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BRIDGING WORLDS: INTEGRATING INDIGENOUS KNOWLEDGE SYSTEMS WITH SCIENCE EDUCATION AND AI: A CASE OF THE LUBOMBO REGION SCHOOLS

BY

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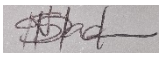

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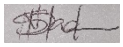

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ABBREVIATIONS

AI	Artificial intelligence
CHAT	Cultural-Historical Activity Theory
IKS	Indigenous Knowledge Systems
HBSCED	Honours Bachelors Science Education Degree
STEM	Science, Technology, Engineering and Mathematics
ZIMSEC	Zimbabwe School Examination Council

ABSTRACT

This research investigates integrating indigenous knowledge systems with science education in Eswatini 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 inclusive 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 study uses Cultural Historical Activity Theory to analyze interactions between indigenous knowledge AI and educational practices. Literature review reveals AI's potential to enhance indigenous knowledge recognition and incorporation while highlighting cultural sensitivity and access challenges. Educators' perceptions and professional development needs are examined. Mixed methods approach with pragmatist philosophy employs exploratory case study design in ten Lubombo region schools. Data collection includes questionnaires focus groups observations and document analysis targeting principals, teachers, and students. Thematic analysis and descriptive statistics are used with ethical considerations prioritized. Findings show indigenous knowledge positively influences child development and academic achievement promoting holistic learning cultural identity and engagement. AI is used for cultural heritage digitization knowledge sharing and improving science curricula accessibility. Challenges include digital divide, technologically knowledge and cultural sensitivity while opportunities include authentic integration global education and personalized learning. AI's potential to transform science education by integrating indigenous knowledge through innovative culturally respectful methods is highlighted. Recommendations include enhancing digital infrastructure providing educator professional development and developing AI powered educational content incorporating local language and culture. 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.

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CHAPTER 1

THE PROBLEM AND ITS SETTING

1.0 INTRODUCTION

The integration of indigenous knowledge systems with science education, coupled with the potential contributions of artificial intelligence (AI), constitutes the central focus of this research. Indigenous knowledge is deeply rooted in the wisdom and practices of local communities. It offers valuable insights into the natural world. By incorporating indigenous perspectives, we can enrich science education and foster a holistic understanding of scientific phenomena. Furthermore, the rapid advancements in AI technologies present novel opportunities to enhance educational practices, including the recognition and seamless integration of indigenous knowledge within science curricula. This study explores the intersection of indigenous knowledge systems, science education, and AI, specifically within the context of Eswatini. Chapter 1 discusses the problem and its setting. It also exposes the significance of the study and its benefits to different stakeholders in the country.

1.1 BACKGROUND TO THE STUDY

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 countries like Zimbabwe. Historically, IK has been sidelined 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 (Harvard Graduate School of Education, 2023). 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.

1.2 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.

1.3 RESEARCH AIM

To investigate AI tools that can effectively integrate indigenous knowledge systems into the science education curricula of Eswatini, thereby enhancing cultural relevance and inclusivity in the learning environment.

1.4 RESEARCH OBJECTIVES

To achieve the research aim, the study set out to:

1. Explore how indigenous knowledge influence child development and academic 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. Access educators' perceptions and attitudes towards the use of AI in bridging the gap between indigenous knowledge systems and formal science education.
5. Recommend informed strategies to ensure the sustainable integration of IK into science curricula using AI.

1.5 RESEARCH QUESTIONS

This research sought to address the following research questions:

1. In what ways does Indigenous Knowledge contribute to child development and academic achievement?
2. How can AI technologies be designed to effectively recognize, incorporate and present indigenous knowledge within science curricula?
3. What are the main challenges and opportunities that educators face when integrating AI and indigenous knowledge in science education?
4. What are educators' perceptions and attitudes towards the use of AI to bridge the gap between indigenous knowledge systems and formal education?
5. What strategies can be developed to ensure the sustainable integration of indigenous knowledge into science curricula with the aid of AI technologies in Eswatini?

1.6 SIGNIFICANCE OF THE STUDY

This study holds significant implications for educational research, policy, and practice. By exploring the integration of indigenous knowledge systems with science education and the role of AI in this process, this research contributes to the advancement of inclusive and culturally responsive pedagogies. The findings provide insights into design and implementation of AI tools that recognize and incorporate indigenous knowledge, fostering a more holistic and comprehensive approach to science education. Moreover, this research aligns with global trends towards the digitization of education and the recognition of diverse knowledge systems. This research further holds immense importance for various stakeholders in Eswatini which are:

Educational Institutions: By recognizing and incorporating indigenous knowledge through AI-supported tools, institutions can promote cultural diversity and respect local traditions.

Cultural Preservation: The study contributes to preserving indigenous knowledge and ensuring its continuity.

Technological Advancement: Leveraging AI for educational purposes aligns with global technological trends and fosters innovation.

By exploring the potential of AI in bridging the gap between indigenous knowledge and formal science education, this study addresses the need for innovative and technology-enhanced educational practices in Eswatini hence producing critical thinkers, global competent, culturally sensitive, inclusive and practical learners which will contribute to the development of the economy in Eswatini.

1.7 DELIMITATION OF THE STUDY

This research specifically focused on the integration of indigenous knowledge systems with science education using AI tools in the context of Eswatini. The research was carried out in the Lubombo region in Eswatini. The chosen region is mostly rural and comprises 66 high schools. Regarding the classification of these schools, it is important to note that the distinction between rural and semi-rural can be context specific. However, given the rural nature of the Lubombo region, many of these schools fell in the rural areas. The research focused on 10 schools among the 66 in the region. The findings and recommendations may not be directly applicable to other geographical regions or cultural contexts.

1.8 LIMITATIONS OF THE STUDY

This research was subject to certain limitations, including the availability and accessibility of relevant data and literature on indigenous knowledge systems in Eswatini. The constraints of time and resources also limited the scope and depth of the research. Additionally, the study cannot preclude biases and subjectivity in data collection and analysis, which should be taken into consideration. To address these limitations, the following strategies were implemented:

1. Data availability and accessibility:

- Establish partnerships with expects and local institutions to gain access to data and literature
- utilise technology to digitise and preserve indigenous knowledge for easier access and study

2. Time and resource constraints:

    - Prioritize key areas of research to ensure depth over breadth within the available time frame
    - Seek additional resources through collaborations to expand scope of the research and Subjectivity
    - Employ a mixed- methods approach to balance qualitative insights with quantitative data
    - Include peer reviews and triangulation methods to validate the findings and reduce potential balances.

1.9 DEFINITION OF TERMS

This section provides definitions for key terms used throughout the research which are:

i. Indigenous Knowledge Systems (IKS):

According to the World Bank (1998) IKS are localised systems developed over long periods, based on local knowledge and expressed in local languages, generally viewed to be in balance with the environment.

IKS refers to a complete body of knowledge, know-how, the expressions, practices, beliefs, understanding, insights, and experiences of indigenous groups generated over centuries of interaction with a particular territory. Indigenous Knowledge is oral, usually not written. (Waren, 1993; Onyacha, 2024).

Working Definition: Indigenous Knowledge Systems are the comprehensive frameworks encompassing the practices, insights, and wisdom accumulated across generations within indigenous communities, often reflecting a codependent relationship with their natural surroundings and cultural heritage.

ii. Science Education:

Science Education is the scholarly and practical discipline concerned with the teaching, learning, and assessment of science content, processes, and the nature of science (McComas, 2014).

It involves the teaching and learning of science to various age groups, focusing on science content, processes, and some social science (Liu & Wang, 2019).

Working Definition: Science Education is a multidisciplinary field that aims to foster scientific literacy and critical thinking through the structured dissemination and assessment of scientific knowledge across various educational levels.

iii. Artificial Intelligence (AI):

Gil de Zuniga et.al (2024) define AI as the tangible real-world capability of non-human machines to perform tasks, solve problems, communicate, interact, and act logically as biological humans do.

According to Sheikh & Prins et.al (2023) AI encompasses a set of sciences and techniques aimed at reproducing by a machine the cognitive abilities of a human being.

Working Definition: Artificial Intelligence is the branch of computer science that focuses on creating systems capable of performing tasks that typically require human intelligence, including learning, problem-solving, and decision-making.

iv. Inclusivity:

Unesco (2023) defines inclusivity in education as a process that helps to overcome barriers limiting the presence, participation, and achievement of learners. Inclusivity aims for a situation where all students can take part in education to enhance their quality of life. Its goal is to ensure that no learner is left behind due to any form of discrimination, and that education systems are transformed to accommodate all learners despite their disabilities.

According to Zeynep & David et.al (2022) inclusivity refers to creating a culture that fosters belonging and incorporation of diverse groups.

Working Definition: Inclusivity is the deliberate effort to create an environment where diverse individuals are actively welcomed, valued, and given equal opportunities to contribute and thrive despite their disabilities.

v. Cultural Diversity:

Cultural diversity refers to the coexistence of diverse knowledge, beliefs, arts, morals, laws, customs, religions, languages, and other human characteristics (Cong Lin, 2019. It is the manifold ways in which the cultures of groups and societies find expression. These expressions are passed on within and among groups and societies (UNESCO, 2001).

Working Definition: Cultural Diversity is the rich variety of cultural expressions, practices, and perspectives that characterise the social fabric of different communities and contribute to the vibrancy of human society.

vi. Child Development:

Levin (2011) posits that child development refers to the physical, cognitive, emotional, and social changes an individual experiences from infancy through adolescence. It is how a child grows and changes over time, including physical and cognitive development (Saracho, 2023).

Working Definition: Child Development is the study of the sequential and complex growth patterns of children, encompassing their physical maturation, cognitive abilities, emotional understanding, and social interactions. In the context of education, child development can be defined as the process through which children grow, acquire skills and knowledge, including perceptual, emotional, intellectual and behavioural capabilities.

vii. Academic Achievement:

Academic achievement represents performance outcomes that indicate the extent to which a person has accomplished specific goals in instructional environments, specifically in school, college and university (Steinmayr et al., 2020). Bolt (2011) states that academic achievement is the progress made towards acquiring educational skills, materials, and knowledge across disciplines.

Working Definition: Academic Achievement is the measurable reflection of a student's learning and mastery of educational content, often gauged through grades, standardised tests, competences and the attainment of academic degrees.

1.10 RESEARCH LAYOUT

The subsequent chapters of this dissertation are structured as follows:

Chapter	Title	Description
1	The problem and its setting	Overview of the dissertation, including research objectives and significance.
2	Review of related literature	Comprehensive analysis of existing literature related to the research topic.
3	Research methodology	Detailed explanation of the research design, methods, and procedures.
4	Data presentation and analysis	Presentation and thorough analysis of the research data
5	Conclusion and Recommendations	Summary of findings, conclusions drawn, and suggestions for future research.

Each chapter is designed to address specific aspects of the research objectives, contributing to a holistic understanding of how indigenous knowledge systems can be integrated with science education and AI.

1.11 CHAPTER SUMMARY

This chapter provided an introduction to the research topic and its context. It discussed the background to the study, the problem statement, research questions, research objectives, significance, delimitation, limitations, definition of terms, and the layout of the subsequent chapters as well as the chapter summary. The research aims to investigate the integration of indigenous knowledge systems with science education using AI in the teaching of science in Eswatini. By exploring the potential of AI in recognizing and incorporating indigenous knowledge, this research seeks to contribute to the development of inclusive and technologically advanced educational practices that bridge the gap between traditional

wisdom and modern scientific understanding. Next is Chapter 2, which is a review of related literature.

CHAPTER 2

REVIEW OF RELATED LITERATURE

2.1. INTRODUCTION

This chapter provides a comprehensive review of literature on the integration of Indigenous Knowledge (IK) systems into the science education curricula of Eswatini using AI technologies. It aims to guide the research by illuminating the theoretical and practical aspects of merging IK and AI in science education. The Cultural-Historical Activity Theory (CHAT) informs the current study. The theory offers a framework for analysing the integration process. The review begins with a discussion on the theoretical framework of CHAT and its relevance to education, setting the stage for the subsequent analysis and discussion. It then explores previous research that has applied CHAT to educational settings, emphasising the significance of context and power dynamics. Finally, the literature review highlights the importance of adopting CHAT as a theoretical framework in this particular study, emphasising its relevance and potential contributions.

2.2. THEORETICAL FRAMEWORK: 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 IKS and AI is equitable and inclusive.

2.3. CULTURAL-HISTORICAL ACTIVITY THEORY (CHAT) AND ITS APPLICATION IN EDUCATION

Cultural-Historical Activity Theory (CHAT), grounded in the seminal work of Lev Vygotsky, offers a comprehensive framework for understanding the complex interplay between individuals and their sociocultural environment. CHAT extends Vygotsky's sociocultural theory, which posits that cognitive development is deeply rooted in social interactions and cultural contexts. This theoretical framework emphasises the collective nature of learning and the role of cultural artefacts, including emerging technologies like Artificial Intelligence (AI), in mediating human activity and cognition.

Vygotsky's theory underscores the significance of tools and signs, such as language and writing, in the development of higher mental functions. It emphasises the interplay between individuals, communities, and the tools they use in their activities (Engeström, 2019). CHAT expands on these ideas by incorporating the concept of an activity system, which includes components such as the subject, tools, rules, community, and division of labour. These elements interact within a system to mediate and facilitate the learning process.

In educational contexts, CHAT provides a lens through which to view the learner's engagement with activities. It considers how cultural artefacts, including AI technologies, serve as mediators between the learner and the learning objectives. By focusing on the

activity system as a whole, CHAT allows educators to design learning environments that are culturally responsive and technologically relevant.

2.4. APPLICATION OF CHAT TO PREVIOUS STUDIES IN EDUCATIONAL SETTING

Previous studies have successfully applied CHAT to analyse various educational phenomena. For example, Engeström (2019) explored the implementation of digital technologies in classrooms through the lens of CHAT, examining how these tools mediate learning activities and shape the roles and interactions of teachers and students. Similarly, Yamagata-Lynch (2024) employed CHAT to investigate the integration of AI in educational contexts, emphasizing the significance of context and the socio-cultural dimensions of this integration.

The application of CHAT in educational settings aligns with the goals of the present study. By adopting this theoretical framework, the research aims to provide a nuanced analysis of the integration of IKS and AI, ensuring that the process is respectful, inclusive, and beneficial to all stakeholders involved. CHAT allows for an examination of the dynamic interplay between individuals, communities, and the tools they use, highlighting the importance of context in learning processes.

The application of CHAT in educational settings has provided valuable insights into the role of AI technologies as mediators in the learning process. For example, studies have shown how AI chatbots can serve as intermediaries that facilitate interaction between students and educational content, thereby reshaping the learning experience (Kuhail et al., 2022). Similarly, the use of CHAT to understand the integration of emerging technologies in mathematics education has revealed the potential for these tools to enhance pedagogical practices and student engagement (Batiibwe, 2019).

2.5. RELEVANCE OF CHAT TO THE STUDY

The relevance of CHAT to the study lies in its ability to address the complex socio-cultural dynamics involved in the integration of IKS and AI in education. This theoretical framework provides a means to understand how these systems interact and evolve within specific contexts, acknowledging the importance of context in learning processes. By adopting

CHAT, the study can uncover insights into the power dynamics at play and ensure that the integration of IKS and AI is equitable and inclusive.

