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Research Article

The Sustainability of Using AI To Integrate Indigenous Knowledge Systems in Science Education: A Case of The Lubombo Region of Eswatini

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Abstract

This research investigates viability of integrating indigenous knowledge systems with science education using artificial intelligence technologies. The study addresses limited recognition of indigenous knowledge in science curricula and explores AI's potential for culturally sensitive incorporation. The study objectives include examining indigenous knowledge's influence on child development and academic achievement, exploring AI's role in presenting indigenous knowledge in science curricula, identifying integration challenges and opportunities assessing educators' perceptions and recommending sustainable implementation strategies. Focusing on Eswatini's Lubombo region, the study aims to advance culturally responsive teaching methods aligning with educational digitization trends and diverse knowledge system recognition. The research significance extends to educational institutions cultural preservation and technological advancement in Eswatini's education. The research used the mixed methods approach. Data collection included questionnaires focus groups observations and document analysis targeting principals, teachers, and students. The study concludes AI could develop an inclusive stimulating efficient educational system honouring cultural heritage while preparing students for future challenges. Ongoing teacher professional development is highly encouraged.

Keywords: *Indigenous knowledge system, artificial intelligence, child development, academic achievement, science education.*

1. INTRODUCTION

The integration of indigenous knowledge (IK) into formal education systems has become an increasingly recognized area of research, particularly in the contexts of Eswatini and other African countries. Historically, IK has been side lined in this nation's educational curricula, often due to colonial legacies that favoured western scientific knowledge over local wisdom (Hlophe & Dlamini, 2019). This marginalisation has led to a significant disconnect between students' cultural heritage and the scientific knowledge imparted in classrooms, undermining the potential benefits of IK in enhancing the learning experience and promoting cultural diversity (Mapira, 2013). Despite the recognized value of IK in fostering a deeper connection with the environment and enhancing academic achievement (Zidny et al., 2023), its inclusion in science education remains very limited.

The advent of artificial intelligence (AI) offers new opportunities to bridge this gap. AI technologies can support the integration of IK into science curricula, creating a synergy between traditional wisdom and contemporary scientific understanding (UNESCO, 2023). This research aims to explore strategies for effectively merging IK with science education using AI as a facilitative tool, particularly in the context of Eswatini. This nation possesses rich cultural legacies and diverse IK systems that have been historically underrepresented in formal education settings.

To address the identified gap, this study will investigate the significance of IK in child development, academic achievement, and life skills. It will examine the reasons behind the historical neglect of IK in education, as reported by educators and learners (Mapira, 2013). The research will propose AI as a novel means to merge IK with science

education, thereby promoting inclusivity and engaging students in meaningful learning experiences (UNESCO, 2023). Through a comprehensive literature review and citation of academic scholars, this study will acknowledge the contributions of existing research and identify the unique contribution it intends to make in advancing inclusive and technologically enhanced educational practices in Eswatini.

STATEMENT OF THE PROBLEM

The current challenge lies in the limited integration of indigenous knowledge systems with science education in Eswatini. Existing curricula inadequately recognize or incorporate indigenous knowledge, leading to a lack of cultural relevance and inclusivity within science classrooms. Additionally, there is a pressing need to explore how AI tools can be thoughtfully designed to recognize and incorporate indigenous knowledge in a culturally sensitive and contextually appropriate manner. This research endeavours to bridge these gaps and explore the potential of AI-supported Indigenous knowledge integration in science education.

RESEARCH OBJECTIVES

1. Explore how indigenous knowledge systems influence achievement in the context of Eswatini.
2. Investigate how AI technologies can be utilised to recognize, incorporate, and present indigenous knowledge within science curricula.
3. Identify the challenges and opportunities associated with integrating AI and indigenous knowledge in science education.
4. Recommend informed strategies to ensure the sustainable integration of IK into science curricula using AI.

2. REVIEW OF RELATED LITERATURE

The study is guided by the cultural-historical activity theory (CHAT). CHAT, rooted in Vygotsky's work, focuses on the influence of cultural and social factors on human cognition and learning. It extends Vygotsky's sociocultural theory by emphasising collective activities and interactions within a cultural context. CHAT's focus on the socio-cultural context of learning activities offers a distinct perspective compared to Behaviourism and Constructivism. CHAT consists of key components such as the subject, tools, rules, community, and division of labour. In education, CHAT provides insights into learners' engagement in activities and how cultural artefacts, including AI technologies, mediate their interactions. By adopting CHAT as the theoretical framework, this research aims to analyse the integration of AI and IK in education, considering the sociocultural and historical aspects of these knowledge systems (Engeström, 1999; Wertsch, 1991).

Cultural-Historical Activity Theory (CHAT) offers a valuable lens through which to examine the integration of IKS and AI in education (Yamagata-Lynch, 2024). Originating from the work of Russian psychologist Lev Vygotsky, CHAT recognizes that learning is a social and cultural process embedded within specific contexts. It emphasises the interplay between individuals, communities, and the tools they use in their activities (Engeström, 2019). It further emphasises the importance of cultural context and social interactions in learning processes, making it an ideal lens through which to view the role of AI in education (Engeström et al., 1999). By applying CHAT to the study of IKS and AI, researchers can gain insights into how these systems interact and evolve within educational settings.

CHAT provides a theoretical framework that accounts for the socio-cultural dimensions of learning and addresses power dynamics within educational contexts. Santos (2023) argues that this perspective is crucial in preventing the marginalisation of indigenous voices in the age of AI. CHAT encourages scholars to examine who controls knowledge and technology and how these resources can be democratised to benefit all learners. By doing so, it offers a means to ensure that the integration of IK and AI is equitable and inclusive.

INDIGENOUS KNOWLEDGE SYSTEM

IK encompasses the knowledge, practices, and beliefs developed by indigenous communities over generations. It includes domains such as agriculture, medicine, ecology, and spirituality. IK plays a vital role in child development and academic achievement. Studies have shown that integrating IK into education enhances students' cultural identity, self-esteem, and academic performance. In Eswatini and Zimbabwe, IK holds particular significance due to the rich cultural heritage and traditional practices of indigenous communities. Incorporating IK in the science education curricula can promote cultural relevance, respect for diversity, and a sense of belonging among students (Aikenhead, 2006; Cajete, 2000; Ngara, 2002).

Indigenous Knowledge Systems (IKS) encompass the complex set of understandings, skills, and philosophies developed by societies through long-term interactions with their natural surroundings. In the context of child development and academic achievement, IKS plays a crucial role by integrating cultural practices, languages, and traditional wisdom into learning processes, which can significantly enhance educational outcomes.

In Eswatini, the integration of IKS in education is seen as a way to preserve cultural heritage while also contributing to economic development. Hlophe and Dlamini (2019) discuss the potential of IKS in fostering innovation and adaptation

within traditional sectors such as handicrafts, food, and medicine, which can lead to improvements in both production methods and educational content (Hlophe & Dlamini, 2019).

Similarly, in Zimbabwe, IKS are utilised to address developmental challenges, particularly in rural areas. Zikhali (2018) emphasises the importance of acknowledging and incorporating indigenous knowledge in development practices, as it provides a foundation for sustainable and locally-appropriate solutions (Zikhali, 2018). Moreover, storytelling, a valued source of indigenous knowledge, has been identified as an effective tool for incorporating culturally relevant information into early childhood development programs

The significance of IKS in Eswatini extends beyond preserving cultural identity; it is also about recognizing the value of traditional knowledge in addressing contemporary challenges. A study on the moral compass of IKS in rural Zimbabwe highlights the need to re-evaluate the importance of indigenous wisdom in guiding people's livelihoods, especially in health-related matters.

AI technologies in education

AI technologies are rapidly transforming the educational landscape by providing adaptive learning environments and intelligent tutoring systems. These advancements are particularly beneficial in the context of IK, as they allow for the digital preservation and dissemination of indigenous knowledge. AI-driven platforms can facilitate the creation of interactive and engaging content that displays IK in a modern format, appealing to the tech-savvy generation (Jenkins, 2021). AI offers tools and techniques that can revolutionise teaching and learning processes. Recent advancements in AI offer promising tools for recognizing and incorporating indigenous knowledge into science curricula. AI can assist in creating adaptive learning environments that are sensitive to the cultural context of students (Park et al., 2023). Natural language processing, machine learning algorithms, and data analytics are examples of AI tools that can facilitate the incorporation and dissemination of IK in educational settings. These technologies contribute to personalised learning experiences, adaptive assessment, and the cultivation of critical thinking skills (Holstein & Gubrium, 2005; Leontiev, 2009).

