.
- Huang, C., Zhang, Z., Mao, B., & Yao, X. (2022). An overview of artificial intelligence ethics. *IEEE Transactions on Artificial Intelligence*, 4(4), 799-819.https://doi.org/10.1109/TAI.2022.3194503
- Ilori, M. O., & Ajagunna, I. (2020). Re-imagining the future of education in the era of the Fourth Industrial Revolution. Worldwide Hospitality and Tourism Themes, 12(1), 3-12. https://doi.org/10.1108/WHATT-10-2019-0066
- Jamro, M. Y., & Jamro, F. A. (2023). AI Matters: Chatbot Integration in Holistic STEM Education.
- Jaramillo, J. J., & Chiappe, A. (2024). The AI-driven classroom: A review of 21st-century curriculum trends. *Prospects*, 1-16.
- Kaswan, K. S., Dhatterwal, J. S., & Ojha, R. P. (2024). AI in personalized learning. In *Advances in Technological Innovations in Higher Education* (pp. 103-117). CRC Press.
- Mahboubi, P. (2022). The knowledge gap: Canada faces a shortage in digital and STEM skills (p. 626). CD Howe Institute.
- Makridakis, S. (2017). The forthcoming Artificial Intelligence (AI) revolution: Its impact on society and firms. *Futures*, 90, 46-60.
- Means, B., & Neisler, J. (2020). Unmasking inequality: STEM course experience during the COVID-19 pandemic. Digital Promise.
- Miailhe, N., & Hodes, C. (2017). Making the AI revolution work for everyone. The Future.
- Mousavinasab, E., Zarifsanaiey, N., R. Niakan Kalhori, S., Rakhshan, M., Keikha, L., & Ghazi Saeedi, M. (2021). Intelligent tutoring systems: a systematic review of characteristics, applications, and evaluation methods. *Interactive Learning Environments*, 29(1), 142-163.
- Moyo, J., Watyoka, N., & Chari, F. (2022, November). Challenges in the adoption of artificial intelligence and machine learning in Zimbabwe's insurance industry. In 2022 1st Zimbabwe Conference of Information and Communication Technologies (ZCICT) (pp. 1-6). IEEE.
- Parliamentary Monitoring Group. (2023). Engagement with DSI on postgraduate funding for STEM careers; new technology & innovation that could assist in providing proper sanitation in schools; with Minister. https://pmg.org.za/committee-meeting/37247/
- Pedro, F., Subosa, M., Rivas, A., & Valverde, P. (2019). Artificial intelligence in education: Challenges and opportunities for sustainable development.
- Reuben, B., & Kabilan, M. K. (2024). Assessment of University Lecturers' Readiness to Adopt Artificial Intelligence (AI) Technology in North-East of Nigeria. *International Journal of Advanced Research in Education and Society, 6*(2), 482-490.
- Srinivasa, K. G., Kurni, M., & Saritha, K. (2022). Harnessing the Power of AI to Education. In *Learning, teaching, and assessment methods for contemporary learners: pedagogy for the digital generation* (pp. 311-342). Springer Nature Singapore.
- Vashishth, T. K., Sharma, V., Sharma, K. K., & Kumar, B. (2024). Enhancing Literacy Education in Higher Institutions with AI Opportunities and Challenges. AI-Enhanced Teaching Methods, 198-215. https://doi.org/10.4018/979-8-3693-2728-9.ch009
- Webb, M., Davis, N., Bell, T., Katz, Y. J., Reynolds, N., Chambers, D. P., & Syslo, M. M. (2017). Computer Science in K-12 school curricula of the 21st century: Why, what and when? *Education and Information Technologies*, 22, 445-468.