Furthermore, CHAT offers a lens through which to examine the democratisation of knowledge and technology, preventing the marginalisation of indigenous voices in the age of AI. By analysing who controls these resources and how they can be distributed more equitably, the study can contribute to a more inclusive and respectful integration of IKS and AI in education.

2.6. INTEGRATION OF AI AND INDIGENOUS KNOWLEDGE (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 Schwab (2017) 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, many lives are now shaped by AI. 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).

2.6.1 IMPLICATIONS FOR CURRICULUM DESIGN

Curriculum designers can use CHAT to create learning experiences that integrate AI and IK in a manner that is culturally sensitive and pedagogically sound. By considering the entire activity system, curriculum developers can ensure that the use of AI in education enhances the learning process without diminishing the value of IK.

CHAT offers a robust theoretical framework for analysing the integration of AI and IK in education. It provides insights into the sociocultural and historical aspects of these knowledge systems and their impact on learning. By adopting CHAT as the guiding theory, educators and researchers can develop strategies that leverage the strengths of both AI and IK to create rich, culturally informed educational experiences.

2.7. INDIGENOUS KNOWLEDGE SYSTEMS

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.

2.8. THE INFLUENCE OF INDIGENOUS KNOWLEDGE ON CHILD DEVELOPMENT AND ACADEMIC ACHIEVEMENT

Indigenous Knowledge Systems (IKS) are increasingly recognized as a critical component in the educational development of children, particularly within communities where these systems form the bedrock of cultural heritage. Child development within indigenous contexts is deeply intertwined with the cultural practices and knowledge systems that have been passed down through generations. Indigenous child development is not solely focused on academic performance but encompasses a broader spectrum of social, emotional, and cultural competencies (Marin, 2013). These competencies include a strong sense of identity, community belonging, and the ability to navigate and contribute to the cultural life of the community. Research has shown that when children are educated within their own cultural paradigms, they exhibit a stronger sense of self and a higher degree of confidence and competence in their learning abilities (Marin, 2013). Indigenous knowledge has been shown to positively influence child development and academic achievement. Studies have highlighted the benefits of incorporating local knowledge and practices into the curriculum, which can lead to improved educational outcomes (Zidny et al., 2020).

The integration of IKS into formal education has been linked to enhanced academic achievement among indigenous students. Studies have indicated that when educational curricula are adapted to include indigenous perspectives and practices, students demonstrate improved understanding and retention of the material (Chinoda, 2019). This is particularly evident in subjects such as environmental science, where traditional ecological knowledge can provide contextually relevant examples and applications (Chinoda, 2019). Furthermore, the inclusion of IKS in education has been found to foster a more inclusive and engaging learning environment, which is conducive to the academic success of indigenous students (OECD, 2017).

Cognitive development in indigenous children is often supported by the rich oral traditions and experiential learning opportunities present within their communities. Storytelling and lullabies for example, are not only a means of entertainment but also a pedagogical tool that conveys moral lessons, historical knowledge, and problem-solving skills (Dlamini, 2017). These narratives play a crucial role in the cognitive and linguistic development of children, providing them with the frameworks to process information and articulate their thoughts effectively (Dlamini, 2017).

While the benefits of integrating IKS into education are clear, there are challenges that need to be addressed. One of the primary concerns is the potential loss of indigenous knowledge due to the dominance of Western educational models (Magni, 2016). It is essential to develop educational programs that are grounded in indigenous methodologies and that respect the epistemological diversity of indigenous communities (Magni, 2016). Additionally, there is a need for educators to be trained in culturally responsive teaching practices to effectively integrate IKS into their classrooms (Magni, 2016).

2.9. 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 IKS, 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 showcases IKS 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).

2.10. INTEGRATION OF AI AND INDIGENOUS KNOWLEDGE 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). This system is influenced by rules (curricular guidelines) and the division of labour (roles of educators and AI tools) (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).

Also, 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.

2.10.1 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.

2.11. EDUCATORS' PERCEPTIONS AND ATTITUDES

Educators play a crucial role in the successful integration of AI and IKS in the classroom. Their attitudes and beliefs significantly influence the adoption and implementation of new technologies. Research indicates that educators who have a positive outlook towards AI and are provided with adequate training are more likely to integrate it effectively into their teaching practices (Osei, 2023).

The integration of Artificial Intelligence (AI) in education has the potential to transform teaching and learning practices, including the incorporation of Indigenous Knowledge (IK) into curricula. Several studies have investigated educators' perceptions and attitudes towards the use of AI in education, providing insights into their readiness and willingness to embrace AI technologies. Doe and Smith (2021) conducted a survey among teachers in various schools, exploring their perceptions of AI integration in the curriculum. The results indicated that while educators recognized the potential benefits of AI, such as personalised learning and enhanced student engagement, they also expressed concerns about the replacement of human interaction and the loss of traditional teaching approaches (Doe & Smith, 2021).

In a similar study conducted by Johnson and colleagues (2022), educators were interviewed to understand their attitudes towards the integration of IK and AI in science education. The findings revealed a range of perspectives, with some educators expressing enthusiasm about

the potential of AI to amplify IK and facilitate culturally responsive teaching, while others raised concerns about the cultural appropriation of indigenous knowledge and the potential for AI to oversimplify or misrepresent IK (Johnson et al., 2022).

Furthermore, Ekeledo and Amadi (2018) explored the perceptions of teachers regarding the integration of indigenous knowledge in science education, emphasising the need for a culturally sensitive pedagogical approach. These insights shed light on the attitudes and challenges educators may face when integrating AI and IKS in science education.

In the context of Eswatini, educators' perceptions and attitudes towards the use of AI in education, particularly in relation to IK, can be influenced by various factors. A study by Mhlanga and Dlamini (2023) in Eswatini explored educators' perceptions of AI integration in classrooms. The findings highlighted a general lack of awareness and understanding of AI among educators, which impacted their attitudes towards its use. There was also limited familiarity with the concept of IK and its potential integration with AI technologies (Mhlanga & Dlamini, 2023).

Similarly, in Zimbabwe, a study by Ndlovu and Moyo (2024) investigated educators' perceptions of AI in the context of IK integration. The results indicated that while some educators recognized the importance of incorporating IK into the curriculum, they expressed concerns about the availability of appropriate AI tools and resources that are culturally relevant and sensitive to local contexts (Ndlovu & Moyo, 2024). Additionally, educators voiced the need for training and professional development opportunities to better understand and utilise AI technologies effectively.

Recent studies have further expanded our understanding of educators' perceptions of AI in education. Kim and Kim (2022) found that STEM teachers appreciated AI for its scaffolding capabilities in scientific writing, though they were concerned about the transparency of AI decisions and the changing role of teachers (Kim & Kim, 2022). Ghimire et al. (2024) reported that university instructors had a generally positive sentiment towards AI language models, which was consistent across different teaching styles (Ghimire et al., 2024). Moreover, a project exploring instructors' attitudes toward AI-based applications in higher education highlighted the need for understanding their knowledge, attitudes, perceived benefits, and perceived harm of such applications (Project AI-HE, 2024).

However, there is often a gap between the potential of AI technologies and the reality of classroom application. Many educators express concerns about the reliability of AI systems and the potential loss of human touch in education (Kumar, 2022). These apprehensions highlight the need for ongoing support and professional development to ensure that educators are comfortable and confident in using AI tools.

Educators' perceptions and attitudes towards the use of AI in education, particularly in relation to IK, play a crucial role in shaping successful integration efforts. While some educators express enthusiasm for the potential benefits of AI, others voice concerns about the loss of traditional teaching approaches and potential misrepresentation of IK. Educators' perceptions of AI in education are crucial for successful implementation. While some educators express concerns about the role of AI in the classroom, others recognize its potential to support and enhance teaching practices (Kim & Kim, 2022).

2.11.1 CHALLENGES AND OPPORTUNITIES OF EDUCATORS IN AI INTEGRATION AND IK INCORPORATION

One of the challenges is the limited awareness and understanding of AI among educators. Addressing this challenge requires comprehensive training and professional development programs to build educators' capacity in AI integration and IK incorporation. Collaborative initiatives involving universities, educational institutions, and relevant stakeholders can play a crucial role in providing the necessary support and resources.

Another challenge is the potential for cultural appropriation and misrepresentation of IK through AI technologies. It is essential to involve indigenous communities, elders, and knowledge holders in the development and validation of AI tools and resources. Co-creation processes that foster collaboration and respect for indigenous perspectives can help ensure culturally sensitive and authentic AI integration.

Opportunities arise from the potential of AI to amplify IK and facilitate culturally responsive teaching practices. AI technologies can support the preservation, revitalization, and dissemination of IK, promoting cultural diversity and inclusivity in education. By incorporating IK into AI-integrated curricula, educators can foster a deeper understanding and appreciation of indigenous knowledge systems among students.

2.12 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 effectively 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).

2.12. BRIDGING KNOWLEDGE SYSTEMS

The integration of AI and IK offers the opportunity to bridge formal scientific knowledge with IK. In Zimbabwe, incorporating IK in science education has been shown to enrich students' understanding and appreciation of their own cultures and traditions (Chirinda & Mavuru, 2008). Integrating AI and IK promotes cultural diversity and inclusivity. In Eswatini, programs that align science education with traditional knowledge have reported positive outcomes in Indigenous students' science learning (Jin, 2021). AI technologies can create personalised learning experiences that respect students' cultural identities. This approach has been beneficial in Eswatini, where culturally responsive programs have supported educational success for Indigenous students (Jin, 2021).

Furthermore, IKS have proven to be invaluable in bridging the divide between theoretical concepts and real-world applications, particularly in the realm of environmental science. For example, in Zimbabwe, the infusion of indigenous agricultural techniques into the educational curriculum has significantly bolstered students' understanding of ecological sustainability and stewardship (Chinoda, 2019). This approach not only deepens students' connection to their environment but also encourages innovative thinking and problem-solving. The interweaving of AI and IK in science education presents a unique opportunity to harmonise modern scientific methods with time-honoured indigenous practices. According to Zidny et.al (2020) in Zimbabwe, AI can be leveraged to simulate indigenous farming techniques, providing a virtual hands-on experience that can enhance students' understanding of sustainable agriculture and its relevance to their cultural practices.

In Eswatini, the integration of AI with IK can lead to the development of digital storytelling platforms that celebrate and preserve local folklore and traditions. These platforms can serve as educational tools that allow students to explore the rich tapestry of their cultural heritage while learning scientific concepts, thereby fostering a sense of pride and ownership in their learning journey (Jin, 2021). Furthermore, the collaboration between AI and IK in these regions can result in the creation of culturally sensitive AI algorithms that are designed with the input of local communities. This collaborative approach ensures that AI technologies are not only effective in delivering educational content but also respectful of the cultural nuances and values of the students they serve (Chinodya, 2019; Pandey, 2023).

Bridging knowledge systems in the teaching of science subjects in Eswatini is a critical step towards creating a more inclusive and culturally relevant curriculum. In Eswatini, the integration of indigenous knowledge systems (IKS) with AI can provide a more holistic approach to science education. By incorporating local ecological knowledge and traditional practices, educators can offer students a deeper understanding of environmental science and sustainability. This approach not only aligns with the national curriculum but also respects and preserves the cultural heritage of the community (Samuel, 2020).

In Eswatini, the pilot of an AI tool called Nomfundo marks a significant advancement in educational technology. Nomfundo, an online-speaking robot (chatbot), has been specifically trained on the Eswatini syllabus, including subjects like entrepreneurship, guidance and counselling, life skills, composition and essay marking, siSwati translation, and more. It is designed to deliver educational content, provide personalised instruction, and facilitate learning experiences that are culturally relevant and responsive to the needs of students (Times of Swaziland, 2024). The introduction of Nomfundo into schools such as Evelyn Baring, Salesian, and Somnjalose High is expected to transform the level of education, making it more accessible and tailored to the local context.

2.13. 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.

2.14. CHAPTER SUMMARY

This chapter provided an overview of the literature relating to opportunities and challenges of integrating Indigenous Knowledge systems into science education curricula in Eswatini contexts through the utilisation of AI technologies. The theoretical underpinnings were explored using Cultural-Historical Activity Theory to analyse power dynamics and knowledge production from a sociocultural lens. Key studies applying CHAT to digitally

mediated learning environments were examined to demonstrate how AI could facilitate two-way knowledge sharing between community elders and youth in a culturally sustaining manner. Considerations around ethics, representation and participation were raised to ensure AI and IK integration processes are democratic and mutually beneficial. In conclusion, the review established a solid analytical framework and highlighted the need for further research exploring sustainable pathways for merging traditional wisdoms with innovative technologies.

CHAPTER 3

RESEARCH METHODOLOGY

3.1. INTRODUCTION

Research methodology is a systematic approach to solving research problems, involving a series of steps that researchers generally adopt along with the logic behind them (Kumar, 2005). The previous chapter highlighted the significance of integrating indigenous knowledge systems with science education via strategic AI technologies. This chapter describes the specific research methods to be utilized to attain the study's objectives. The chapter covers research design, data collection tools, procedures, analysis, ethics, and quality assurance issues.

3.2. RESEARCH PHILOSOPHY

This study adopted a pragmatist philosophical approach, as it aligns well with the research objectives and allows for a blending of quantitative and qualitative methods to address real-world challenges in the integration of indigenous knowledge systems, science education, and AI. Pragmatism is a practical and flexible philosophical approach that emphasizes the importance of understanding the consequences of ideas and actions (Creswell & Creswell, 2018). Pragmatist philosophers, such as John Dewey, William James, and Charles Peirce, argue that the truth or meaning of an idea or proposition lies in its practical consequences (Hookway, 2016). This focus on practical solutions and outcomes was well-suited for this study, which sought to investigate the integration of indigenous knowledge systems and AI in science education and address the challenges faced in this domain.

Pragmatism bridges the gap between post-positivist and social constructivist worldviews by acknowledging the value of both objective and subjective knowledge (Feilzer, 2010). Post-positivists emphasize the importance of quantitative data and objective measurement, while social constructivists focus on the subjective, socially constructed nature of reality (Creswell & Creswell, 2018). Pragmatism allows for the use of multiple methods, both quantitative and qualitative, to understand the research problem and find practical solutions (Creswell & Plano Clark, 2018).

By adopting a pragmatist approach, this study blended quantitative data, such as student performance metrics and the effectiveness of AI-based learning tools, with qualitative insights from teachers, students, and indigenous knowledge holders. This mixed-methods approach provided a more comprehensive understanding of the challenges and opportunities related to the integration of indigenous knowledge systems and AI in science education, ultimately leading to practical solutions that can be implemented in real-world educational settings (Creswell & Plano Clark, 2018).

3.3. RESEARCH APPROACH

Research studies often employ three primary methodological approaches: quantitative, qualitative, and mixed methods (Creswell, 2014). The mixed methods approach involves integrating or combining qualitative and quantitative research and data within a single study (Creswell, 2014). Qualitative data is typically derived from open-ended sources without pre-determined responses, while quantitative data comes from close-ended sources such as tests, questionnaires, or psychological instruments (Creswell, 2014). Various terms are used to describe this blended approach, including "integrating, synthesis, quantitative and qualitative methods, multi method, and mixed methodology," but the most commonly used term is "mixed methods" (Teddlie, 2010).