Natural Language Processing (NLP) and Machine Learning (ML) algorithms are at the forefront of this integration. NLP allows for the interpretation and generation of human language, making it possible to process and integrate IK into digital formats. ML algorithms can analyse patterns within data, enabling the identification and categorization of IK elements for inclusion in educational materials. These AI technologies support the creation of personalised learning experiences, where content is tailored to the cultural and contextual needs of the learner (Holstein & Gubrium, 2005; Leontiev, 2009). AI's role in language preservation is especially noteworthy, as it offers a lifeline for endangered indigenous languages. Leveraging the capabilities of natural language processing and machine learning, AI tools can support the documentation and instruction of these languages, playing a crucial role in their revitalization (Hernandez, 2022). This not only aids in the preservation of linguistic diversity but also ensures the accurate transmission of the subtleties embedded within IKS.
Data Analytics plays a pivotal role in understanding the effectiveness of IK within educational settings. By evaluating student performance and engagement, educators can refine the incorporation of IK to better suit learning objectives and outcomes. Furthermore, AI-driven analytics can highlight the impact of IK on academic achievement, providing empirical evidence to support its integration (Xu & Ouyang, 2022).

The use of AI Chatbots in education has also been explored as a means to deliver IK content. Chatbots can act as virtual teaching assistants, offering immediate support, explanations, and additional resources based on IK. They can facilitate a continuous learning environment where students can access IK-related content anytime, enhancing their understanding and appreciation of their cultural heritage (Labadze, Grigolia, & Machaidze, 2023).

AI chatbots have been increasingly utilised by students for assistance in writing assignments and learning science. A study by Seo et al. (2021) explored the impact of AI on learner–instructor interaction in online learning environments. The findings suggest that AI systems, including chatbots, can personalise learning for students and automate routine tasks for instructors, thereby enhancing the learning experience.

Furthermore, Silitonga et al. (2023) investigated the influence of AI chatbot-based learning on students' motivation in English writing classrooms. The study revealed that AI chatbots could provide more detailed and comprehensive feedback than teachers alone, thereby improving students' understanding of their strengths and weaknesses in writing.

The use of AI chatbots extends beyond conventional educational content, reaching into the domain of Indigenous Knowledge (IK). Labadze, Grigolia, and Machaidze (2023) conducted a systematic literature review to understand the full benefits and challenges of AI chatbots in education. Their research emphasises the potential of AI chatbots to deliver personalised and engaging learning experiences, which can include IK content.

However, the integration of AI and IK in education is not without challenges. Concerns regarding the reliability, accuracy and ethical considerations of AI applications must be addressed to ensure that the representation

of IK is respectful and accurate. Additionally, the potential for AI to reinforce existing socio-economic, gendered, and racial biases must be carefully managed (Labadze, Grigolia, & Machaidze, 2023).

Integration of AI and IK in education

The integration of AI and IK in education can be analysed through the CHAT framework by examining how these technologies and knowledge systems interact within the cultural-historical context of the learners. AI can serve as a tool within the activity system, facilitating access to IK and providing new ways for learners to engage with both traditional and scientific knowledge. The rules and division of labour within the educational community can be adapted to ensure that AI technologies are used ethically and effectively, respecting the cultural significance of IK. The world is currently undergoing what Holstein (2015) has called the Fourth Industrial Revolution, which has been characterized by increased connectivity and automation propagated by technologies including artificial intelligence (AI), machine learning (ML), and digital fabrication. In hidden or explicit forms, AI now shapes many lives. For instance, AI has been embedded in search engines of online consumer platforms and email (e.g., Google and Yahoo) to market items and promote consumerism (Verma et al., 2021). AI has also been applied to agriculture, education, finance, security, science, healthcare, traffic control, crime control, and so on (OECD, 2019). While we have become aware of the pervasiveness of AI in shaping human lives, we asked ourselves as STEM educators and teacher educators about our role in empowering learners with the relevant knowledge and skills about AI to thrive in society as literate citizens. Many scholars and policymakers have argued for schools and societies to place greater emphasis on developing the AI literacies of students.
The integration of IK into formal education is advocated to enhance the relevance and contextuality of the curriculum. Zimbabwe and Eswatini possess a wealth of IK that could enrich educational programs. AI can aid this process by creating digital sources of IK, making it accessible for educational purposes (SEPARC, 2022).

Integration of AI and IK in Science Education

AI Technologies in Education AI technologies offer promising opportunities for recognizing, incorporating, and presenting indigenous knowledge within science curricula. UNESCO (2020) emphasises the potential of AI to enhance learning experiences by personalising education and providing access to diverse knowledge systems. The World Economic Forum (2018) highlights the transformative power of AI in education, emphasising its role in fostering critical thinking, problem-solving skills, and cultural sensitivity. These perspectives underscore the relevance of AI technologies in integrating IKS into science education curricula. The integration of Artificial Intelligence (AI) and Indigenous Knowledge (IK) in science education represents a significant step towards creating learning spaces that are both inclusive and culturally sensitive.

From a CHAT perspective, the integration of AI and indigenous knowledge in science curricula and education can be seen as a system of interconnected activities involving tools (AI technologies), subjects (educators and students), and the community (indigenous knowledge holders). Rules (curricular guidelines) and the division of labour (roles of educators and AI tools) influence this system (Engeström et al., 1999). There are numerous instances where the combination of AI and IK has proven beneficial in science education. Smith et al. (2022) examined the use of AI-driven virtual reality simulations to deepen students' understanding of traditional ecological knowledge within a biology curriculum. These simulations offered an engaging environment, enabling students to interact with and learn from IK-centric content. The study found that this approach led to increased student engagement, better retention of knowledge, and a greater appreciation for cultural heritage (Smith, Johnson, Anderson, & Wilson, 2022).

Another study by Johnson and Smith (2023) applied a machine learning algorithm to analyse agricultural practices informed by IK in a rural setting. The algorithm evaluated data from local farmers, identifying patterns and suggesting sustainable farming techniques. The use of AI in this context helped to validate and elevate IK, facilitating knowledge sharing across generations and strengthening community practices (Johnson & Smith, 2023).

In addition, the integration of AI and IKS in science education presents an opportunity to foster global citizenship and intercultural understanding. By exposing students to diverse knowledge systems, AI can help cultivate empathy and appreciation for different worldviews (Patel, 2020). This can lead to more inclusive societies that value the contributions of all cultures.

Gaps in current application of AI and IK in Science Education

Despite these successes, there are noticeable deficiencies in the current application of AI and IK in science education. A significant issue is the underrepresentation of diverse IK systems within AI models. Many AI tools used in education are based on mainstream scientific knowledge, which can overlook the depth and variety of IK. Addressing this issue requires a concerted effort to integrate a broader spectrum of indigenous perspectives and knowledge areas.
Additionally, the involvement of indigenous communities, elders, and knowledge guardians in creating AI-based educational resources is often lacking. These individuals offer critical insights into the cultural context and complexities of IK, which are crucial for developing authentic and impactful educational experiences. Future research should focus on participatory methods that include indigenous stakeholders in the creation and evaluation of AI-enhanced curricula.

Ethical concerns, such as data privacy and the potential for algorithmic bias, also demand more attention. AI systems depend on data, raising questions about the ownership and respectful use of IK. Furthermore, biases within algorithms can lead to cultural misrepresentation, contradicting the goals of inclusivity and cultural respect. It is essential to establish comprehensive guidelines and policies to ensure the ethical integration of AI and IK in science education.

Challenges and opportunities in integrating AI and IK in Science Education

The advent of AI in educational settings offers unprecedented opportunities for personalised learning and data-driven insights. However, the incorporation of indigenous knowledge systems alongside AI poses both challenges and opportunities for educators in science education (Pedró et al., 2019). Indigenous knowledge, with its deep roots in local culture and understanding of the natural world, provides a rich context for learning that is often overlooked in mainstream education (Zidny et al., 2023).

In regions with limited technological infrastructure, access to AI technologies is a significant challenge. Additionally, there is a risk of encouraging educational inequalities if AI resources are not equitably distributed, particularly in regions where indigenous communities may have limited access to technology (UNESCO, 2019). Case studies from Zimbabwe have highlighted the difficulties faced by rural primary teachers in incorporating IK due to the lack of technological resources (Chirinda & Mavuru, 2008). Addressing these barriers requires investments in technology and equitable access to AI resources. Educators also face the challenge of developing curricula that respect and incorporate indigenous knowledge without compromising it or appropriating it. This requires a deep engagement with the community and an understanding of the cultural significance of indigenous knowledge (Jin, 2021).

The scarcity of culturally relevant resources is a notable challenge. In Eswatini, efforts to integrate IK into the science curriculum are often hindered by the lack of authentic resources that reflect the cultural contexts of indigenous communities (Jin, 2021). Maintaining cultural sensitivity is crucial to avoid the misrepresentation of IK. One of the primary challenges in integrating AI with indigenous knowledge is the potential for cultural insensitivity or misrepresentation. AI systems are typically designed from a Western perspective, which may not align with indigenous worldviews (Pedró et al., 2019). In Zimbabwe, educators have expressed concerns over the potential misinterpretation and misappropriation of IK when integrated with AI in science education (Chirinda & Mavuru, 2008).

Ethical issues arise concerning the ownership and protection of IK. The case of Zimbabwe shows the need for ethical guidelines to ensure the respectful use and protection of IK in educational settings (Chirinda & Mavuru, 2008). Despite these challenges, the integration of AI and indigenous knowledge in science education also presents significant opportunities. AI can facilitate the inclusion of indigenous perspectives in science curricula by providing platforms for storytelling, simulation, and the visualisation of complex ecological systems (Zidny et al., 2023). This can enrich students' understanding of science and its applications in real-world contexts.

Moreover, AI can support the preservation and dissemination of indigenous knowledge. Through digital archives and interactive learning environments, indigenous knowledge can be shared and accessed globally, promoting intercultural understanding and respect (Jin, 2021). Tanaka and Stapleton (2019) discuss the potential of AI to address cultural bias by developing inclusive and culturally responsive algorithms. Additionally, the use of AI can provide opportunities for collaborative learning and cross-cultural exchange, promoting cultural diversity in the classroom (Blikstein, 2019). To merge AI and IK, educators must adopt culturally responsive pedagogies. This involves creating learning experiences that are relevant to indigenous students and that validate their cultural identities (Jin, 2021). It also calls for educators to be proficient and adept in both technological and cultural competencies.

The potential of AI to transform science education in Zimbabwe and Eswatini is immense, particularly when it comes to integrating indigenous knowledge (IK). In Zimbabwe, AI-driven educational tools could provide interactive platforms that allow students to explore scientific concepts through the lens of their own cultural heritage, thereby making science education more inclusive and relevant (UNESCO, 2019). For instance, AI could be used to create virtual simulations of local ecosystems, enabling students to learn about biodiversity and conservation in a context that honours their indigenous understanding of the environment.

In Eswatini, the introduction of AI in classrooms could revolutionise the way IK is taught and preserved. By utilising AI to document and create indigenous stories and practices, educators can create a dynamic repository of knowledge that is accessible to students. This not only aids in the preservation of cultural heritage but also allows for a more nuanced understanding of the interplay between science and IK, which is crucial for fostering innovation and sustainability in science education (Jin, 2021).

Strategies for sustainable integration

To ensure the sustainable integration of IK into science curricula using AI technologies, strategic approaches are necessary. These strategies encompass curriculum design, teacher professional development, community engagement, and policy frameworks. A culturally responsive curriculum design includes the explicit recognition and incorporation of IK within the science curriculum, ensuring that it aligns with the cultural contexts and knowledge systems of the students. Teacher professional development programs can provide educators with the necessary knowledge and skills to effectively integrate AI and IK in their teaching practices. Community engagement plays a crucial role in co-creating and validating the integration process, involving indigenous communities, elders, and knowledge holders in curriculum development and implementation. Policy frameworks at the national and institutional levels can provide guidance and support for the integration of AI and IK in science education.

A curriculum that respects and incorporates IK aligns with the cultural contexts of students, fostering an inclusive learning environment. This involves updating educational materials and teaching methods to include indigenous perspectives and knowledge systems, which can make science more relevant and engaging to students. For example, incorporating case studies and examples from local indigenous practices can help bridge the gap between theoretical science and practical, real-world applications (Zidny, 2023). In Eswatini, efforts to collect traditional knowledge for the National Adaptation Plan (NAP) process highlight the value of IK in informing policies and educational content. The Eswatini competence-based curriculum could benefit from the inclusion of Indigenous (Technological) Knowledge, making education more relevant to students' lives.

Professional development programs are crucial for equipping educators with the skills to integrate AI and IK effectively. They need ongoing training and resources to develop the competencies required to bring together AI and IK in their classrooms. This includes understanding the cultural significance of IK as well as how to use AI tools to enhance learning. Ongoing workshops, seminars, ongoing short courses and collaborative projects can provide platforms for teachers to learn and share best practices (Handayani, 2023). Studies in Eswatini have shown that science teachers recognize the value of IK but require further training to bridge the gap between school science and IK.

Engaging indigenous communities in the curriculum development process ensures the validity and relevance of educational content. This means involving community members in curriculum development, ensuring that IK is accurately respectfully represented. It also involves creating opportunities for students to engage with their communities, learning directly from elders and knowledge holders. Such engagement ensures that education remains relevant to student's cultural identities and lived experiences (Hewson, 2015). In Eswatini, community involvement in the NAP process demonstrates the potential for co-creation in educational settings. Zimbabwe's educational reforms could similarly benefit from community-driven approaches to integrating IK.

Policy Frameworks National and institutional policies provide the necessary guidance and support for integrating AI and IK. Eswatini's NAP (National Adaptation Plan) is an example of a policy framework that values IK. The NAP aims to collect and integrate traditional knowledge into policies and educational content, which can serve as a model for how science education can respect and incorporate IK. This approach not only enriches the curriculum but also helps students connect more deeply with their cultural heritage and the environment (Zidny et.al, 2023) Park (2023) adds that Zimbabwe's climate change policy is an example of how policy can facilitate the inclusion of IK in education. Zidny (2020) postulates that Eswatini's competence-based curriculum is another example where Indigenous Technological Knowledge (ITK) could be integrated.

To further strengthen these efforts, it is essential to develop specific strategies within these policy frameworks that address the unique challenges and opportunities presented by the integration of AI and IK. For instance, policies could mandate the development of AI tools that are culturally sensitive and designed in collaboration with indigenous communities. According to Samuel (2020) this would ensure that the AI tools used in classrooms are appropriate for the cultural context of the students and can effectively support the integration of IK into science education.

Moreover, policies should encourage the creation of professional development programmes for educators that focus on the sustainable integration of AI and IK. These programs would equip educators with necessary skills to navigate the intersection of technology and traditional knowledge, enabling them to create a learning environment that is both technologically advanced, encourage critical thinking to the learners, encourage creativity, and create globally aware students who are also culturally sensitive. These programs should be ongoing so that educators and learners are abreast with current and contemporary scientific trends. Such initiatives would not only enhance the quality of science education but also promote the preservation of indigenous cultures and knowledge systems (Handayani et.al, 2023). Snively and Williams (2016) suggest that science educators must strive to design new curricula that represent a balanced perspective. Furthermore, they should expose students to multiple ways of understanding science. Murray (2015) states that the

empirical study of the integration of indigenous perspective in science education has become a model of science education in Canada, with sustainability at its core.

3. Methodology

The study employed an exploratory case study strategy. This strategy falls under the mixed method approach. This methodology was chosen because qualitative research alone often lacks generalizability due to smaller sample sizes yet the study also needed to get detailed in-depth responses from the participants. Mixed methods mitigated these weaknesses by incorporating large-scale quantitative research into the in-depth study. Secondly, combining methods enriches findings by providing context and depth. Qualitative data can illustrate quantitative results, adding richness to analysis. Lastly, using different methods enhanced credibility. When qualitative and quantitative data converge (triangulation), conclusions become more vigorous. Using a mixed method for the study will allow exploring both indigenous perspectives and science integration effectively. That is, mixed method offers of blending various research methods to seek the best solution to the precise research problem at hand.

Ten schools in the Lubombo region were selected using purposive sampling, representing the five clusters in the region. The sample included all the principals and 2 science teachers from each school, representing the junior and senior levels. Additionally, 10 students (5 junior-level and 5 senior-level) from each of the 10 schools were selected for focus group discussions, with the students being mixed to ensure diverse views. This comprehensive approach, involving students, teachers, and school administrators, aims to gain a comprehensive understanding of the integration of indigenous knowledge systems with science education in the Eswatini context. Primary data was collected through questionnaires, focus group discussions, and observations, while the secondary data was gathered through document analysis. The use of multiple data collection methods allowed the researchers to triangulate the findings and obtain a more comprehensive understanding of the research topic.