Creswell (2005) provides a more precise and operational definition of mixed methods research as "the collection, analysis, and integration of quantitative and qualitative data in a single or multiphase study." Tashakkori and Creswell (2007) further elaborate on the definition, highlighting the necessity of integration at every stage of the research process: "Research in which the investigator collects and analyzes data, integrates the findings, and draws inferences using both qualitative and quantitative approaches in a single study or program of inquiry."

In other words, high-quality mixed methods research involves blending various research methods at all stages of the study – from formulating research questions to sampling, data collection, analysis, and interpretation (Onwuegbuzie, 2004). Mixed methodology was used in this study. This approach is chosen because it allows researchers to leverage the strengths of both qualitative and quantitative approaches to find the best solution to the specific research problem at hand.

The mixed method was suitable for this study because qualitative research alone often lacks generalizability due to smaller sample sizes. Mixed methods mitigate this weakness by incorporating large-scale quantitative research. Secondly, combining methods enriches findings by providing context and depth. Qualitative data can illustrate quantitative results, adding riches to analysis. Lastly, using different methods enhances 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 AI integration effectively. That is, mixed method offers of blending various research methods to seek the best solution to the precise research problem at hand.

3.4. RESEARCH STRATEGY

Research design refers to the comprehensive strategy or blueprint that researchers develop to address specific research questions or goals (Hennink, Hutter, and Bailey 2020). It considers practical aspects such as time, budget, and resources to create a feasible plan that can be effectively implemented. For this study, an exploratory case study research design was used. This qualitative approach has been widely employed to investigate complex phenomena within a specific context, especially in the initial stages of research when there is limited existing theory or understanding of a phenomenon. Cases are purposefully selected based on the researcher's judgment, providing informative and relevant insights into the research questions (Hancock, Algozzine, and Lim 2021). The data is then analyzed to identify patterns, themes, or stories that emerge from the case, leading to a cohesive account of the case study. The chosen exploratory case study research design is expected to provide contextualized knowledge about and offer insights that can inform both theory and practice, on how AI can bridge Indigenous knowledge systems and science education.

3.5. TARGET POPULATION AND RESEARCH SAMPLING

The research population, as defined by Tuckman (2018) and Sidhu (2016), refers to the group of individuals from which the researcher selects a sample to conclude about. For this specific research project, the targeted population consists of 66 schools in the Lubombo region. The Lubombo region is made up of 5 clusters namely: Siteki, Mpaka, Bigbend, Mhlume, and Siphofaneni. Each cluster contains an average of 15 schools. To effectively manage data collection, interviews, and observations, the research will focus on 10 schools. While this sample size may not fully represent the 66 schools in the region, the selected schools will

offer valuable insights due to their representation of rural and semi-urban areas, different socioeconomic backgrounds, and varying levels of Indigenous knowledge integration. From each cluster, 2 schools will be chosen. This focused approach allows for richer data collection, including interviews, focus groups, and classroom observations. By deliberately selecting diverse schools, such as the School for the Deaf catering to children with disabilities, the study aims to promote inclusivity, and equity, and enhance the potential applicability of the findings.

3.6. RESEARCH SAMPLE AND SAMPLING TECHNIQUES

Sampling is a method used to select a portion of a larger population for study (Lakens 2022). The goal is to represent the population as closely as possible and to draw general conclusions about the population based on the characteristics and responses of the sample. Since studying an entire population is often impractical, sampling is necessary due to time, cost, and accessibility constraints. There are different techniques for selecting a sample from the population, which can be broadly categorized into probability and non-probability sampling. In this study, non-probability sampling techniques was used, specifically purposive sampling. Purposive sampling involves consciously selecting participants based on specific criteria deemed important for the research question (Whitehead and Whitehead 2020). This type of sampling is often employed in qualitative research to gain an in-depth understanding of a particular phenomenon rather than to generalize findings to a larger population.

For this particular study, 10 schools in the Lubombo region will be selected using purposive sampling, representing the five clusters. The sample will further include 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 focused 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 and AI in the Eswatini context.

3.7 DATA COLLECTION INSTRUMENTS

Research instruments are the tools used by researchers to collect data for a study (Fox & Bayat, 2007). The use of multiple research instruments is recommended by Fox and Bayat

(2017) in order to counteract potential bias that could arise from relying on a single data collection method. Using a combination of instruments helps the researcher keep track of observations and report findings more accurately. The selected instruments must be valid and precise, as the failure to choose appropriate instruments may result in the researcher failing to capture meaningful data. For this study, the primary data were collected through questionnaires, focus group discussions, and observations, while the secondary data will be gathered by analyzing relevant documents. The use of multiple data collection methods allowed the researcher to triangulate the findings and obtain a more comprehensive understanding of the research topic.

3.7.1 QUESTIONNAIRES

Questionnaires were the primary data collection instrument in this research. They were designed based on the study's objectives and research questions, and they allow the researcher to gather a large amount of information efficiently (Maddon, 2000). The questionnaires included both closed-ended and open-ended questions to provide respondents the opportunity to explain their perspectives (Leedy, 2016). The key advantages of using questionnaires are that they can guarantee confidentiality, which may elicit more honest responses from participants (Branmen, 1994; Hannagan, 1988), and they can be administered to large samples (Tuckman, 1978). The data obtained can also be statistically analyzed to generate new insights (Harambos & Holborn, 1996).

However, the potential limitations include the risk of misinterpretation of questions by respondents and the lack of opportunity for further probing (Best & Khan, 1996). To mitigate these challenges, the researcher conducted pre-testing to ensure the workability of the questionnaires. Overall, the use of questionnaires aligned with the research objectives, as they helped the researcher explore how indigenous knowledge influences child development and academic achievement, as well as educators' perceptions towards integrating indigenous knowledge and AI in science education in Eswatini.

3.7.2 FOCUS GROUP DISCUSSION (FDG)

In a qualitative research study, a Focus Group Discussion (FGD) is a valuable method to elicit in-depth insights, opinions, and perspectives from a small group of participants on a specific topic (Krueger & Casey, 2015). The design of an FGD typically involves several key

elements, including the group size, participant selection, the role of the moderator, the discussion guide, and the duration of the session. Krueger and Casey (2015) recommend that focus groups typically have 6 to 10 participants, with a range from as few as four (4) to as many as twelve (12). This size ensures a diversity of perspectives while maintaining active discussion and participation. Participants are carefully selected based on specific criteria, such as their demographic characteristics, experiences, or knowledge related to the research topic. This homogeneity within the group facilitates open dialogue, while the diversity of perspectives captures a range of viewpoints.

An experienced moderator guides the FGD, keeping the participants focused on the research objectives while encouraging open and honest discussion. The moderator uses a semi-structured interview guide to maintain the flow of the discussion and ensure consistency across multiple focus group sessions. Focus group discussions typically last between 60 to 90 minutes, allowing sufficient time for in-depth exploration of the research topic while maintaining participant engagement and attention.

For the purpose of this study, the use of FGDs provided several benefits. The depth of insights gained from the interactive group setting can offer a deeper understanding of the perspectives, experiences, attitudes of educators (teachers and administrators) and students involved in science education. The contextual understanding derived from engaging with educators and students in a group setting helped to better understand the cultural, educational, and institutional factors that shape the integration of indigenous knowledge and AI in Eswatini's science education system. Furthermore, the exploratory nature of FGDs was particularly useful in the initial stages of the research, as the open-ended and interactive nature of the discussions can help identify key themes, challenges, and opportunities that may not have been anticipated in the research design. The participant interaction during the FGDs can also foster a dynamic exchange of ideas, where participants can build on each other's contributions, challenge or validate one another's perspectives, and potentially uncover new avenues for investigation.

By employing FGDs in the study on the integration of indigenous knowledge and AI in Eswatini's science education, the researcher gained a rich, contextual understanding of the topic from the perspective of the key stakeholders – the educators. The insights

gathered can informed the development of more targeted and effective strategies for integrating these elements in the educational system.

3.7.3 DOCUMENT ANALYSIS

In addition to questionnaires, the researcher employed documentary analysis as another key data collection method for this study. Documentary analysis is an indispensable technique as it can provide both qualitative and quantitative data (Mupanduki, 2012). The researcher reviewed documents such as science syllabi for both junior and senior levels in all the science subjects which are: Science, Biology, Physics, Chemistry, Mathematics, Geography, Agriculture, Mathematics, Add Maths, Consumer Science, and curriculum records from the Ministry of Education etc. This documentary search complemented the questionnaire data, as it can help validate and expand the information gathered.

The main advantage of using documentary analysis is that it can provide large quantities of inexpensive data (Mupanduki, 2012). It allowed the researcher to gain valuable insights into the factors influencing indigenous knowledge and its integration in science education curricula in Eswatini. However, a potential limitation of documentary analysis is the risk of gathering outdated or unreliable information, as some internet sources and library resources may not be regularly updated (Mupanduki, 2012). To mitigate this, the researcher carefully selected credible and up-to-date documents to review.

The use of documentary analysis aligns well with the aim and objectives of this study. It enabled the researcher to explore how indigenous knowledge influences child development and academic achievement, as well as investigate how AI technologies can be utilized to recognize, incorporate, and present indigenous knowledge within science curricula in Eswatini. The insights gained from the documentary review also helped identify the challenges and opportunities associated with integrating AI and indigenous knowledge, and inform the development of strategies for the sustainable integration of indigenous knowledge into science education using AI.

3.8 DATA COLLECTION PROCEDURE

Upon receiving the introductory letter from BUSE, the first step was to gain access to the research sites. This involved contacting the relevant authorities, such as the Ministry of

Education and Training in Eswatini, to obtain the necessary permissions and clearances to conduct the study in the selected schools. To build connection and gain the confidence of the participants, the researcher began by scheduling introductory meetings with the school principals and teachers. During these meetings, the researcher explained the purpose and objectives of the study, address any concerns or questions the participants may have, and emphasize the importance of their participation in the research. The data collection process commenced with the distribution of digital questionnaires to the principals and science teachers. These questionnaires were designed for them to indicate demographic information, such as gender, teaching experience, and their roles (principal or science teacher). The digital format allowed for efficient data collection and analysis.

Following the questionnaire phase, the researcher visited the selected schools to conduct classroom observations during the teaching of science subjects. This provided valuable insights into the teaching and learning practices, as well as the integration of indigenous knowledge and the use of AI technologies in the science curriculum. After the classroom observations, the researcher sought the assistance of the teachers in forming the students' focus groups. The focus group discussions allowed the researcher to delve deeper into the participants' perceptions, attitudes, and experiences regarding the use of AI in bridging the gap between indigenous knowledge systems and formal science education. The researcher recorded the focus group discussions to ensure accurate data capture. Throughout the data collection process, the researcher maintained constant communication with the participants, providing updates and addressing any concerns that may arise. This approach ensured the smooth and successful implementation of the study.

3.9 DATA ANALYSIS

The study used semi-structured questionnaires, FGD guides, and document analysis to explore the integration of indigenous knowledge systems with science education and AI in Eswatini. The data were analyzed using thematic analysis, specifically open coding (thematic analysis). 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, and respondent details from the questionnaire instrument will be analyzed using the Statistical Package for Social Science.

3.10 QUALITY ASSURANCE PROCEDURE

To ensure the validity, reliability, and credibility of the research findings, the study employed a comprehensive set of quality assurance measures throughout the research process. Triangulation was a key strategy, involving the collection of data from multiple sources, including focus group discussions, questionnaires, and relevant documents, to corroborate the findings and provide a more holistic understanding of the research phenomena. The study also utilized both qualitative and quantitative methods, enabling cross-validation of the results through methodological triangulation. Additionally, the coding and analysis of the qualitative data was conducted by multiple researchers, employing investigator triangulation to minimize individual bias and enhance the reliability of the interpretations.

The researcher further strengthened the credibility of the study by conducting member checking sessions, where the preliminary findings and interpretations were presented to the participants (educators) for their feedback and validation. This ensured that the researchers' understanding accurately reflects the participants' perspectives and experiences. Peer debriefing, wherein the research process and findings were regularly reviewed and discussed with the research team, as well as with external peers and subject matter experts, who provide an external perspective, identify potential biases, and enhance the overall credibility of the study.

To ensure transparency and allow for external evaluation of the study's rigour and dependability, the researcher maintained a detailed audit trail, documenting the research procedures, data collection, analysis, and decision-making processes. The researcher also engaged in ongoing self-reflection, critically examining their own biases, assumptions, and influence on the research process, thereby minimizing the impact of researcher subjectivity on the findings. Finally, the study provided rich, detailed descriptions of the research context, participants, and the phenomena under investigation, enabling readers to assess the transferability of the findings to other similar contexts. For the quantitative data analysis, the researcher conducted inter-rater reliability checks to ensure the consistency and accuracy of the coding process. By implementing this comprehensive set of quality assurance procedures, the researcher aims to enhance the validity, reliability, and credibility of the study, ensuring that the

research findings provide robust and trustworthy insights into the integration of indigenous knowledge and AI in science education in Eswatini.

3.11 ETHICAL CONSIDERATIONS

The study adhered to ethical standards, ensuring confidentiality and minimizing potential impacts on participants (American Psychological Association, 2013). Consent was sought from participants data collection commences. Participation by respondents was voluntary during the study. Individual's wish to participate is esteemed, as they were given the room to step down if they no longer want to participate as informed consent of the study. The researcher also took time to explain the purpose of the study to potential participants for them to be fully aware of the nature and scope of the research including their role in it. The researcher took obligatory steps to ensure anonymity and confidentiality of all the respondents who participated in this research. To ensuring anonymity, pseudo names were used to refer to contributions made by accomplices in this study.

3.12 METHODOLOGICAL LIMITATIONS OF THE STUDY

The potential limitations of the research methods are acknowledged, considering their impact on the interpretation of results (Shenton, 2004). Smooth flowing of the research could be hindered mainly by various limitations namely time, financial constraints, inaccessibility to some important information for the study as well as the issue of confidentiality which limited information disclosure by some of the respondents. It could also be difficult for participants' questionnaires or surveys to all respond to the questions since some expect to be compensated or given token of appreciation.

3.13 CHAPTER SUMMARY

This chapter has provided a detailed overview of the research design. By incorporating recent sources and adhering to ethical standards, the methodology outlined ensures a rigorous approach to answering the research questions. The mixed methods approach combined with careful sampling and validated instruments, positions the study to contribute valuable insights to the field of education. The strategic methodology outlined here is intended to achieve the study's goal of promoting culturally-responsive education through synergizing indigenous

knowledge with modern technological advancements in teaching science subjects. The next chapter is a presentation and discussion of results.

CHAPTER 4

PRESENTATION AND DISCUSSION OF RESULTS

4.1 INTRODUCTION

This chapter presents the results and analysis of both qualitative and quantitative data. The findings are also compared with previous research and literature to identify similarities and differences. Data was collected from 10 schools in the Lubombo region, purposefully selected to represent the 5 clusters. Respondents included 20 science teachers, 10 school principals, and 100 science students (10 students each from five junior-level and five senior-level classes in each school) who participated in a focus group discussion. Data collection further included document analysis of all science subjects' syllabi and observation of 10 science lessons. The study used a mixed methods approach, combining data from various sources to enhance the validity and reliability of the research outcomes.

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).