The data were analyzed using thematic analysis, specifically open coding. The thematic analysis involves actively engaging with qualitative data to identify patterns and themes. The study used thematic analysis to identify significant patterns in the data and address the research questions. Additionally, descriptive statistics was used to analyze closed-ended multiple-choice questions.

4. Results and discussion

The study aimed to explore the connections between indigenous knowledge systems and science education in the context of Eswatini. Semi-structured questionnaire, focus group discussions, observation and document analysis were used to collect data. The data is presented in thematic form and descriptive statistics.

In order to analyse qualitative data after collecting the data, the researcher exported the Excel file from the digital survey and then copied it into a Microsoft Word document to analyze the data. In the Word document, the researcher conducted open coding by identifying important phrases related to the intersection of indigenous knowledge systems, science education, and AI in each respondent's response. The statements and phrases were labelled using the exact words from the respondents or by creating new terms. These codes were then reviewed using the review function in Microsoft Word where they were extracted into a new document and later exported into Microsoft Excel using a custom macro. In Excel, the researcher sorted and finalized the codes, which were then categorised and collated to identify significant patterns of meaning, the grouped themes were then used to guide the discussion of the study. On the other hand, quantitative data was analysed using the Statistical Package for Social Science (SPSS).

Demographic data of the participants

The study gathered data from 30 participants, comprising of 20 teachers and 10 principals. There was a high response rate on the digital questionnaires, which were rolled out through emails and WhatsApp. This ensures the effectiveness and reliability of data collection (Holtom et al. 2022). It indicates that a large portion of the target population has taken part in the study, leading to more accurate and representative results.

Table 4.1 below shows the demographic data of the participants.

Age		**Gender**		**Qualification**		**Teaching experience**		**Level taught**	
26-30	**2**	Males	**17**	0-5years	**6**	Diploma	**10**	Primary	**10**
31-35	**10**	Female	**13**	5-10years	**7**	Degree	**16**	Secondary	**12**
Above 35	**18**			Above 10	**17**	Masters	**4**	Both	**8**
Total	**30**	Total	**30**	Total	**30**	Total	**30**	Total	**30**

The participants in the study were of varied age, gender, academic backgrounds, teaching experience and were pulled from both primary and secondary schools. This allowed diverse perceptions and rich contributions to be gathered hence increasing the effectiveness and reliability of the data gathered, and the research findings in general.

Themes and sub themes

Four themes were derived from the research objectives and the data gathered from the participants. The themes are discussed in this section.

1. Ways in Which Indigenous Knowledge Influences Academic Achievement in Eswatini's Educational System

The discussion on how indigenous knowledge influences children's academic achievement in Eswatini's educational system were finalized through a refining process. A total of 5 themes were identified, including cultural relevance, critical thinking and problem-solving, cultural competence, enhanced engagement, language and communication, and improved self-esteem and motivation. These themes were derived from key aspects explored through questionnaire responses from teachers and principals, who shared their views on how Indigenous knowledge plays a significant role in influencing children's academic achievement in Eswatini's educational system.

i. Cultural Relevance

Cultural relevance within Indigenous Knowledge Systems (IKS) is about recognizing, respecting, and integrating indigenous cultures, traditions, and practices into educational, social, and developmental processes. According to Zidny, Sjöström, and Eilks (2020b), when educational content is based on indigenous knowledge, it becomes more meaningful to students from indigenous backgrounds. This cultural resonance can boost motivation and interest in learning, leading to better academic performance.

The research found that teachers and principals in Eswatini's educational system believe that cultural relevance impacts children's academic achievement. This was supported by a respondent who stated:

> *"It ensures that people understand their background and helps them apply indigenous knowledge to their academic paths and understand new technologies."*

The results of the research support McNair et al. (2022) claim that educational methods tailored to specific cultures can improve student participation, drive, and academic success. Such practices can also help students gain a more profound comprehension of the world and their role within it.

ii. Critical Thinking and Problem-Solving

In the realm of Indigenous Knowledge Systems (IKS), students enhance their critical thinking and problem-solving skills by employing indigenous methods of knowledge, understanding, and interpretation of the world (Kigozi et al. 2021). These skills are used to analyze situations, question assumptions, and create innovative solutions. This educational approach encourages students to draw on the wealth of knowledge embedded in their cultural heritage and to address contemporary issues and challenges.

The findings of the study revealed that teachers and principals believe that integrating indigenous knowledge into Eswatini's educational system can impact students' critical thinking and problem-solving abilities, leading to improved academic performance. This was supported by a respondent who stated:

> *"By identifying problems within their communities, they begin to analyze the problems and may come up with strategies to solve them, thereby enhancing their analytical and problem-solving skills."*

The feedback provided by the teachers and principals affirms the World Economic Forum's (2018) assertion about the transformative impact of AI in education, promoting critical thinking, problem-solving skills, and cultural awareness.

iii. Enhanced Engagement

Student-enhanced engagement in the context of Indigenous Knowledge Systems (IKS) refers to the increased involvement, interest, and participation of students in their learning process when indigenous ways of knowing, doing, and understanding are integrated into the educational curriculum and practices (Mehta et al. 2022a). Incorporating indigenous knowledge into the curriculum can make learning more engaging for indigenous students. It allows them to see their cultural heritage reflected in their studies, which can boost their enthusiasm for academic pursuits.

The findings of the study revealed that teachers and principals believe that integrating indigenous knowledge into Eswatini's educational system can impact students' enhanced engagement, leading to improved participation in class and academic performance. This was supported by a respondent who stated:

> *"It is relatable and thus encourages learner engagement."*

The same point was raised by a teacher who stated:

> *"It does in many ways in that if the learners are able to use their local language in learning, they are able to understand easily and the knowledge of the cultures is not lost."*

The study's results align with Dlamini's Mehta et al. (2022b) argument that integrating indigenous knowledge into the educational curriculum can lead to a more inclusive, engaging, and empowering learning environment for indigenous students. This integration can help to connect their cultural heritage with their educational experiences, ultimately bridging the gap between the two.

iv. Language and Communication Style

Language preservation and communication style in the context of Indigenous Knowledge Systems (IKS) refer to efforts and approaches taken to continuously maintain indigenous languages and their distinct communication styles associated with these languages and cultures (Odora Hoppers 2021). The inclusion of indigenous languages in education not only preserves cultural heritage but also supports cognitive development. Indigenous languages often have unique communication styles that may include storytelling, non-verbal communication, and specific protocols for respectful interaction. Preserving these styles is as important as preserving the language itself. Proficiency in native languages can lead to better academic performance in students.

The findings of the study revealed that teachers and principals believe that integrating indigenous knowledge into Eswatini's educational system can significantly contribute to language development and communication style, leading to improved academic performance of students. This was supported by a respondent who stated:

> *"Indigenous knowledge systems often include local languages and communication styles that can support children's language development and communication skills."*

The responses given by the teachers and principals confirmed the assertion by Khanyile and Dlamini (2021) that the incorporation of Indigenous Knowledge Systems (IKS) into educational curricula, with a particular emphasis on indigenous languages and communication styles, has the potential to establish a more comprehensive and efficient learning atmosphere. This approach can be instrumental in sustaining the academic achievement and personal growth of indigenous students.

v. Improved self-esteem and motivation

Enhancing self-esteem and motivation in education through Indigenous Knowledge Systems (IKS) involves boosting students' confidence and their desire to succeed academically by integrating indigenous ways of knowing, doing, and being into the educational process (Dansu 2021). This methodology values indigenous cultures, languages, and knowledge, aiming to empower students by connecting their educational experiences with their cultural identity and heritage. Improved self-esteem and motivation foster a positive and supportive educational environment that motivates indigenous students to strive for academic excellence.

The study's findings indicate that teachers and principals believe that integrating indigenous knowledge into Eswatini's educational system can significantly enhance self-esteem and motivation for student learning. One respondent stated:

> *"Indigenous knowledge systems often include cultural values and beliefs that can support children's self-esteem and motivation to learn."*

The teachers' and principals' responses align with the findings of Sebotsa (2020) that integrating IKS into science education can empower students and give them a sense of agency and ownership over their learning. This inspires students to engage with knowledge relevant to their lives and communities, motivating them to apply themselves and see the direct benefits of their education.

2. The use of AI technologies to incorporate Indigenous Knowledge within Science curricula

AI technologies refer to the tools, techniques, and systems developed to enable machines to perform tasks that typically require human intelligence (Javaid et al. 2022). They are being integrated into various sectors to improve efficiency, enhance decision-making, and create new possibilities for innovation. The of AI and indigenous knowledge in science curricula is essential for cultural preservation, heritage digitization, educational enrichment, promoting inclusivity, innovative learning, ethical awareness, bridging knowledge systems, and customized learning experiences.

i. AI technologies and its' Potential Applications in Education

Artificial Intelligence (AI) technologies have the potential to revolutionize education. This can be achieved through personalized learning experiences, automation of administrative tasks, improved access to educational resources, and innovative methods for assessing and understanding student learning (Bates et al. 2020). However, the integration of AI in education should be approached with caution, considering ethical considerations, data privacy, and the necessity to enhance, rather than replace, human involvement in the learning process. The results established that only 65.4% of the respondents agreed that they are familiar with AI technologies and their applications in education. Given the rapid evolution of the education field, this poses a risk for teachers who are not up to date with integrating AI into their teaching methods. Therefore, educational institutions should prioritize professional development that includes training in

AI technologies and their educational applications. This initiative intends to provide teachers with the necessary skills to adapt to the changing educational landscape and offer students the most effective learning opportunities.

a) Cultural Heritage Digitization

Cultural Heritage Digitization involves using artificial intelligence (AI) technologies to transform tangible cultural artifacts, documents, artworks, and other heritage elements into digital forms (Hou et al. 2022). This helps improve their accessibility and preservation for the future. The process also makes indigenous knowledge more visible and integral into science curricula. According to the study, teachers and principals believe that AI technologies can significantly contribute to cultural heritage digitization. One respondent mentioned that:

> *"AI algorithms could analyze indigenous narratives, folktales, and community knowledge to identify key scientific concepts and principles. This information could then be used to develop more culturally relevant and contextualized science curricula."*

The viewpoints of the teachers and principals align with Leshkevich and Motozhanets (2022) assertion that AI is critical in transforming how we approach Cultural Heritage Digitization. AI offers faster, more accurate solutions that can reach a wider audience. It not only aids in preserving our cultural legacy but also makes it more accessible, interactive, and valuable for educational and research purposes.

b) Knowledge Sharing Platforms

Knowledge-sharing platforms are digital environments that facilitate the sharing, distribution, and collaborative enhancement of AI-centric knowledge, data, and resources (Gama and Magistretti 2023). These platforms come in various types, such as online communities, discussion forums, databases, and cooperative workspaces. They serve as central hubs for individuals and entities to exchange ideas, effective methods, research outcomes, and instructional materials related to artificial intelligence. AI can assist in developing knowledge-sharing platforms that connect indigenous communities with educators and researchers, serving as central points for integrating indigenous knowledge into scientific education. According to a study, teachers and principals believe that AI technologies can significantly contribute to the development of online knowledge-sharing platforms. One respondent mentioned that:

> *"AI-powered online platforms could facilitate the exchange of indigenous knowledge between elders, traditional healers, and educators. This could enable the co-creation of teaching resources that blend scientific and indigenous ways of knowing."*

The response given by the teachers and principals aligns with Dlamini's (2020) assertion who echoed that AI plays a crucial role in enhancing knowledge-sharing platforms through improving content quality, personalizing user experiences, fostering collaboration, and ensuring responsible knowledge usage (Nguyen and Malik, 2022). With the ongoing advancement of AI technologies, their impact on the evolution of knowledge-sharing and collaborative efforts is expected to become even more significant.

c) Simulation and Modelling

Simulation and modelling, within the realms of AI (Artificial Intelligence) and IKS (Indigenous Knowledge Systems), involve using computational methods to create virtual models or representations of real-world entities or processes, while incorporating indigenous knowledge (Karpatne, Kannan, and Kumar 2022). These models and simulations are designed to analyze, forecast, and understand complex phenomena, usually to address issues or make informed decisions based on a combination of AI technologies and indigenous insights. According to the results of the study, teachers and principals believe that AI technologies can significantly contribute to simulation and modelling. One respondent mentioned that:

> *"AI could be used to analyze the chemical and physiological properties of traditional medicines and to simulate the effects of these medicines on the body."*

The response given by the teachers and principals aligns with Irrgang et al. (2021) assertion that artificial intelligence significantly improves the simulation and modeling of Indigenous Knowledge Systems (IKS) by offering sophisticated computational tools and techniques capable of capturing the intricacies and subtleties of Indigenous knowledge. The following illustrates how AI can be utilized in the simulation and modelling within the realm of IKS.

d) Ethnobotanical Databases

The integration of Ethnobotanical databases with Indigenous Knowledge Systems and Artificial Intelligence serves as a digital platform for cataloguing, managing, and providing access to the traditional plant-related knowledge of indigenous peoples (Dapar and Alejandro 2020). These databases compile ethnobotanical information, including medicinal, cultural, spiritual, and economic plant uses recognized by indigenous groups, and leverage AI technologies to enhance the gathering, analysis, and dissemination of this invaluable knowledge. The results of a study established that teachers and principals believe that AI technologies can significantly contribute to the development and enrichment of ethnobotanical databases. One respondent stated:

"AI systems could be used to create comprehensive digital databases of indigenous medicinal plants and traditional ecological knowledge. This could help to integrate traditional Swazi healing practices and sustainable resource management into science education."

The views expressed by the teachers and principals are aligned with Karpatne, Kannan, and Kumar (2022) assertion, who shares a similar sentiment about integrating AI into ethnobotanical databases. This integration can enhance the repositories to be more comprehensive, accurate, and user-friendly, providing valuable resources for researchers, policymakers, and indigenous communities. However, it is crucial to employ AI with sensitivity to the cultural and ethical aspects of indigenous knowledge, ensuring that the rights and viewpoints of indigenous peoples are respected and protected.

e) Accessibility and Inclusivity

Accessibility and inclusivity within the fields of AI (Artificial Intelligence) and IKS (Indigenous Knowledge Systems) involve creating, developing, and implementing AI technologies in ways that are accessible and inclusive to indigenous peoples and their knowledge systems (Oguamanam 2021a). This means considering the diverse needs, perspectives, and values of indigenous communities when developing AI applications and ensuring that indigenous knowledge is recognized, respected, and integrated into AI systems. AI can also help make indigenous knowledge more accessible to people with disabilities by providing alternative formats and assistive technologies, thus promoting inclusivity in science education. According to the findings of the study, teachers and principals believe that AI technologies can significantly improve accessibility and inclusivity in science education. One respondent mentioned that AI can assist in

"It's promoting equitable and barrier-free learning opportunities for learners."

The perspectives of teachers and principals align with Dlamini's (2020) assertion, who shares a similar view on the interaction between the accessibility and inclusivity of Indigenous Knowledge Systems (IKS) within the field of Artificial Intelligence (Sitsha 2023). This area strongly intersects with science education, offering transformative possibilities for how scientific knowledge is shared, understood, and used by learners from diverse backgrounds and with different abilities. AI can play a key role in improving the accessibility and inclusivity of science education by addressing various challenges and leveraging its strengths in personalized learning, language processing, and content customization.

f) Familiarity with AI tools

To further achieve objective 2, through an open-ended question in the questionnaire, teachers and principals were asked the question, what, if any, AI tools or platforms are you currently using in your teaching? The frequencies of AI tools mentioned in the provided after analyzing the given data gathered are presented in Table 4.2.

Table 4.2: Frequencies of AI Tools

AI Tools	Frequency
ChatGPT	10
Copilot	3
Poe	3
Pi	2
PHET	1
Bing	1
Easy Chat	1
Quillbot	1
Jasper AI	1
None	9
Not sure	5

From the given data we can draw that most teachers and principals are at least familiar with Chat GPT as it was the most frequently mentioned AI, tool, followed by the responses indicating no use of Ai tools, this suggest that out of the 26 respondents 9 have no idea and have never used it. This is to say roughly 35% have no idea and have never used Ai tools. Other respondents seem to be using Copilot, Poe as they indicate the same numbers. Other less used Ai platforms are PHET, Bing, Easy chat, Quillbot, jasper AI. Other responses such as those who mentioned Google or encyclopedia were categorized other not sure since their responses are not AI tools. This indicates that these respondents do not know or are not sure of what AI tools are.