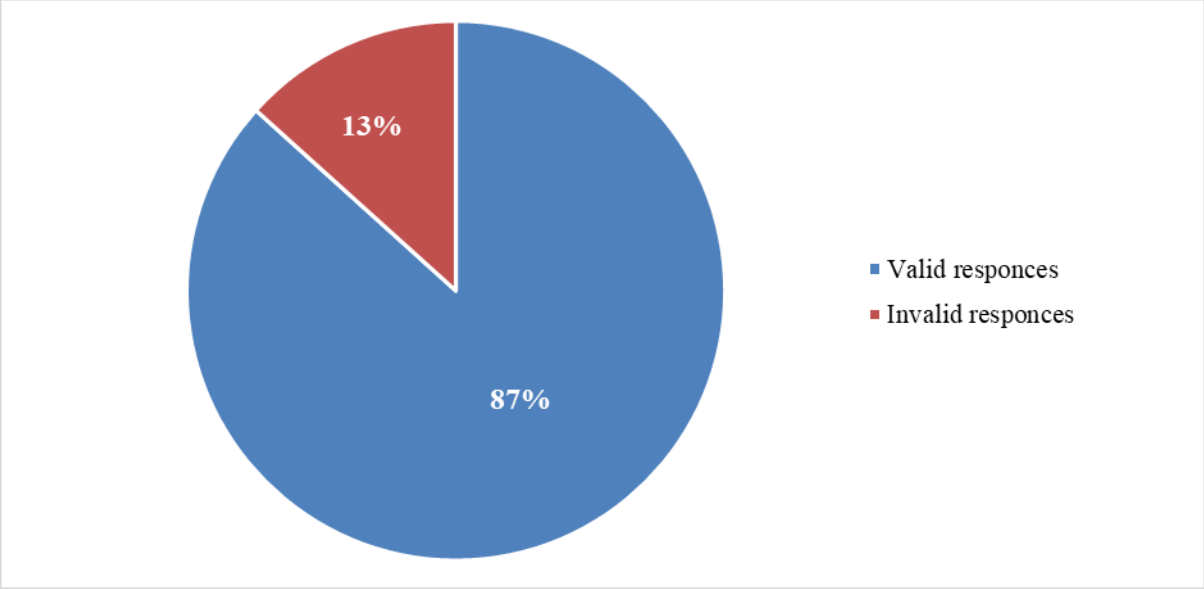
4.1.1 RESPONSE RATE

The study aimed to gather responses from a total of 30 participants, including 20 teachers and 10 principals. Figure 4.1 below shows the response rate for the digital questionnaire rolled out to the teachers via WhatsApp. A high response rate is important as it ensures the effectiveness and reliability of data collection, especially in surveys and questionnaires (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. A high response rate also reflects the success of reaching and engaging with respondents, thereby enhancing the credibility of the findings. The figure below indicates that the study achieved an 87% response rate which is an indication that the data will provide enough data saturation for analysis of both qualitative and quantitative constructs.

Figure 4.1

Response rate



4.2 DEMOGRAPHIC DATA

The collection and analysis of demographic data are essential for gaining insights into the overall traits and attributes of a particular population (Vaupel, Villavicencio, and Bergeron-Boucher 2021). In this study, the research focused on examining the distribution of survey participants according to various demographic factors, including age, gender, years of teaching experience, the highest level of education attained, and the educational levels that they were currently teaching.

4.2.1 Age Of The Respondents

The incorporation of indigenous knowledge systems and AI into science education represents a substantial change that is likely to be successful across the varied demographic of educators involved in the process (Druker-Ibanez and Caceres-Jensen 2022). Teachers of different age

groups may have differing abilities to manage change, which could impact the success of the integration. Younger teachers may be more proficient with technology and comfortable using AI tools, having grown up in the digital age, while older teachers might need more training and support to feel confident in utilizing AI in their teaching practices (Chan and Lee 2023). Therefore, the study examined the age of respondents to provide information about the participants that may influence the results and interpretation of the study. The findings of the study indicates that a majority (61.5%) of the respondent in the study were in the 36 years and above age bracket.

Table 4.1

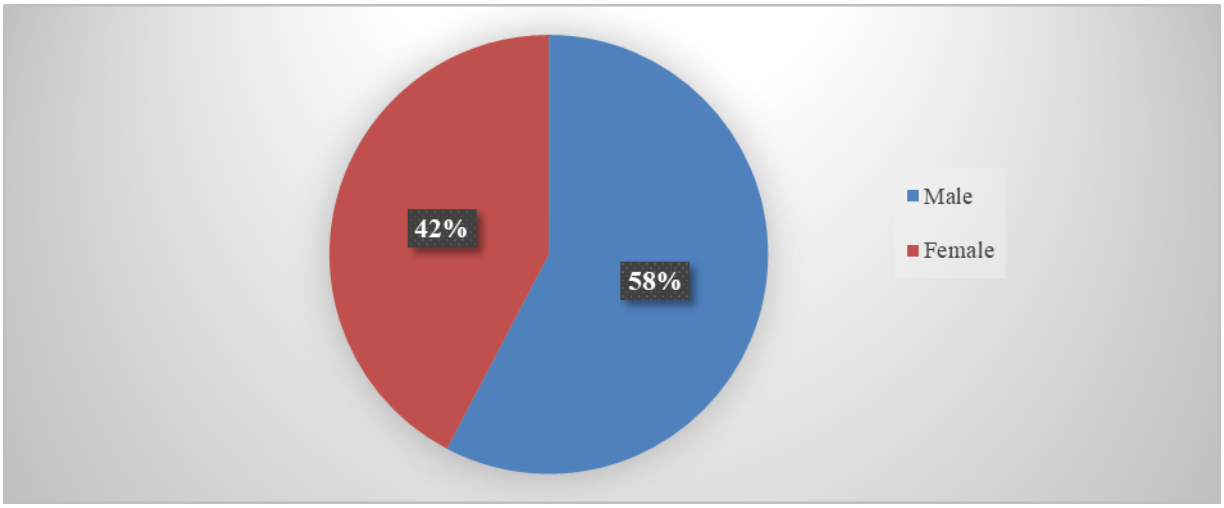
Age of the respondents

Age	Frequency	Percentage
26 years – 30 years	1	3.8
31 years – 35 years	9	34.6
36 years and above	16	61.5
Total	26	100.0

4.2.2 GENDER OF THE RESPONDENTS

Ample evidence from research has shown that gender can influence teaching styles, classroom interactions, and the perception of subjects such as science and technology (El-Emadi, Said, and Friesen 2019). Understanding the gender distribution among teachers involved in the study was essential to provide informed recommendations for creating an inclusive, representative, and effective integration of Indigenous knowledge systems with science education and AI.

Figure 4.2: *Gender of the respondents*



The study showed that 58% of the respondents were males, 42% were females. This indicates a 16% gender gap of science teachers in the Lubombo region. Addressing the gender gap in teaching AI and IKS in science is essential for creating a more equitable, diverse, and innovative society.

4.2.3 Years Of Teaching Experience

Thomas (2019) suggests that teachers with more years of experience may have a deeper understanding of pedagogical techniques and classroom management (Wolff et al. 2015). This understanding can influence how teachers integrate indigenous knowledge systems and AI into their teaching. Therefore, understanding the range of teaching experience can help in designing professional development programs that cater to teachers at different stages of their careers. This ensures that all educators are equipped to integrate indigenous knowledge systems and technologies.

Table 4.2: *Years of teaching experience*

Number of years	Frequency	Percentage
Less than a 1 year	1	3.8
2 to 5 years	2	7.7
6 to 9 years	6	23.1
10 years and above	17	65.4
Total	26	100.0

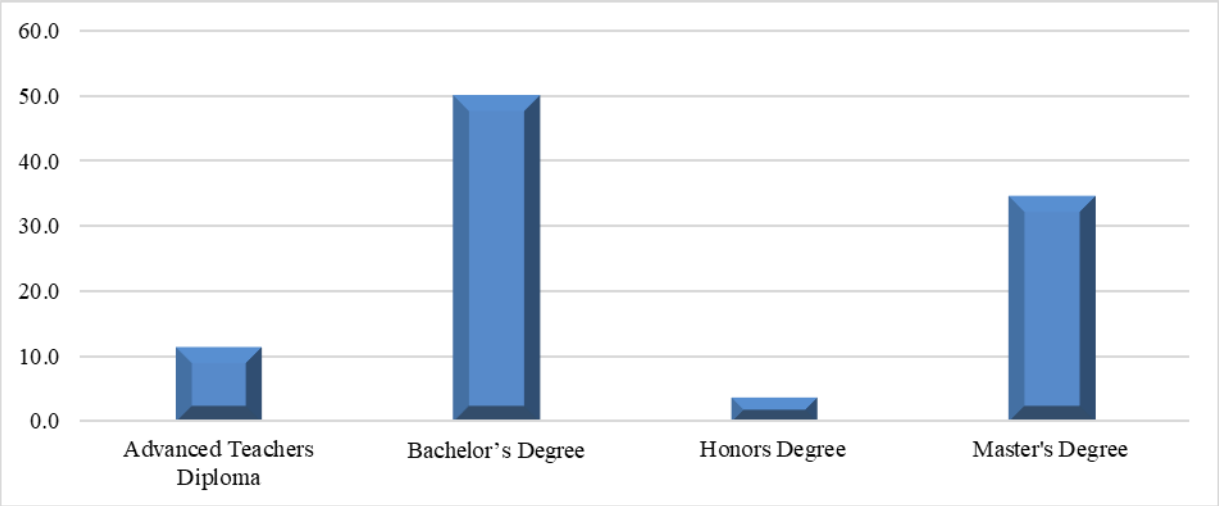
The study findings indicate that the respondents were mostly teachers and principals with at least 10 years of work experience.

4.2.4 Qualification Of The Respondents

Literature suggests that teachers with advanced qualifications may have a significant impact on curriculum development and could be instrumental in integrating Indigenous knowledge and AI into the science curriculum in a meaningful way (Koirala 2023). Therefore, assessing teachers' highest qualifications in the study provides valuable insights into their academic background and professional capabilities. These are critical factors in the successful integration of indigenous knowledge systems with science education and AI.

Figure 4.3

Respondents' Highest Education Level



The findings of the study in figure 4.3 above indicate that a 50% of science teachers in secondary and high school at least have a bachelor's degree. The implication of having highly qualified teachers in integrating AI (Artificial Intelligence) into IKS (Indigenous Knowledge Systems) in science education pose a lot of advantages for successful implementation of the innovation.

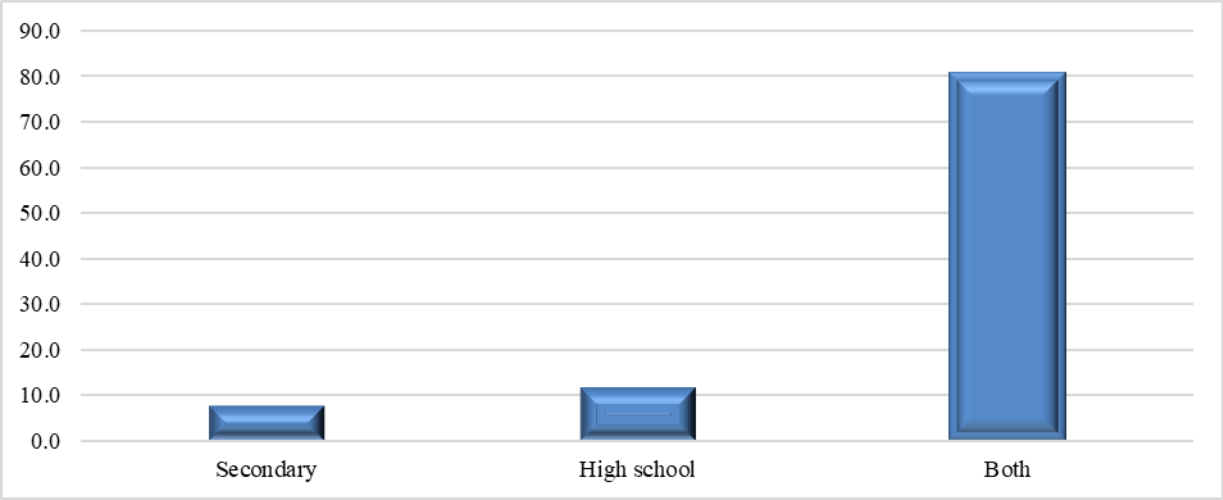
4.2.5 Education Level Being Taught

The integration of Indigenous Knowledge Systems (IKS) and Artificial Intelligence (AI) may have varying impacts on learners across different stages of education. Thus, educators are likely to encounter diverse outcomes when implementing AI within the framework of IKS

across various grade levels. The assessment of the targeted academic levels taught by theteachers' aims to investigate and comprehend the distribution of science teachers across secondary and high schools.

Figure 4.4

The Education Level Being Taught by the Respondents



The study's findings indicate that 80% of the science teachers who took part in the study teach both high school and secondary classes. Integrating AI into science education in this context requires careful planning, cultural sensitivity, and a flexible approach to teaching. This approach offers the opportunity to create a rich learning environment that respects indigenous knowledge while also preparing students for future technological advancements.

4.3 THEMES AND SUB-THEMES

The study aimed to explore the connections between indigenous knowledge systems, science education, and AI in the context of Eswatini. A semi-structured questionnaire was used to gather both qualitative and quantitative data. Also, a focus group discussion was used to collect data. Additionally, data collection involved analyzing the science subjects' syllabi

(Biology, Physics, Chemistry, Mathematics, Additional Mathematics, Geography, Agriculture and Consumer Science) and observing 10 science lessons from the selected schools. The study employed a mixed methods approach to ensure the validity and reliability of the research outcomes by combining data from various sources. The findings of the study are categorized into the following themes: Assessing the influence of indigenous knowledge on child development and academic achievement in the context of Eswatini. Examining the use of AI technologies to recognize, integrate, and present indigenous knowledge within science curricula. Exploring the challenges and opportunities associated with integrating AI and indigenous knowledge in science education. Analyzing educators' perceptions and attitudes towards the use of AI to bridge the gap between indigenous knowledge systems and formal science education and lastly informed strategies to ensuring sustainable integration of IK into science using AI.

4.3.1. The Influence of Indigenous Knowledge On Child Development And Academic Achievement In The Context Of Eswatini

Indigenous knowledge, also known as traditional knowledge or local knowledge, refers to the understanding, skills, and wisdom that have been developed and sustained by indigenous cultures and communities over generations (Zidny, Sjöström, and Eilks 2020a). This knowledge is often closely tied to a specific environment or territory and includes a wide range of practices, such as agriculture, health, education, spirituality, and the arts. It is important for child development and academic achievement as it helps nurture well-rounded individuals who are connected to their roots and capable of contributing meaningfully to their communities. Recognizing Indigenous knowledge as a valuable asset to society, education should reflect the diversity of human experience and wisdom (Abas, Aziz, and Awang 2022). A semi-structure questionnaire containing open ended and closed ended questions was developed to ask teachers and principals on their understanding of the influence of Indigenous knowledge on Child Development and academic achievement in schools. Under these objective sub-themes that were discussed were categorized and listed under each of the following sub-headings.

4.3.1.1 The role of indigenous knowledge in the overall development of children in Eswatini

The themes were finalized through a refining process, integrating key aspects. A total of 5 themes were derived to guide the discussion on teachers' and principals' perspectives on the role of indigenous knowledge systems in children's development in Eswatini. The key aspects explored through the questionnaire responses indicate that teachers and principals perceive that indigenous knowledge contributes to holistic learning, community and collectivism, cultural identity and belonging, sustainable living, empowerment and self-determination in children's development in Eswatini.