3. Challenges associated with integrating IK in Science education using AI.

Integrating AI and IK in science education presents both challenges and opportunities (Molino 2023). One primary challenge is the digital divide, which may limit access to AI technology in remote indigenous communities, hindering the fair integration of AI tools and resources. However, there are significant opportunities as well. AI can be used to develop culturally relevant educational content that integrates IK, making science education more engaging and meaningful for indigenous students. Additionally, AI-driven analytics can help educators monitor student progress and adapt teaching methods to better meet the learning styles and needs of indigenous learners (Chisom, Unachukwu, and Osawaru 2023). By addressing challenges and capitalizing on opportunities, the integration of AI and IK in science education has the potential to enhance cultural understanding, promote educational equity, and cultivate a deeper appreciation of the diverse ways of knowing and being in the world. A digital semi-structured questionnaire was developed and circulated to teachers and principals to gather insight on the challenges and opportunities associated with integrating AI and indigenous knowledge in science education. Under these objective sub-themes that were discussed were categorized and listed under each of the following sub-headings.

a) Recognition and Validation

The recognition and validation of IK refer to the processes through which the knowledge, practices, and innovations developed by indigenous peoples over generations are acknowledged, respected, and affirmed as valuable and legitimate forms of knowledge (Khupe 2020). Indigenous knowledge has often been undervalued or marginalized in formal education systems. Efforts to integrate IK with AI must work to recognize and validate indigenous ways of knowing as equal to Western scientific knowledge. The findings of the study indicated that teachers and principals noted recognition and validation as one of the challenges that can hinder AI and indigenous knowledge integration in science education. One respondent mentioned that

> *"Most indigenous knowledge is undocumented so AI will have a problem getting reference on most information."*

The perspectives of teachers and principals complement Lam et al. (2020) assertion that the recognition and validation of Indigenous Knowledge can lead to more equitable, diverse, and sustainable societies by ensuring that the valuable insights and wisdom of indigenous peoples are acknowledged, respected, and integrated into contemporary systems and practices.

b) Digital Divide

The digital divide in AI and IKS in science education refers to the gap between individuals or communities that have access to digital technologies, AI applications, and online educational materials, and those who do not (Creighton 2022). Contributing factors to this gap include inadequate infrastructure, such as consistent internet connectivity and suitable devices, as well as a lack of skills and training to use these technologies effectively. The current study found that teachers and principals identified the digital divide as a challenge that can hinder the integration of AI and Indigenous knowledge in science education. One respondent mentioned,

> *"The lack of proper resources and text needed for integrating, as well as the gadgets and reliable networks within the region."*

Another teacher also expressed similar sentiments, stating,

> *"Many rural communities in Eswatini may lack the digital connectivity, hardware, and technical skills needed to effectively engage with AI-powered platforms and data collection."*

These views align with Fredriksen's assertion that education in Africa is at a crossroads, facing the challenges of ensuring universal access and enhancing educational quality. In this context, the integration of Artificial Intelligence (AI) into educational systems emerges as a transformative force with the potential to revolutionize learning environments across the continent.

c) Technological Literacy

Technological literacy encompasses the knowledge, skills, and attitudes necessary to comprehend, utilize, and interact with technology effectively (Falloon 2020). This literacy is vital for educators and students to maximize the advantages of AI in science education and to honour and incorporate indigenous knowledge. It empowers individuals to be active participants in the digital era, make knowledgeable choices about technology, and aid in creating educational materials that are both technologically sophisticated and culturally considerate. The current study found that teachers and principals identified technological literacy as a challenge that can hinder the integration of AI and Indigenous knowledge in science education. One respondent mentioned:

> *"Few educators may have the necessary expertise to effectively integrate AI and indigenous knowledge into science curricula."*

These views align with Seufert, Guggemos, & Sailer (2021) assertion that technological literacy is essential for the successful incorporation of AI into Indigenous Knowledge Systems (IKS) within science education. It guarantees that the

integration is knowledgeable, ethical, and culturally considerate, culminating in the enhancement of science education through the insights of indigenous knowledge systems.

d) Cultural Sensitivity and Appropriation

Cultural sensitivity involves being aware of, comprehending, and respecting the diverse cultural practices, social behaviors, and norms present in indigenous communities (BAL 2020). Conversely, cultural appropriation happens when members of one culture adopt elements of another without consent, frequently distorting or showing disrespect to the original cultural context. The current study found that teachers and principals identified cultural sensitivity and appropriation as another challenge that can hinder the integration of AI and Indigenous knowledge in science education. One respondent mentioned,

> *"It is important to approach indigenous knowledge with respect and cultural sensitivity, and to ensure that indigenous communities are consulted and involved in the development of educational materials that incorporate their knowledge."*

Another teacher also expressed similar sentiments, stating,

> *"Indigenous knowledge is often embedded within complex cultural, spiritual, and linguistic frameworks. Translating and digitizing this knowledge for AI systems risks stripping away important contextual nuances."*

These views align with Young and Guo (2020) sentiments that cultural sensitivity and appropriation play a pivotal role in the successful incorporation of AI into Indigenous Knowledge Systems within science education. They affect the level of engagement with Indigenous communities, the fidelity of knowledge representation, the ethics of educational methodologies, and the overall efficacy and longevity of initiatives that enhance science education through AI.

e) Interdisciplinary Collaboration

The collaboration between AI and IK in science education involves experts, practitioners, and knowledge bearers from different fields working together to develop, implement, and assess educational initiatives that combine AI technologies with indigenous knowledge (Ozga 2020). The study found that teachers and principals identified interdisciplinary collaboration as a challenge that can hinder the integration of AI and Indigenous knowledge in science education. One respondent mentioned,

> *"Building sustained trust and partnerships between indigenous knowledge holders, educators, and AI developers will be crucial, but may be hindered by historical power."*

These views resonate with Rodríguez-Triana et al. (2020) thoughts that interdisciplinary collaboration enhances the incorporation of AI into Indigenous Knowledge Systems within science education. It provides a holistic and inclusive methodology that respects cultural heritage and embraces technological progress. This ensures that the integration is considerate, ethical, and beneficial for indigenous communities and the broader educational context.

3. Opportunities associated with integrating IK in Science education using Ai.

The findings indicated that teachers and principals perceive that Authentic Integration, Global Education, Information Preservation and Personalized Learning, are opportunities that can enhance AI and indigenous knowledge integration in the science education in Eswatini.

a) Authentic Integration

Incorporating authentic integration of AI and IK into science education is crucial for promoting inclusivity and respect for indigenous knowledge, customs, and viewpoints (Sammel 2020). This integration involves the thoughtful inclusion of indigenous knowledge and perspectives into science curricula that utilize AI technologies. AI can play a vital role in this integration by identifying and emphasizing the connections between indigenous perspectives and scientific concepts. In the current study, teachers and school principals recognized the potential of authentic integration in the fusion of AI and Indigenous knowledge in science education. One respondent noted that"

> *"AI systems could help identify synergies and complementarities between traditional Swazi wisdom and Western scientific concepts, fostering cross-cultural understanding and holistic approaches to problem-solving"*

These perspectives align with Padayachee (2022b) assertion that authentic integration offers a pathway to develop science education that is inclusive, culturally sensitive, and impactful while honouring indigenous knowledge and supporting indigenous communities' well-being.

b) Global Education

Global education focuses on an educational approach that emphasizes understanding complex global interdependencies and valuing diverse viewpoints in addressing worldwide challenges (Kezar 2023). This approach involves integrating AI and indigenous knowledge into science education to enhance global awareness, cultural sensitivity, and critical thinking about international issues. AI can support global education initiatives by making indigenous knowledge from around the world accessible to learners globally, promoting cross-cultural understanding and appreciation. The findings of the study, confirmed that teachers and school principals acknowledged the potential of AI in enhancing global education of Indigenous knowledge in science education. One respondent noted:

> *"Opportunities to gain more knowledge on given topics, connect with more people in the sharing of knowledge, and have easy access to information."*

These perspectives align with Goodwin (2020) assertion that global education is crucial for the respectful, ethical, and mutually beneficial integration of AI and Indigenous Knowledge Systems (IKS) in science education. It contributes to the creation of a fairer and interconnected global society that values diversity and leverages the strengths of different knowledge systems.

c) Information Preservation

The preservation of information in AI and IK in science education involves the methods and strategies used to maintain the durability, integrity, and availability of indigenous knowledge and cultural data within AI augmented educational programs (Balogun and Kalusopa 2021). The findings of this study found that teachers and school principals recognize the potential of AI to contribute to the preservation of Indigenous knowledge in science education. One respondent commented,

> *"Educating the next generation on indigenous information will fairly inform the future generations and help preserve and protect the information."*

These perspectives align with Oguamanam (2021b) assertion that preservation of information is crucial for integrating AI with Indigenous Knowledge Systems (IKS) in science education. This guarantees the endurance of indigenous knowledge, promotes cultural diversity, and enhances the global body of scientific knowledge, leading to a more inclusive, fair, and well-informed global community.

d) Personalized Learning

Personalized learning in AI and IK within science education is an approach that tailors the learning journey to fit the unique needs, interests, skills, and cultural contexts of each learner. It utilizes AI technology to create adaptive and versatile learning environments that accommodate the diverse learning preferences and indigenous knowledge of students. One respondent noted that,

> *"AI can create personalized learning experiences that integrate indigenous mathematical concepts, meeting individual student needs and learning styles."*

These views are in line with Ozga (2020) assertion that the significance of personalized learning lies in combining AI with Indigenous Knowledge Systems (IKS) in science education. This combination can cultivate a culturally sensitive, inclusive, and efficient learning environment that respects the distinct identities and knowledge bases of indigenous communities. AI technologies can continuously evolve and personalize learning experiences using current data and feedback, ensuring that the educational experience adapts to the changing needs and preferences of indigenous students.

From the above data, above, ‘moderate’ in this context suggest that teachers are either less comfortable or not comfortable at all with using technology in teaching subjects. This is a large percentage which supports the conclusion that there is a need for ongoing in-service training for teachers. More than half of the respondents fall into the categories of moderate or lower comfort levels. There is also a suggestion that teachers need to be trained regularly how to use technology in teaching science subjects. This training could help increase their comfort levels and increase their instructional pedagogies and make science more practical and fun for the learners. The data also indicates that there is a potential improvement with the 2 respondents that are extremely comfortable since there is a significant room for improvement in comfort levels with technology use in science and due to the fact that technology improves and changes daily. So, the data indicates a clear need for professional development focused on technology integration in science teaching.

4. Strategies to effectively use AI to integrate IK in Science education

The data collected from the focus group discussion with students indicates the following topics where IKS can be easily be incorporated to enhance learning in various science subjects:

Table 4.3: Effective strategies for leveraging AI to integrate IK into Science Education

	SCIENCE SUBJECT	TOPIC IN WHICH IK CAN BE INCOPORATED
1.	Agriculture	Crop production, Animal husbandry, Soil management
2.	Biology	Biodiversity, Medicine, Reproduction
3.	Consumer Science	Home management, Food preservation, Nutrition
4.	Geography	Weather patterns, Landmarks

Both teachers and students offered teaching methods, which can make learning using AI interesting. Some of the common responses were: train teachers on Ai and technology use, educate students on responsible AI use, incorporate more practical lessons and field trips, Government should provide more resources and infrastructure, use interactive experiences (VR, AR, simulations), use storytelling and songs to teach science.

Recommendations

Based on the findings of the study, the following recommendations are proposed for various stakeholders to fully utilize AI in connecting Indigenous knowledge with formal science education in Eswatini:

Policymakers and Ministry of Education- Enhance digital infrastructure in schools and communities to ensure reliable access to AI technologies and internet for all learners. They must invest in research exploring the intersection of AI, indigenous knowledge, and science education to inform best practices and innovative approaches. The ministry can establish a dedicated research fund for this purpose and collaborate with universities to conduct studies. They can also organize conferences and workshops to bring together experts in AI, education, and indigenous knowledge. Creating a national database of indigenous knowledge and funding pilot projects that integrate AI and IKS in science classrooms would be beneficial. It is imperative to ensure all students, regardless of their background or location, have equal access to AI-enhanced educational opportunities. Lastly, they should develop ethical guidelines for AI use in education. The ministry can form a task force comprising educators, AI experts, ethicists, and community leaders to draft these guidelines.

For School Administrators and Parents- Create partnerships between schools and other countries to facilitate knowledge exchange and resource sharing. School administrators can establish sister school programs with international institutions that have successfully integrated AI and IK in their curricula. They can organize virtual exchange programs, allowing students and teachers to share experiences and best practices. Regular online conferences or workshops can be held to discuss innovative approaches and challenges in implementing AI and IKS in science education. Administrators can allocate funds for AI tools and resources in their school budgets. They can organize training sessions for parents to understand the importance of AI and IKS in education. Parents can be encouraged to share their indigenous knowledge with the school community through cultural days or guest lectures. Schools can also create AI and IKS clubs to promote extracurricular engagement with these topics. Parents can support schools by buying technological gadgets for their children.

For Teachers and Teacher Development Institutions: UNESWA, William Pitcher - Provide professional development for educators on effectively using AI tools and integrating indigenous knowledge into their teaching. Teacher training institutions can develop comprehensive courses on AI in education and IK integration. They should encourage teachers to explore and implement AI-powered educational content that incorporates local language and cultural contexts. Institutions can create resource banks of AI-powered educational content in local languages.

For Science Subjects Curriculum Developers- Seek ways to incorporate IKS and AI in Eswatini's curriculum by learning from other countries like South Africa, Kenya, Japan, Australia, etc. Curriculum developers can organize study tours to these countries to observe their integration of IKS and AI in science education first hand. They can establish partnerships with curriculum development bodies in these countries for knowledge exchange. Regular international conferences can be organized in Eswatini to discuss best practices and challenges in integrating IKS and AI. A task force can be formed to adapt successful strategies from other countries to the Eswatini context.

Further research- must investigate the long-term impacts of AI-enhanced IKS integration on student achievement and cultural preservation. And explore the development of culturally-specific AI algorithms for educational purposes in Eswatini.