4.3.1.1.1 Holistic Learning

Holistic learning in child development is an approach that encompasses the entire child's physical, emotional, social, and cognitive dimensions during the learning process (Cantor et al. 2021). It acknowledges the interconnectivity of a child's development and the mutual influence of all developmental areas. The goal of holistic learning is to foster balanced growth in children, making certain that no aspect of their development is overlooked. The results of the study revealed that a frequently emerging theme on the role of indigenous knowledge on children development has been holistic learning. This was voiced by one teacher that:

> *"Integrating indigenous knowledge with formal education can create a better-rounded and culturally relevant learning experience for children in Eswatini"*

The findings of the study concur with (Miseliunaite, Kliziene, and Cibulskas 2022) that holistic learning respects each child's individuality and prepares them for the complexities of the modern world. Its intention is to produce well-rounded individuals who are not only academically proficient but also emotionally intelligent, socially adept, physically healthy, and culturally aware.

4.3.1.1.2. Community and Collectivism

In child development, the community and collectivism prioritize the group or community over the individual (Verma 2020). This approach helps children develop social skills, empathy, and a sense of responsibility towards others. The findings of the study indicate that

the respondents acknowledge that Indigenous knowledge contributes to community and collectivism. One of the respondents articulates that:

> *"Indigenous knowledge systems often include moral and ethical codes of conduct, which can help children develop values and behaviours that align with their community's standards."*

Another teacher echoes this sentiment, stating:

> *"Indigenous knowledge systems often emphasize social and emotional competencies, such as cooperation, respect, and empathy, which can support children's development of these skills."*

The responses given by the teachers and principals align with Zhou, Qu, and Li (2022) who posited that community and collectivism play a crucial role in child development by providing a framework for cultural identity, personal growth, socialization, and support. These factors contribute to the development of responsible, compassionate, and socially competent individuals who are prepared to contribute positively to their communities.

4.3.1.1.3 Cultural Identity and Belonging

Cultural identity encompasses the characteristics, beliefs, values, and traditions shared among members of a cultural group, which shape an individual's understanding of their own identity and connection to a specific cultural community (Karjalainen 2020). Indigenous knowledge plays a vital role in helping children establish a profound sense of cultural identity and belonging. Through learning about their heritage, language, customs, and the history of their people, children can comprehend their place in the world and within their community. This sense of belonging is crucial for their emotional well-being and self-esteem. The findings of the study suggest that teachers and principals recognize the significant contribution of indigenous knowledge to the development of cultural identity and sense of belonging in children. One of the respondents expressed that:

> *"Indigenous knowledge systems give children a sense of identity and connection to their culture, heritage, and community."*

Similar sentiments were echoed by another respondent, emphasizing on cultural identity and belonging on children development that:

"It helps to preserve cultural heritage so children can maintain their identity."

The responses provided by the teachers and principals align with Eaude (2024) findings, which emphasize the crucial role of cultural identity and belonging in child development. This research suggests that these factors play a foundational role in shaping children's self-perception and their sense of belonging in the world. Additionally, cultural identity influences their social interactions and contributes significantly to their overall well-being and future success in life.

4.3.1.1.4 Sustainable Living

Sustainable living in the context of child development involves raising children in a way that promotes environmental stewardship, social responsibility, and economic well-being for present and future generations (Makuch and Aczel 2020). Indigenous knowledge encompasses a wealth of wisdom and practices cultivated over generations, offering valuable insights into sustainable ways of living. Children are taught to respect and coexist with the natural world, fostering a deep understanding of ecological harmony. This knowledge is increasingly crucial as our global community grapples with pressing environmental challenges. Therefore, integrating sustainable living principles into child development can help ensure that the next generation is equipped with the knowledge, skills, and values necessary to create a sustainable and resilient future.

The findings of the study suggest that teachers and principals also noted the significant contribution of indigenous knowledge to instil sustainable living principles in child development. One of the respondents expressed:

"Indigenous knowledge often emphasizes the importance of environmental stewardship and sustainable living, which can positively shape children's values and behaviours."

The study's findings complement Zikhali (2018), who emphasized the importance of acknowledging and incorporating indigenous knowledge in development practices as it provides a foundation for sustainable and locally-appropriate solutions. According to Padayachee (2022), incorporating indigenous knowledge into child development programs can help ensure that future generations are equipped with the wisdom and skills needed to live sustainably and address the environmental challenges of the 21st century.

4.3.1.1.5 Empowerment and Self-Determination

Empowerment and self-determination in child development refer to the processes and practices that enable children to develop a sense of agency, make informed decisions, and take control of their own lives while being grounded in their indigenous cultural heritage and values (Olsen 2023). Studying history and the challenges faced by their ancestors empowers Indigenous children to take charge of their own lives and contribute to the improvement of their communities. This knowledge fosters a sense of pride and motivation to make positive changes.

The study's findings suggest that teachers and principals also noted another role played by IKS in child development, i.e., empowerment and self-determination. Referring to the contribution of the Indigenous knowledge system on empowerment and self-determination in children's development, one of the respondents expressed that Indigenous knowledge

> *"It provides basic information to children for a common understanding of their surroundings to solve their life problems naturally."*

The findings of the study are consistent with Jensen and Sanner (2021) , who argued that being aware of intimate family histories contributes to the emotional well-being of children and empowers them to understand their rights. This understanding helps them advocate for themselves and their communities, ensuring that Indigenous voices are heard and respected.

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

The themes for 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.

4.3.1.2.1 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.

4.3.1.2.2 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.

4.3.1.2.3. 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.

4.3.1.2.4 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.

4.3.1.2.5 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.

4.3.1.3. Respondents' Perception on the Importance of Indigenous Knowledge in the Development of Children in Eswatini?

The analysis of the study included descriptive statistics, such as mean and standard deviation, to assess how teachers and principals in Eswatini perceive the importance of indigenous knowledge in children's development. The questionnaire utilized a five-point Likert scale, with ratings from 1 to 5: 1 (Slightly important), 2 (Somewhat important), 3 (Moderate), 4 (Very important), and 5 (Extremely important). The average of the ratings was calculated and used as the threshold for the statement. If the mean of a statement was less than 3, it indicated that the respondents considered indigenous knowledge to be less or not important for child development in Eswatini. Whereas a score of 3 or above indicated that respondents considered indigenous knowledge to be important for child development in Eswatini.

Table 4.3

The Importance of Indigenous Knowledge in the Development of Children in Eswatini

Statement	N	Minimum	Maximum	Mean	Std. Deviation
How important do you think indigenous knowledge is in the development of children in Eswatini?	26	2	5	3.85	.881
N	26				

Based on the table results, it is evident that teachers and principals in Eswatini recognize the importance of indigenous knowledge in child development, as indicated by a mean value of 3.85, which surpasses the threshold mean of 3. The study's findings support (Manzunzu, 2020) assertion that integrating indigenous knowledge into child development practices can result in more culturally responsive, inclusive, and effective educational and developmental outcomes. This approach ensures that children are not only prepared for the future, but also stay connected to their past, which is essential for a healthy and balanced upbringing.

4.3.2 The Use Of Ai Technologies To Recognize, Incorporate, And Present Indigenous Knowledge Within Science Curricula

AI technologies, or Artificial Intelligence 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 integration 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. A digital semi-structured questionnaire was developed and circulated to teachers and principals to gather insight on utilizing AI technologies in the science curricula. Also, a focused group discussion was done in addressing this objective. Under this objective sub-theme that were discussed were categorized and listed under each of the following sub-headings.

4.3.2.1. 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 study aimed to explore teachers' and principals' knowledge and awareness of AI technologies and their potential applications in education. The results in the table below establish 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.

Table 4.4

Do you think AI technologies and its' potential applications in education?

	Frequency	Percent	Valid Percent	Cumulative Percent
No	9	34.6	34.6	34.6
Yes	17	65.4	65.4	100.0
Total	26	100.0	100.0	

4.3.2.1. The use of AI Technologies to Recognize and Incorporate Indigenous Knowledge Within Science Curricula

4.3.2.1.1 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.

4.3.2.1.2 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.

4.3.2.1.3 Simulation and Modelling

Simulation and modeling, 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.

4.3.2.1.4 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.

4.3.2.1.5 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.

4.3.2.1.6 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 4.5.

Table 4.5: *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.

4.2.3.1.7 Students' Perspectives on AI technologies and IKS in Science Curricula

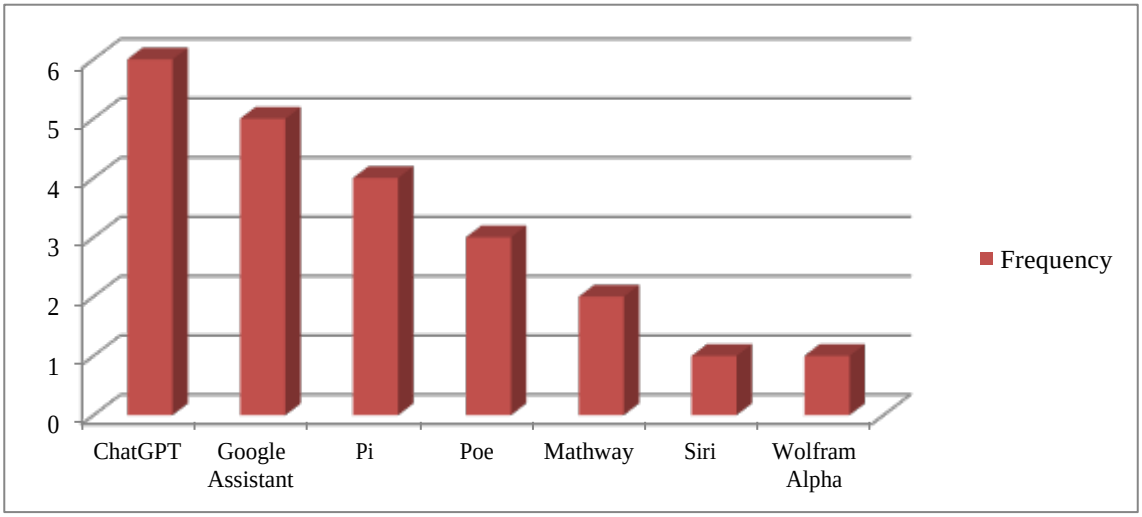
To gain a further comprehensive understanding of the use of Ai technologies to recognize, incorporate, and present IKS within science curricula, a focus group discussion (FDG) was

further conducted with students from the 10 selected schools. The insights gathered from these discussions provide valuable students perspective to complement the teachers views and the principals

4.2.3.1.8 Common AI tools used by learners

The FDG revealed that students are familiar with various Ai tools, which they use for homework, assignments, and TikTok content creation or Instagram. The most frequently mentioned Ai tools were: Chat GPT, Google Assistant, Pi, Poe, Mathway, Siri, Wolfram Alpha. This data can be presented as follows:

Figure 4.5: Common AI Tools Used by Learners



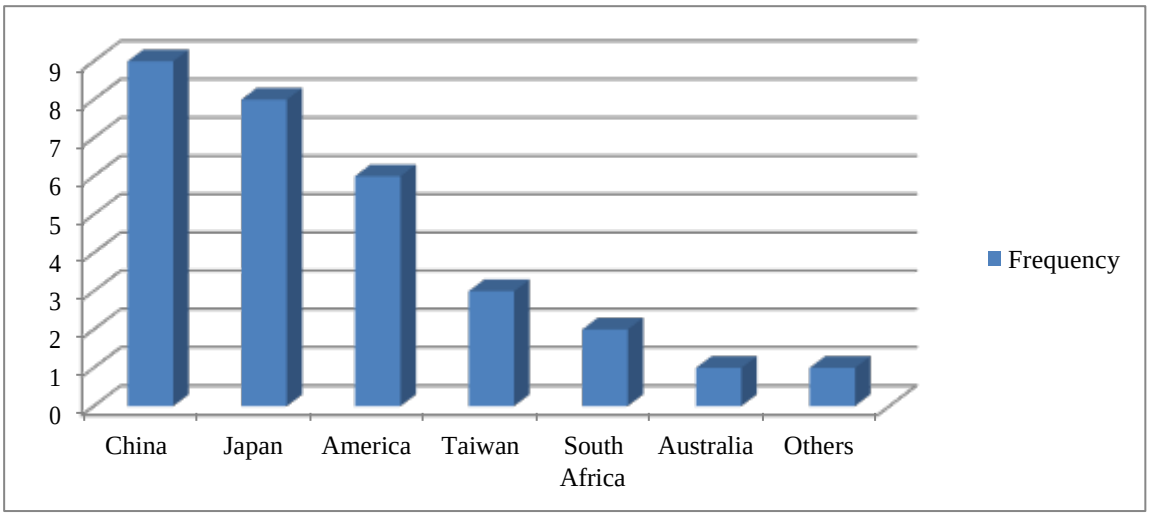
This data indicates that students are actively engaging with Ai technologies to write assignments and homework's, demonstrating the potential for integrating Ai tools more formally into the science curriculum. It also seems that students are way ahead of teachers in terms of Ai or technology use. This indicates that there is a high need to educate teachers on the usage of Ai tools so that they are ahead of their learners and always abreast with technology.

4.2.3.1.9 Perceptions of Countries Using IKS and AI in Teaching Science

Students identifies several countries they know to be using IKS and Ai in teaching science subjects. The countries they mentioned, in order of frequency include: China, Japan, America, Taiwan, South Africa, Australia and others like Kenya etc. This information can be presented in Figure 4.6, which follows.

Figure 4.6

Countries that use IKS and AI



This perception indicates that students are aware, observing and cognisant of global trend towards integrating AI and IKS in science education which could potentially motivate their interest in similar approaches in Eswatini. This is a great start which can help in integrating IKS and Ai into science formal education as learners are a bit aware of some countries which use Ai and IKS. This could be used as a base for our implementation,

4.2.3.1.10 Use of Ai in Eswatini schools for teaching Science

When asked about the use of Ai in Eswatini schools for teaching science, a majority of the students 90% indicated that the teachers do not use AI in their schools to teach science. Only 10% indicated that the teachers use Ai in teaching some science subjects.

This finding aligns with the earlier observation from teachers and principals that the integration of AI into science education in Eswatini is still in its infant stages. It highlights a significant opportunity for growth and improvement in the use of AI technologies to enhance science education and incorporate IKS. These insights from the students complement the perspectives of teachers and principals, providing a more holistic view of the current state of Ai and IKS in Eswatini's science curricula. The student's familiarity with Ai tools suggests step to embracing these technologies in formal education setting.

4.3.2.2 Respondents' Perceptions on the Ability of AI to Accurately Represent Indigenous Knowledge in Science Curricula

The analysis of the study included descriptive statistics, such as mean and standard deviation, to assess the perceptions of teachers and principals on the ability of AI to accurately represent indigenous knowledge in science curricula. The questionnaire utilized a five-point Likert scale, with ratings from 1 to 5: 1 (Slightly confident), 2 (Somewhat confident), 3 (Moderate), 4 (Very confident), and 5 (Extremely confident). The average of the ratings was calculated and used as the threshold for the statement. If the mean of a statement was less than 3, it indicated that the respondents considered indigenous knowledge to be less or not important for child development in Eswatini. Whereas a score of 3 or above indicated that respondents considered indigenous knowledge to be important for child development in Eswatini.

Table 4.6

Respondents' Perceptions on the Ability of AI

Statement	N	Minimum	Maximum	Mean	Std. Deviation
2.4. How confident are you in the ability of AI to accurately represent indigenous knowledge in science curricula?	26	1	5	2.96	1.248
N	26				

Based on the results in the table, it is clear that teachers and principals in Eswatini have not yet recognized the potential of AI to accurately represent indigenous knowledge in science curricula, as indicated by a mean value of 2.96, which is less than the threshold mean of 3. These findings contradict Martínez et al. (2023) assertion that AI in science education enhances learning outcomes, increases accessibility to science, provides insights into student performance, and prepares students for future technological careers. With the ongoing advancement of AI, its influence in science education is expected to grow, creating new opportunities for teaching and learning.

Although the integration of AI into science education in Eswatini may be in its early stages, there is a clear opportunity to build a strong foundation that can lead to transformative changes in the country's educational system. With strategic planning, investment, and

collaboration, Eswatini can effectively use the power of AI to enhance science education and prepare its students for the challenges and opportunities of the 21st century.

4.3.4 Challenges And Opportunities Associated With Integrating AI And Indigenous Knowledge In Science Education

Integrating Artificial Intelligence (AI) and Indigenous Knowledge (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.

4.3.4.1 Respondents' Perspectives on Challenges of AI And Indigenous Knowledge Integration in Science Education

The themes were further finalised through a refining process which integrated key aspects. A total of 5 themes were derived to guide the discussion on teachers and principals' perspectives on the challenges of AI and indigenous knowledge integration in the science education. The findings indicated that teachers and principals perceive that: Recognition and Validation, Digital Divide, Technological Literacy, Cultural Sensitivity and Appropriation, and Interdisciplinary Collaboration are challenges that can hinder AI and indigenous knowledge integration in the science education in Eswatini.

4.3.4.1.1 Recognition and Validation

The recognition and validation of Indigenous Knowledge (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.

4.3.4.1.2 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.

4.3.4.1.3 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, and 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.

4.3.4.1.4 Cultural Sensitivity and Appropriation

Cultural sensitivity involves being aware of, comprehending, and respecting the diverse cultural practices, social behaviours, 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.

4.3.4.1.5 Interdisciplinary Collaboration

The collaboration between AI (Artificial Intelligence) and IKS (Indigenous Knowledge Systems) 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.

4.3.4.2 Respondents' Perspectives on Opportunities of AI And Indigenous Knowledge Integration in Science Education

The themes were further finalised through a refining process which integrated key aspects. A total of 4 themes were derived to guide the discussion on teachers and principals' perspectives on the opportunities of AI and indigenous knowledge integration in the science education. 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.

4.3.4.2.1 Authentic Integration

Incorporating authentic integration of AI (Artificial Intelligence) and IKS (Indigenous Knowledge Systems) 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.

4.3.4.2.2 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.

4.3.4.2.3 Information Preservation

The preservation of information in Artificial Intelligence (AI) and Indigenous Knowledge Systems (IKS) 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.

4.3.4.2.4 Personalized Learning

Personalized learning in AI (Artificial Intelligence) and IKS (Indigenous Knowledge Systems) 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.

4.3.4.2.5 Teachers Comfortability with Using AI and Technology in Teaching Science

To further show the challenges teachers and principals were asked the question;' How comfortable are you with the use of AI in your teaching practices?' this question was asked in order to check if teachers are comfortable with using technology or Ai tools and to check if that is not a challenge to them. The findings were as follows

Table 4.7

Teachers Comfortability with Using AI and Technology

How Comfortable	Frequency
Extremely Comfortable	2
Very Comfortable	9
Slightly comfortable	2
Somewhat comfortable	3
Moderate	10

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.

4.3.4.2.6 Exploring professional development opportunities in Ai for enhancing educational practices

Teachers were further asked the question, ‘would you be interested in professional development opportunities that focus on the use of AI in education?’ Their responses were 100% showing that they are interested in professional development. This interest in professional development opportunities demonstrates a clear and pressing need for teacher in-service training and that it should be an ongoing process. This 100% positive response rate clearly shows the recognition among science educators of Ai growing importance in the educational field. It also highlights their acceptance and eagerness to adapt and enhance their skills to better serve students’ needs in this changing world and technology driven era. This interest in learning for Ai related training suggest that the government and institutions, policy makers and curriculum developers should invest and prioritize the development and implementations of such programs to remain relevant in this fast-changing technological world to remain more relevant and create globally competent students. The 100% interest in teachers also shows that teachers are not only open to change but are actively seeking ways to evolve their teaching methods to fit this technological era. This positive attitude is crucial for the successful integration of Ai technologies and IKS in science education.

4.3.5. EDUCATORS' PERCEPTIONS AND ATTITUDES TOWARDS THE USE OF AI IN BRIDGING THE GAP BETWEEN INDIGENOUS KNOWLEDGE SYSTEMS AND FORMAL SCIENCE EDUCATION

Teachers' perceptions and attitudes toward the use of AI to bridge the education gap can vary widely based on several factors, including their familiarity with technology, their teaching philosophy, the resources available to them, and the specific context in which they work. Hou et al. (2022) noted that these perceptions and attitudes are not static and can change over time as teachers gain more experience with AI and as the technology itself evolves.

The aim of this objective was to assess teachers' and principals' perceptions and attitudes towards the use of AI in bridging the gap between indigenous knowledge systems and formal education, as it plays a crucial role in the effective use of AI in education. To collect data on teachers' perceptions and attitudes toward the use of AI to bridge the gap between indigenous knowledge systems and formal education, a digital semi-structured questionnaire was developed and circulated to teachers and principals.

The overall perception is that the majority of respondents view AI positively in bridging the gap between Indigenous Knowledge Systems (IKS) and formal science education, with varying levels of enthusiasm and understanding of its potential. Common themes include improved accessibility and dissemination of information, enhanced engagement and contextualization of learning, facilitation of collaboration between IKS holders and formal educators, preservation and digitization of IKS, and the potential for personalized and culturally relevant experiences. Levels of awareness vary, with some respondents showing a deep understanding of AI’s potential applications, others expressing positive sentiment but lacking specific ideas, and a few indicating limited awareness and uncertainty about AI’s role. Specific benefits mentioned include instant feedback for learners, contextualization of mathematical problems using Indigenous scenarios, digitization and preservation of endangered IKS, cross-cultural exchange and collaboration, and analysis and interpretation of IKS.

Challenges and concerns include potential loss or distortion of cultural context through digitization, intellectual property rights and data ownership issues, the need for building trust and partnership with indigenous communities, the time required to properly organize and digitize IKS, and overcoming the digital divide in rural areas. Noteworthy responses include

one respondent providing a comprehensive answer outlining both opportunities and challenges and another mentioning AI's role in generating hypotheses and designing experiments in scientific research. A few respondents indicated it is too early to predict AI's potential or that they are not yet aware of its potential, with one mentioning that it will take time to bridge the gap due to the informal nature of

From the responses a total of 4 themes were derived to guide the discussion on teachers and principals' perceptions and attitudes towards the use of AI to bridge the gap between IKS and formal science education. The findings indicated that teachers and principals perceive that cultural contextualisation, systemic challenges, knowledge preservation and community empowerment that these can bridge the gap between indigenous knowledge systems and formal education.

4.3.5.1 Cultural contextualization

In the field of science education, cultural contextualization in AI (Artificial Intelligence) and IKS (Indigenous Knowledge Systems) involves integrating indigenous cultures, values, and knowledge into the development and implementation of AI-powered educational resources and curricula. This approach ensures that science education is relevant and accessible for indigenous students, while also respecting and preserving their cultural heritage. Cultural contextualization in AI and IKS science education is essential for creating an educational environment that is inclusive and effective for Indigenous students. It helps to bridge the gap between indigenous and scientific knowledge systems, fostering a deeper understanding and appreciation of both. AI plays a significant role in connecting Indigenous Knowledge Systems (IKS) with formal education, facilitating cultural contextualization. One teacher noted that:

> *"AI can present mathematical problems using examples and scenarios from indigenous cultures, making learning more relevant and meaningful."*

The responses from the teachers support the argument made by Hoppers (2021) that educators and policymakers should strive for a more culturally contextualized education that respects indigenous knowledge systems, contributing to the academic success and cultural preservation of indigenous communities.

4.3.5.2 Knowledge preservation

Knowledge preservation involves intentional efforts to conserve, protect, and pass on the knowledge, wisdom, and cultural heritage of indigenous peoples using AI technology. It encompasses documenting, storing, and sharing indigenous knowledge in ways that respect cultural practices, ensure data sovereignty, and support the continuity of indigenous knowledge systems. Preserving knowledge in AI and IKS science education is crucial for safeguarding the priceless cultural legacy of indigenous communities, while leveraging AI's capabilities to enhance the accessibility, understanding, and application of this knowledge in contemporary contexts.

> *"One teacher said: AI-powered technologies could: 1. Aid in digitizing, preserving, and sharing endangered indigenous knowledge, making it more accessible for inclusion in science curricula."*

The findings of the study complement Dlamini's (2020) argument that artificial intelligence can be employed to preserve, respect, and integrate indigenous knowledge into formal education systems, ensuring its accessibility for future generations and enriching the global knowledge base with greater diversity and inclusivity.

4.3.5.3 Community empowerment

Community empowerment, in the context of AI (Artificial Intelligence) and IKS (Indigenous Knowledge Systems) science education, involves enabling indigenous communities to actively engage in, contribute to, and benefit from the incorporation of AI technologies into their educational frameworks and traditional knowledge practices. This empowerment is facilitated through initiatives designed to bolster the capabilities, autonomy, and decision-making abilities of community members. It focuses on fostering a cooperative and fair relationship among indigenous communities, scientists, educators, and technologists with the goal of ensuring that AI integration upholds and enriches the cultural integrity and prosperity of indigenous people while simultaneously advancing global scientific knowledge and innovation. One respondent noted:

> *"Empower local teachers, elders, and community members to actively participate in the co-creation of indigenous knowledge-based educational content and pedagogies."*

These perspectives align with Gama and Magistretti (2023) assertion that AI can be a powerful tool for empowering indigenous communities by bridging the gap between their knowledge systems and formal education. It can support cultural preservation, enhance educational opportunities, and create pathways for economic and social development. However, it is crucial that the integration of AI is done in a respectful, collaborative, and culturally sensitive manner, with the full participation and consent of indigenous peoples.

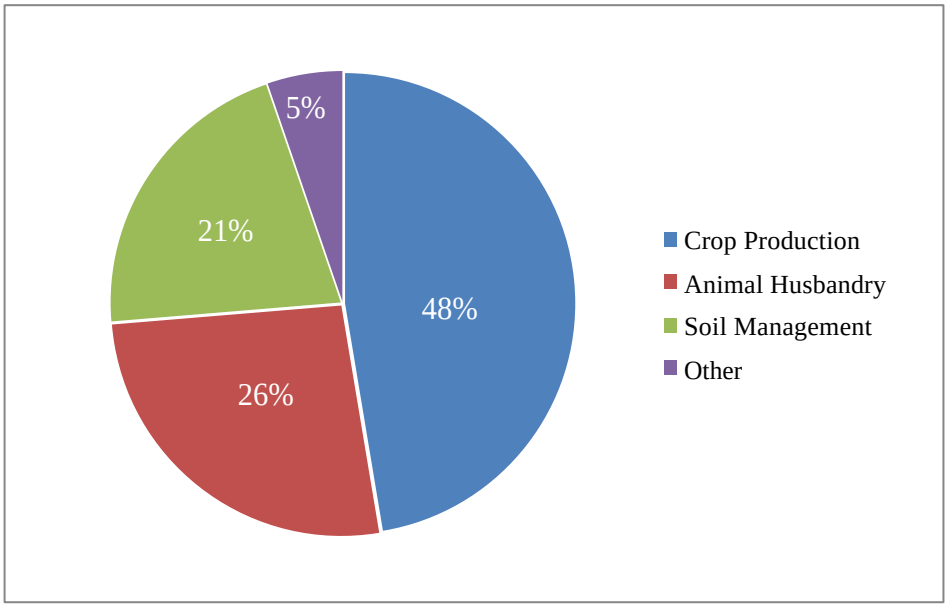
4.4 INFORMED STRATEGIES FOR SUSTAINABLE INTEGRATION OF IKS INTO SCIENCE CURRICULA USING AI TECHNOLOGIES IN ESWATINI

4.4.1 RECOMMENDING INFORMED STRATEGIES TO ENSURE THE SUSTAINABLE INTEGRATION OF IKS INTO SCIENCE

To address our objective 5 of this study, which seeks to develop strategies for sustainable integration of IKS into science curricula with the aid of Ai technologies in Eswatini, we analysed the responses from students focused group discussions and the questionnaire from teachers regarding topics that could best incorporate IKS to enhance learning. The question was open ended and the question that was asked students was: ‘suggest which topics can best incorporate indigenous knowledge to make learning easy.’ 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:

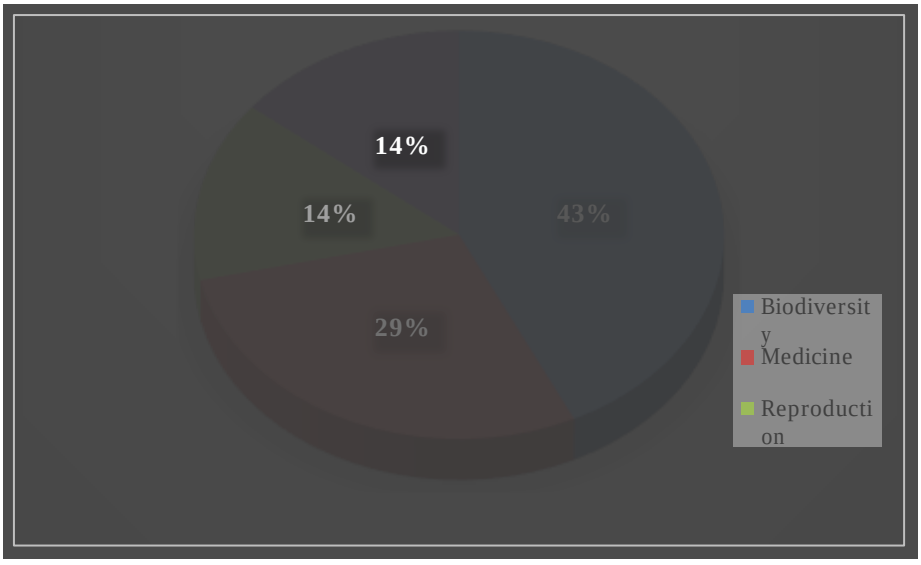
1. Agriculture
    - Crop production
    - Animal husbandry
    - Soil management