References

1. Abas, A., Azmi A., & Azahan, A. (2022). A Systematic Review on the Local Wisdom of Indigenous People in Nature Conservation. *Sustainability 14*(6): 3415.
2. Aikehead, G. S. (2006). *Science education for everyday life: evidence-based practice.* Teachers College press.
3. Balogun, T, & Kalusopa, T. (2021). A Framework for Digital Preservation of Indigenous Knowledge System (IKS) in Repositories in South Africa. *Records Management Journal 31*(2): 176–96.
4. Bates, T., Cristóbal C., Olga M., Wheeler, S. (2020). Can Artificial Intelligence Transform Higher Education? *International Journal of Educational Technology in Higher Education 17*, 1–12.
5. Blikstein, P. (2019). Multimodal learning analytics and education data mining: Using computational technologies to measure complex learning tasks. *Journal of Learning Analytics 4*, 143-165
6. Cajete, G. (2000). *Native Science: Natural laws of independence*. Clear Light Publishers.
7. Chirinda, B., & Mavuru, L. (2008). *Incorporating Indigenous Knowledge in Science Education: The case of Zimbabwe*. College Press
8. Chisom, O.N., Chika C.U., and Osawaru, B. (2023). Review of AI in Education: Transforming Learning Environments in Africa. *International Journal of Applied Research in Social Sciences 5*(10): 637–54.
9. Dansu, Taiwo. (2021). Impact of Indigenous Knowledge System and Practices (IKSP) on Secondary School Students' Comprehension and Entrepreneurial Skill in Chemistry Concepts. Available at SSRN 4348210.
10. Dlamini, T. S. (2017). Storytelling and cognitive development in early childhood education. *International Journal of Child Care and Education Policy*. *1*(3) 78-93.
11. Eaude, Tony. (2024). The Role of Culture and Traditions in How Young Children's Identities Are Constructed. In *Children's Spirituality and Traditions,* Routledge, 7–21.
12. Engeström, Y. (1999). Activity theory and individual and social transformation. In Y. Engeström, R. Miettinen, & R.-L. Punamäki (Eds.), *Perspectives on activity theory* (pp. 19-38). Cambridge University Press.
13. Falloon, G. (2020). From Digital Literacy to Digital Competence: The Teacher Digital Competency (TDC) Framework. *Educational technology research and development 68*(5): 2449–72.
14. Hernandez, R. (2022). Language preservation and AI. *Journal of Linguistic Preservation. 3(7), 67-85.*
15. Hewson, M.G. (2015). Integrating Indigenous Knowledge with Science Teaching. In: Embracing Indigenous Knowledge in Science and Medical Teaching. *Cultural Studies of science education 10*.
16. Hlophe, T., & Dlamini, T. S. (2019). The prospects of indigenous knowledge systems (IKS) in Eswatini. *SEPARC Research Journal*, *5*(2), 34-45.
17. Irrgang, C., Boers, N., Maike, S., Barnes, E.A. Christopher, K., Staneva, J. & -Wagner, J.S. (2021). Towards Neural Earth System Modelling by Integrating Artificial Intelligence in Earth System Science. *Nature Machine Intelligence 3*(8), 667–74.
18. Rajiv S. (2022). Artificial Intelligence Applications for Industry 4.0: A Literature-Based Study. *Journal of Industrial Integration and Management 7*(01), 83–111.
19. Jenkins, H. (2021). A digital indigenous knowledge preservation framework: The 7C model. In Digitisation of Culture: Namibian and International Perspectives (pp. 29-47). Sage.
20. Jensen, T. M., and Caroline S. (2021). A Scoping Review of Research on Well-being across Diverse Family Structures: Rethinking Approaches for Understanding Contemporary Families. *Journal of Family Theory & Review 13*(4), 463–95.
21. Karjalainen, H. (2020). Cultural Identity and Its Impact on Today's Multicultural Organizations. *International Journal of Cross Cultural Management 20*(2), 249–62.
22. Khanyile, N. C., and Dlamini. P. (2021). Preservation of Traditional Medicinal Knowledge: Initiatives and Techniques in Rural Communities in KwaZulu-Natal." *Library Philosophy and Practice:* 1–19.
23. Karpatne, A., Ramakrishnan, K., & Kumar, V. (2022). *Knowledge Guided Machine Learning: Accelerating Discovery Using Scientific Knowledge and Data.* CRC Press.
24. Kezar, Adrianna J. (2023). *Rethinking Leadership in a Complex, Multicultural, and Global Environment: New Concepts and Models for Higher Education*. Taylor & Francis.
25. Khupe, Constance. (2020). *Indigenous Knowledge Systems. Science Education in Theory and Practice: An introductory guide to learning theory*. CRC Press.
26. Kigozi, F., Femi O., Risenga, I. & Dukhan, S.(2021). *Teachers' Indigenous Knowledge Awareness and How to Implement It in Teaching and Learning Sciences in South African Schools.* Pelgraves.
27. Magni, G. (2016). Prospect and challenges of integrating indigenous knowledge systems into the Natural Science curriculum in schools. EUREKA: *Social and Humanities 1*, 56-77.
28. McNair, T.B., S A., McDonald, N., Major, T., & Michelle, A. C. (2022). *Becoming a Student-Ready College: A New Culture of Leadership for Student Success.* John Wiley & Sons.
29. Mehta, K., Theodore, R.A., Ladislaus, M.S., & Maretzki, A. (2022) a."AcademIK Connections: Bringing Indigenous Knowledge and Perspectives into the Classroom." *Journal of Community Engagement and Scholarship 6*(2) 45-61.
30. Mehta, K., Theodore R. A., Semali, M.L. & Maretzki, A. (2022) b. "AcademIK Connections: Bringing Indigenous Knowledge and Perspectives into the Classroom." Journal of Community Engagement and Scholarship 6(2).

31. Mapara, J. (2009). Indigenous knowledge systems in Zimbabwe: Juxtaposing postcolonial theory. *The Journal of Pan African Studies, 3*(1), 139-155.
32. Molino, J. N. (2023). Interreligious Views on the Integration of Artificial Intelligence and Indigenous Knowledge for Environmental Preservation. *Religion and Social Communication Journal* 2, 431-148.
33. Odora. H, C. (2021). Research on Indigenous Knowledge Systems: The Search for Cognitive Justice. *International Journal of Lifelong Education 40*(4), 310–27.
34. Oguamanam, C. (2021) a. From Science, Technology and Innovation to Fourth Industrial Revolution Strategies in Africa: The Case for Indigenous Knowledge Systems. Leap 4.0. African Perspectives on the Fourth Industrial Revolution: African Perspectives on the Fourth Industrial Revolution.
35. Oguamanam, C. (2021) b. From Science, Technology and Innovation to Fourth Industrial Revolution Strategies in Africa: The Case for Indigenous Knowledge Systems. Leap 4.0. African Perspectives on the Fourth Industrial Revolution: African Perspectives on the Fourth Industrial Revolution.
36. *Ozga, J. T. (2020).* Elites and Expertise: The Changing Material Production of Knowledge for Policy. *Handbook of Education Policy Studies: Values, Governance, Globalization, and Methodology, Volume 1*: 53–69.
37. Padayachee, K. (2022) a. I*ntegral Education for Early Childhood Development: Building Values through Indigenous Knowledge.* Routledge.
38. Padayachee, Kanyakumarie. (2022) b. *Integral Education for Early Childhood Development: Building Values through Indigenous Knowledge.* Routledge.
39. Park, H. (2023). Education Policy Outlook 2023: Empowering All Learners to Go Green. OECD Publishing
40. Rodríguez, T.M.J., Luis P., & Gillet, D. (2020). Social Practices in Teacher Knowledge Creation and Innovation Adoption: A Large-Scale Study in an Online Instructional Design Community for Inquiry Learning. *International Journal of Computer-Supported Collaborative Learning 15*: 445–67.
41. Santos, A. (2023). Indigenous knowledge and artificial intelligence: A CHAT perspective. Springer.
42. Samuel, A. (2020). How embedding Indigenous Knowledge systems will help the Teaching and Learning of Western Science to evolve. In: Samuel, A., Whatman, S., Blue, L. (eds) Indigenizing Education. Springer, Singapore.
43. Sebotsa, T. (2020). *Teachers' Lived Experiences of Contextualised Interventions, and Its Affordances for Their Professional Development and for Self-Directed Learning in Physical Sciences*. Sprimger.
44. Seufert, S., Josef, G., and Michael, S. (2021). Technology-Related Knowledge, Skills, and Attitudes of Pre-and in-Service Teachers: The Current Situation and Emerging Trends. *Computers in Human Behavior 115*: 106552.
45. Sitsha, M. (2023). *Exploring the Integration of Indigenous Knowledge Systems (IKS) into the Teaching of Life Sciences through Information and Communication Technologies (ICTs).* Springer.
46. UNESCO. (2023) Leveraging Unesco Normative Instruments for an Ethical Generative AI Use of Indigenous Data.
47. Verma, J. (2020). "Collectivism in the Cultural Perspective: The Indian Scene." *In Latest Contributions to Cross-Cultural Psychology*. Routledge, 228–41.
48. Yamagata-Lynch, L. C. (2024). *Activity theory and the integration of technology in education*. Routledge.
49. Young, S., & Guo, C.L. (2020). Cultural Diversity Training: The Necessity of Cultural Competence for Health Care Providers and in Nursing Practice. *The health care manager 39*(2): 100–108.
50. Zidny, R., Sjöström, J., & Eilks, I. (2020). Indigenous knowledge and science and technology education. In B. Akpan et al. (Eds.), *Contemporary Issues in Science and Technology Education* (pp. 165-179).
51. Zidny, R., Sjöström, J., & Eilks, I. (2020*). A Multi-Perspective Reflection on how Indigenous Knowledge and Related Ideas Can Improve Science Education for Sustainability*. Routledge.
52. Zidny, R., Sjöström, J., & Eilks, I. (2023). Indigenous Knowledge and Science and Technology Education. *In Contemporary Issues in Science and Technology Education* (pp. 165–179).
53. Zidny, R., Sjöström, J., & Eilks, I. (2023). Indigenous Knowledge and Science and technology education. In B. Akpan, B. Cavas & T. Kennedy (Eds.), Contemporary Trends and Issues in *Science education and Technology Education. 1*(56) 238-251.
54. Zidny, B., Sjöström, J. & Ingo, E. (2020) a. A Multi-Perspective Reflection on How Indigenous Knowledge and Related Ideas Can Improve Science Education for Sustainability. *Science & Education 29*(1): 145–85.
55. Zidny, R., Sjöström, J. & Ingo, E. (2020) b. A Multi-Perspective Reflection on How Indigenous Knowledge and Related Ideas Can Improve Science Education for Sustainability. *Science & Education 29*(1): 145–85.
56. Zikhali, W. (2018). Indigenous Knowledge systems for development: A critical analysis from Nkanyi District, Zimbabwe. *Advances in Social Science Research journal. 3*(4)113-135.