Figure 4.7: Agriculture Frequency



2. Biology
    - Biodiversity
    - Medicine
    - Reproduction

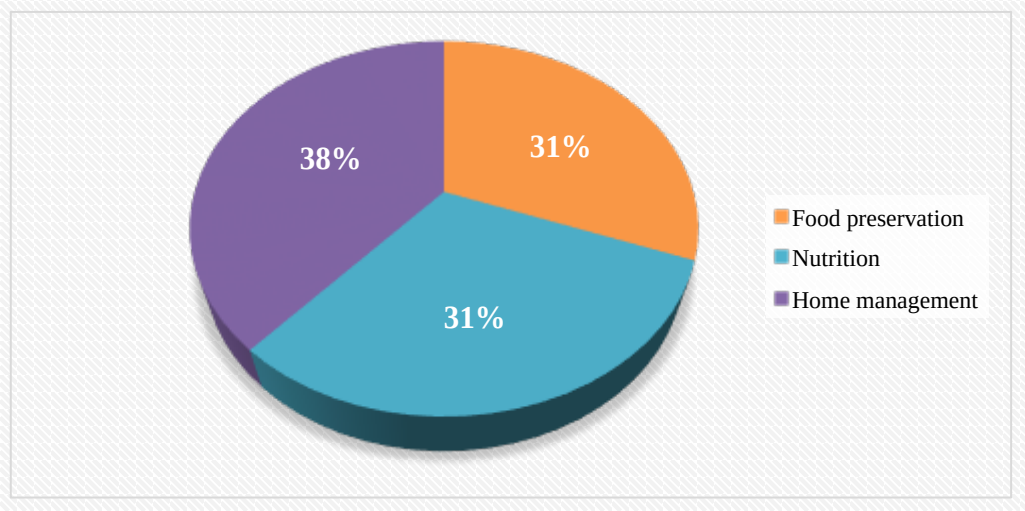
Figure 4.8: Biology Frequency



3. Consumer Science
    - Home management
    - Food preservation

- Nutrition

Figure 4.9: Consumer Science frequency

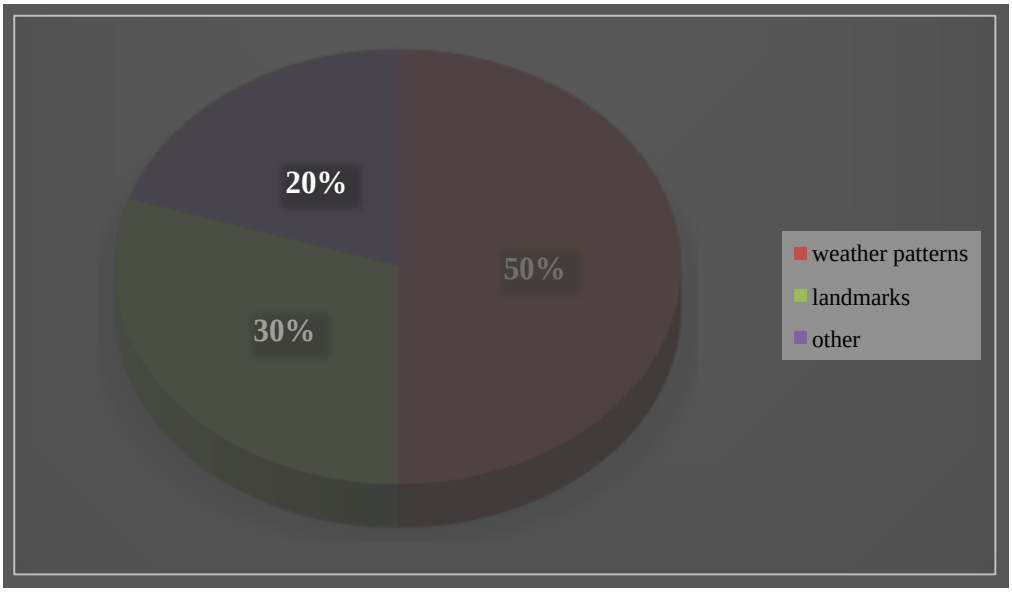


4. Geography

- Weather patterns
- Landmarks

Figure 4.10

Geography Frequency

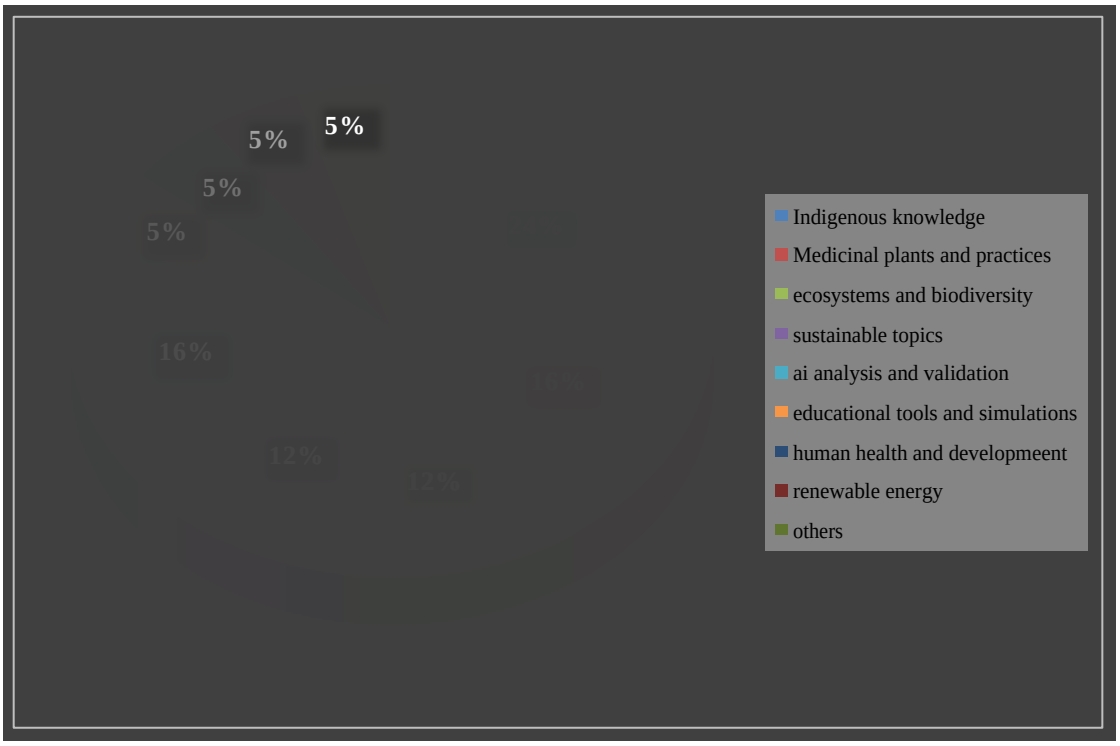


Similarly, teachers and students were asked the same question on 'Can you suggest any topics in the Science curriculum where indigenous knowledge and AI can be integrated?' in

order to get informed strategies on which topics can be used in science for a sustainable integration of science. The mentioned subjects like: Biology, Earth and environmental science, chemistry, physics, agriculture, geography, integrated science. The questions were open ended in order to get the honest opinions on the topics and subjects where IKS and Ai can be integrated in science. Due to the different responses, the data was analyzed a grouped into common themes which are: indigenous knowledge, medicinal plants and practices, ecosystem and biodiversity, sustainable practices, Ai analysis and validation, educational tools and simulations, human health and development, renewable energy and the information is presented in Figure 4.11.

Figure 4.11

Topics in science curriculum where IKS and AI can be integrated



Both the information above, by the students, teachers give information on the science subjects and specifically which topics can be used to integrate IKS and AI effectively. One of the strategies from the strategies is leveraging indigenous knowledge such as incorporating traditional ecological knowledge, weather prediction methods and astronomical knowledge will provide a clear understanding of scientific concepts. By utilizing Ai for validation and analysis such as medical plant properties and farming techniques to bridge the gap between

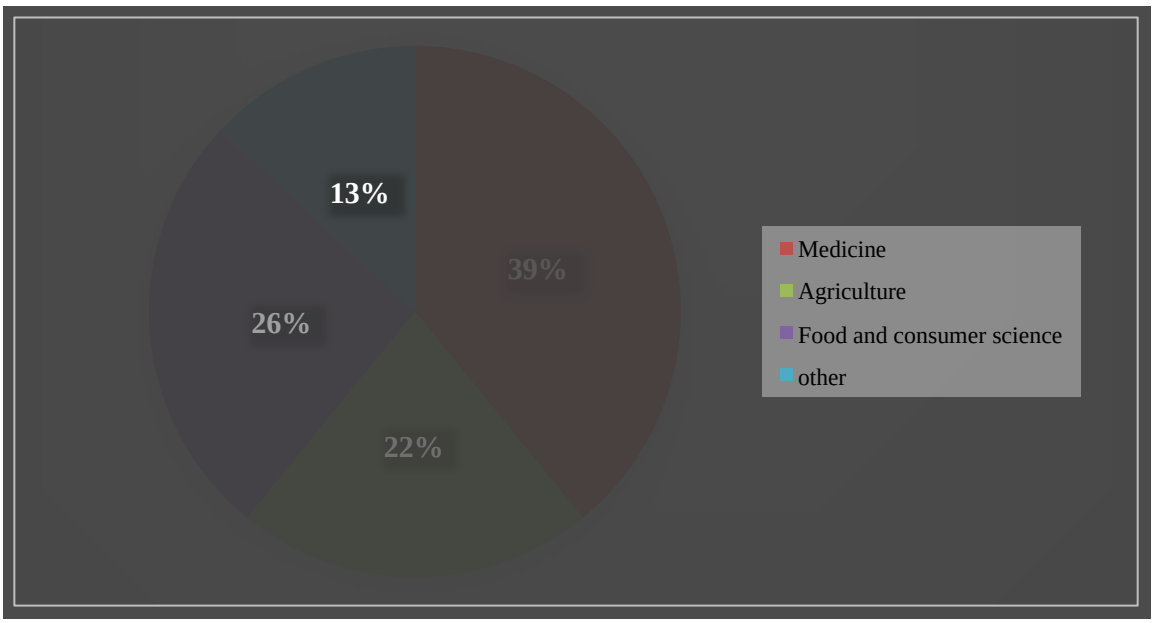
modern farming techniques and IKS. Also, by promoting sustainable practices such asintegrating agricultural practices and natural resources management techniques from IKS with AI solutions will assist in teaching students about sustainability. Also, by developing Ai powered interactive modules and simulations that incorporate IKS will make learning of science relevant and more fun and practical. Lastly, by exploring traditional health topics using Ai to provide a comprehensive understanding of biology and health science such as reproduction, sexual and asexual. Looking at the above graph by the educators, principals and that of the students above pie chart responses one can clearly suggest that these topics can help curriculum developers, and give them insights on the strategies of incorporating IKS and Ai into the science curricula in Eswatini just like other countries.

4.4.1.2 Integration of Eswatini cultural or local knowledge in science education

Another question was asked the learners 'which aspects of your culture or local knowledge do you think should be included in in your science education?' This question was open ended and was meant to get the honest opinions of the learners. Below is a graph representing the information after data analysis. The information is presented as following:

Figure 4.12

Aspects of culture or local knowledge that should be included in science education



From the responses gathered from the data, learners were able to give strategies to ensure cultural or local knowledge in science education the responses included the following: traditional medicine as the most frequently mentioned aspect, with all the responses highlighting its importance. Respondents emphasized the use of local plant, traditional remedies etc. This suggests a strong cultural connection to IKS practices and a desire to preserve this knowledge within the scientific field.

Agriculture was the second most common response. Most respondents noted the importance of traditional farming methods and the potential for integrating modern technologies like Ai power drones for crop management. This indicates the desire to blend IKS and Ai approaches in the learning of science.

Many responses highlighted the importance of including traditional food preparation and preservation techniques in science education especially in consumer science curricula. This reflects the importance of the traditional food and practices. From this data we were able to get information which basically addresses our objective 5 on the strategies that can be developed to ensure the sustainable development of IKS and Ai into the science curricula in Eswatini.

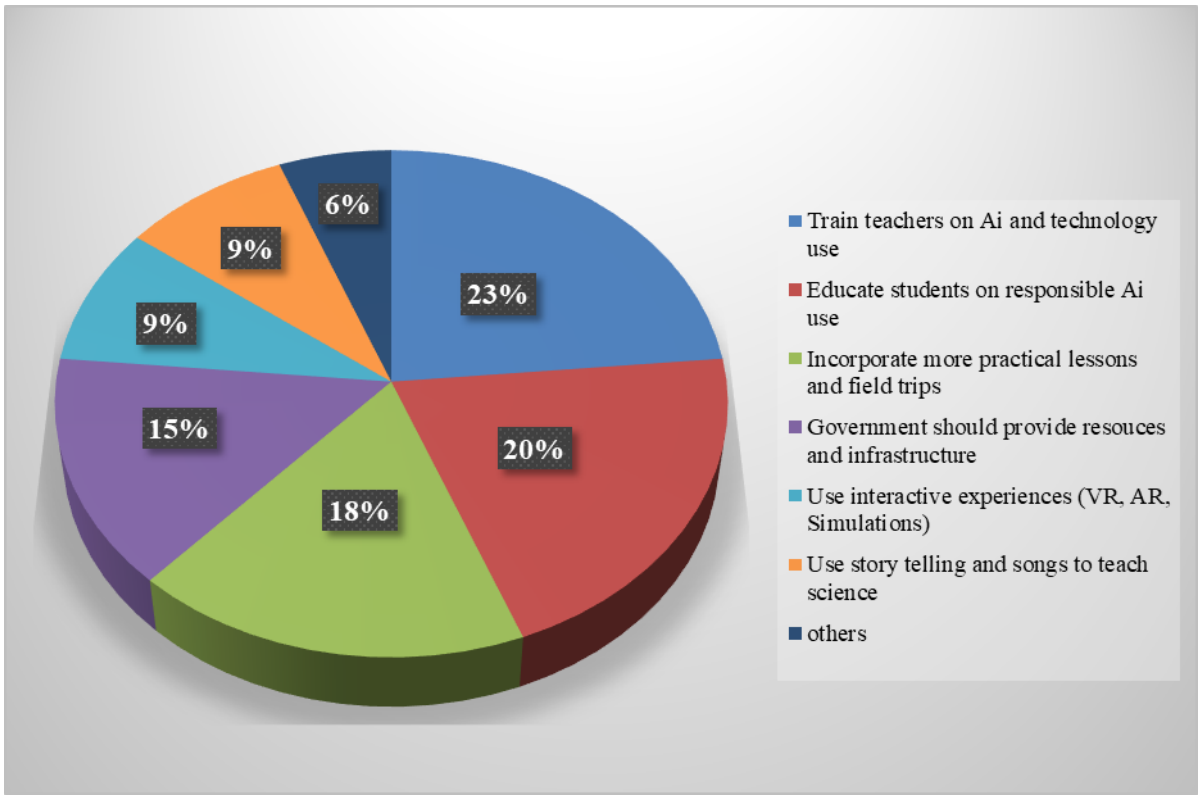
Learners were also asked “What are your suggestions for making science education more fun, practical and engaging with the help of Ai and indigenous knowledge”. This question aimed also at offering strategies that can be used for informed strategies to ensure the sustainable integration of IKS and Ai into science education in order to respond to our objective 5. 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.

From the data in Figure 4.13 (below), 23% of the learners recommend professional training because this is a crucial step as teachers need to be abreast with Ai technologies and IKS order to be able to incorporate it effectively in the teaching strategies. This could involve workshops, online courses, ongoing training (in-service) development programmes. 20 % suggest that students should be educated on the responsible use of AI for developing digital literacy and ethical issues. 18% feel that teachers should incorporate practical lessons and field trip, e.g. including AI tools, exploring local ecosystems to connect IKS with scientific concepts. 15 % feel the government should provide resources for example by providing

computers, internet access, Ai based educational software's to schools. 9% suggest the use of interactive experiences e.g. simulations, virtual reality, augmented reality etc to blend scientific learning experiences. 95 also suggest use of storytelling and songs in teaching science to make science learning fun and easy. 6% include various innovative ideas that could be explored further. A summary of this this information is presented in Fure 4.13.

Figure 4.13

Suggestions for enhancing science education using Ai and IKS.



These suggestions reveal a positive contribution in enhancing science education using Ai and IKS. I believe it's very encouraging to see that students are able to contribute that they as students as well as their teachers needs to be educated on the use ok Ai tools and IKS in order to integrate AI and IKS in enhancing teaching and learning in science education.

4.4.1.3 Document Analysis Findings

To further achieve objectives 2 and 3, document analysis of the Science syllabus was examined in order to find answers. The document analysis is for JC (Junior certificate) and (EGCSE) 2024-2026. The main purpose of analysing the JC and EGCSE science syllabi for

2024-2026 was to identify any explicit mentions or incorporation of indigenous knowledge in the teaching of science and to determine if there are any references to the use of technologies, particularly AI, in the teaching and learning of science subjects and to provide a clear understanding of the current curriculum to compare with the actual teaching practices observed in the classroom. The approach that was used was downloading the syllabuses and reading them with the intention of achieving the purpose. I read and analysed the different subjects and the findings were as follows:

Physics

The EGCSE Physics syllabi for 2024 to 2026 emphasize understanding the technological world and applying scientific methods to everyday life. The curriculum covers topics such as mechanics, electricity, magnetism, waves, and atomic physics. However, there is no explicit mention of integrating indigenous knowledge systems in the content or teaching methods. The focus remains on conventional scientific principles and their applications, with no reference to indigenous perspectives or knowledge.

Mathematics

The Mathematics syllabi for JC and EGCSE aim to develop mathematical skills and understanding. The curriculum includes topics such as algebra, geometry, trigonometry, statistics, and calculus. Similar to Physics, there is no specific mention of incorporating indigenous knowledge systems in the curriculum. The teaching methods and content are centred around traditional mathematical concepts and problem-solving techniques, without any integration of indigenous mathematical knowledge or practices.

Additional Mathematics

The Additional Mathematics syllabi for JC and EGCSE are designed to extend students' mathematical skills and understanding beyond the standard curriculum. Topics include advanced algebra, calculus, and complex numbers. There is no explicit mention of integrating indigenous knowledge systems in the content or teaching methods. The focus is on advanced mathematical theories and applications, with no reference to indigenous mathematical practices or knowledge.

Biology

The Biology syllabi cover a wide range of topics, including human biology, plants, ecosystems, genetics, and evolution. The curriculum aims to develop an understanding of biological concepts and their applications. While the syllabi include discussions on biodiversity and ecosystems, there is no explicit inclusion of indigenous knowledge systems. The focus is primarily on scientific theories and principles, with limited reference to traditional ecological knowledge or indigenous practices related to biology.

Chemistry

The Chemistry syllabi aim to develop an understanding of chemical principles and their applications. Topics covered include atomic structure, chemical reactions, organic chemistry, and environmental chemistry. Similar to the other subjects, there is no explicit mention of integrating indigenous knowledge systems in the teaching of chemistry. The curriculum is heavily focused on conventional chemical concepts and laboratory practices, with no reference to indigenous chemical knowledge or traditional practices.

Agriculture

The Agriculture syllabi include topics on crop production, animal husbandry, soil science, and sustainable farming practices. While the curriculum covers traditional farming methods, it does not explicitly mention indigenous knowledge systems. There is some potential for incorporating indigenous knowledge in topics related to sustainable farming and environmental management, but this is not explicitly stated in the syllabi. The focus remains on modern agricultural practices and scientific principles.

Geography

The Geography syllabi cover physical and human geography, including topics such as climate, landforms, population, and environmental management. There is some potential for incorporating indigenous knowledge systems in topics related to environmental management and sustainability. For example, discussions on traditional land use practices and indigenous approaches to resource management could be included. However, the syllabi do not explicitly state the integration of indigenous knowledge systems, and the focus remains on conventional geographical concepts and theories.

Consumer Science

The Consumer Science syllabi focus on topics such as nutrition, family health, consumer rights, and resource management. While the curriculum aims to develop practical skills and knowledge for everyday life, there is no explicit mention of integrating indigenous knowledge systems. The focus is on modern consumer practices and scientific principles related to health and nutrition, with no reference to traditional knowledge or practices.

Technology

The Technology syllabi cover topics such as design and technology, information and communication technology (ICT), and technical drawing. The curriculum aims to develop technical skills and understanding of technological principles. Similar to other subjects, there is no explicit mention of incorporating indigenous knowledge systems. The focus is on modern technological concepts and practices, with no reference to traditional technological knowledge or indigenous innovations.

Based on the analysis of the JC and EGCSE science syllabi for 2023 and 2024, there is no explicit mention of integrating indigenous knowledge systems in the teaching of Physics, Mathematics, Additional Mathematics, Biology, Chemistry, Agriculture, Geography and Consumer Science. The current syllabus does not actively support or encourage the integration of IKS and Ai into science teaching. They maintain the traditional approach to science education. The observations also confirmed that educators are not using strategies that incorporate IKS and Ai in the science teaching and learning, aligning with the lack of emphasis on these areas in the syllabi. This analysis suggests a gap in the curriculum that could be addressed to enhance the relevance and inclusivity of science education by incorporating indigenous knowledge and AI. It provides a room for recommending curriculum revisions and teacher training to bridge this gap and enhance science teaching in the country and produce globally competent learners.

4.4.1.4 Observation Findings

Observations were also done in order to check if the educators made use of technologies, Ai and IKS in the process of teaching and learning as part of objective 2 and 3. During the lesson observation period, science lessons were monitored in ten different schools. The focus

was on identifying the use of IKS and AI in the teaching methods employed by the teachers. The observations were structured to capture any instances where these elements were integrated into the curriculum. The schools are marked with A to J. The findings were as follows: In all the schools visited, there was a noticeable absence of IKS in the science lessons. This omission was consistent across all observed lessons, indicating a gap in the integration of culturally relevant knowledge in science education.

In School A, the science lesson on plant biology focused solely on textbook content without referencing any local plant species or traditional uses of plants. This pattern was observed in all other schools, where the curriculum strictly adhered to standard scientific concepts without incorporating indigenous knowledge. Similarly, the use of AI in teaching science was not observed in any of the schools. AI, which can enhance learning through personalized education and interactive tools, was completely absent from the teaching methods. The lessons relied on traditional teaching aids such as textbooks, chalkboards, and occasional multimedia presentations, but no AI-driven tools or applications were utilized. In School E the lesson on chemical reactions was conducted using a standard lecture format with no AI tools to simulate experiments or provide interactive learning experiences. This was a common trend in all the schools, where technology use was limited to basic multimedia aids.

The data collected reveals that neither IKS nor AI is being utilized in the science lessons observed across all the schools. The absence of IKS and AI in science teaching has implications for student engagement and learning outcomes. Students miss out on the opportunity to connect scientific concepts with their cultural heritage and to benefit from the enhanced learning experiences that AI can provide. In school F, students showed limited engagement during a physics lesson that could have been made more interactive and relatable with the use of AI simulations or references to traditional engineering practices.

The findings from the observations indicate a significant gap in the integration of Indigenous Knowledge Systems and Artificial Intelligence in science teaching across the ten schools. Addressing these gaps requires targeted professional development for teachers, investment in resources, and a curriculum that values both traditional knowledge and modern technology.

4.5 CHAPTER SUMMARY

This study investigated the integration of indigenous knowledge systems and AI into science education in the Lubombo region. Data were collected from 10 schools, including science teachers, principals, and students. A mixed methods approach was used, combining qualitative and quantitative data. The study found a high response rate (87%) and analyzed demographic data like age, gender, teaching experience, and qualifications. This chapter further explored the connection between indigenous knowledge, science education, and AI in Eswatini. It examined the influence of indigenous knowledge on child development and academic achievement, focusing on themes like holistic learning, community and collectivism, cultural identity, sustainable living, empowerment, and self-determination. The study also investigated the use of AI to integrate indigenous knowledge into science curricula, considering challenges and opportunities. Finally, it analyzed educators' perceptions of AI in bridging the gap between indigenous knowledge and formal science education. The research aims to inform strategies for sustainably integrating indigenous knowledge into science using AI.

CHAPTER 5

SUMMARY, CONCLUSIONS, AND RECOMMENDATION

5.0 INTRODUCTION

This chapter presents a detailed overview of the research conducted on integrating indigenous knowledge systems (IKS) and artificial intelligence (AI) in science education in Eswatini in the Lubombo region schools. It begins with a summary of the study, including brief overviews of each chapter and the challenges encountered during the research process. The chapter then provides conclusions aligned with each research objective, followed by targeted recommendations for relevant stakeholders. Finally, suggestions for further research are outlined to guide future investigations in this field.

5.1 SUMMARY OF THE RESEARCH

Chapter 1 introduced the study, providing background information on the integration of indigenous knowledge into formal education systems, particularly in Eswatini in the Lubombo region. It outlined the statement of the problem, research aims, objectives, and questions, emphasizing the significance of the study for various stakeholders. It went on to discuss the delimitations and limitations of the study. Definitions of key terms, working definitions, research layout, and chapter summary were discussed in this chapter.

Chapter 2 presented a detailed literature review, exploring existing research on indigenous knowledge systems, their role in education, and the potential of AI in bridging the gap between IKS and formal science education. It also discussed the theoretical framework, which is CHAT (Cultural-Historical Activity Theory), applications of CHAT to previous studies in educational settings, relevance of CHAT to the study, and integration of AI and IKS in education. The literature review covered topics including; indigenous knowledge systems, the influence of IKS on child development and academic achievement, AI technologies in education, integration of AI and IKS in science education, gaps in current applications of AI and IK in science education, educators' perceptions and attitudes, challenges and opportunities in integrating IK in science education, bridging knowledge systems, strategies for sustainable integration, and a chapter summary.

Chapter 3 gave a detailed the research methodology, including the research philosophy, paradigm, design, target population and sampling, sampling techniques, data collection instruments, data collection procedures, and data analysis employed in the study. Quality assurance procedures, ethical considerations, limitations of the study, and a chapter summary were also included.

Chapter 4 presented the findings of the study, analysing the data collected and discussing the results in relation to the research objectives and questions. Themes and subthemes included: The influence of indigenous knowledge on child development and academic achievement in the context of Eswatini. The use of AI technologies to recognize, incorporate, and present indigenous knowledge within science curricula. Challenges and opportunities associated with integrating AI and indigenous knowledge in science education, educators' perceptions and attitudes towards the use of AI in bridging the gap between IKS and formal science education, informed strategies for sustainable integration of IKS into science curricula using AI technologies in Eswatini, and a summary.

5.1.1 CHALLENGES ENCOUNTERED

During the course of this research, several challenges were encountered that impacted the data collection process and overall study implementation. Some schools required monetary incentives to participate in the study, which was not initially budgeted for and posed financial constraints. Additionally, the timing of the research coincided with mock examination preparations, resulting in limited availability of some participants and reduced cooperation from certain schools.

The frequent absence of headteachers in some schools necessitated multiple visits, causing delays in data collection and increasing the time and resources required for the study. Furthermore, the response rate for questionnaires fell short of expectations, with 26 out of the anticipated 30 respondents completing the forms. This slightly reduced sample size may have impacted the generalizability of the findings. Lastly, a significant challenge was the lack of familiarity with AI and IKS concepts among some respondents, which required additional explanation and potentially affected the depth of responses received.

5.2 CONCLUSIONS

Based on the research objectives and questions, the following conclusions were drawn:

1. Influence of Indigenous Knowledge on Child Development and Academic Achievement

Indigenous knowledge significantly influences child development and academic achievement in Eswatini by contributing to holistic learning, fostering community and collectivism, strengthening cultural identity and belonging, promoting sustainable living practices, and encouraging empowerment and self-determination. It enhances cultural relevance in education, stimulates critical thinking and problem-solving skills, improves cultural competence, increases student engagement, develops language and communication skills, and boosts self-esteem and motivation in academic pursuits. This leads to the conclusion that IKS is very important for child development and academic achievement because it is intertwined with the cultural practices and knowledge systems that have been passed down through generations. IKS's impact on child development is not solely focused on academic performance but encompasses a broader spectrum of social, emotional, and cultural competencies, which is why it should be integrated into formal science curricula. Based on the results, teachers and principals in Eswatini recognize the importance of IKS in child development.

2. Utilization of AI Technologies for Incorporating Indigenous Knowledge

AI technologies can be effectively utilized to recognize, incorporate, and present indigenous knowledge within science curricula through various means. These include cultural heritage digitization, development of knowledge sharing platforms, creation of simulation and modelling tools, establishment of ethnobotanical databases, and enhancement of accessibility and inclusivity within science curricula. From the study, it appeared that learners were now ahead of their teachers in using AI tools. This poses a risk for teachers who are not up to date with technology and AI usage in their instructional methods in teaching science. Therefore, educational institutions should prioritize professional development that includes AI technologies and their educational applications so that all teachers can be abreast with technological changes and adapt. A teacher should always be four steps ahead of the learners,

but in this case, it seems the learners are now ahead as they are actively engaging with AI tools in writing their assignments, homework, and creating content for TikTok and Instagram.

3. Challenges and Opportunities in Integrating AI and Indigenous Knowledge

The integration of AI and indigenous knowledge in science education presents both challenges and opportunities. Challenges include gaining recognition for indigenous knowledge, addressing the digital divide, promoting technological literacy, respecting cultural sensitivity, and avoiding appropriation of indigenous knowledge. Opportunities encompass authentic integration of IKS into curricula, facilitation of global education initiatives, preservation of indigenous information, and creation of personalized learning experiences. It was noted that by addressing the challenges and capitalizing on opportunities, the integration of AI and IK in science education has the potential to enhance cultural understanding, promote equity, and cultivate a deeper understanding of diverse ways of knowing and being globally relevant. Technological literacy is important, and both teachers and learners need to be educated on how to use technology and incorporate AI tools and IKS in the teaching and learning process.

4. Educators' Perceptions on Using AI to Connect IKS with Formal Science Education

Educators' views on using AI to connect indigenous knowledge systems with formal science education revealed several key themes. These include the importance of cultural contextualization in AI-enhanced education, systemic challenges in implementation, the potential for knowledge preservation through AI tools, and the opportunity for community empowerment through technology-enhanced learning. It was noted that educators are not comfortable with the use of AI in their teaching practices, hence creating negative or mixed feelings in their attitude. This means that there is a huge need to provide professional development and training so that they are comfortable with using technology and AI tools in teaching science. Teachers' perceptions and attitudes towards the use of AI to bridge the education gap vary widely based on factors such as familiarity with technology, teaching philosophy, resources available to them, and the context in which they work. The perceptions were not static; however, a majority of the respondents view AI positively in bridging the gap between IKS and formal science education, with varying levels of enthusiasm and understanding of its potential.

5. Strategies for Sustainable Integration of IK into Science Curricula Using AI

The study identified several strategies for sustainable integration of indigenous knowledge into science curricula using AI. These include developing AI-powered educational content that incorporates local languages and cultural contexts, creating partnerships between schools and other countries to facilitate knowledge exchange, and implementing ethical guidelines for AI use in education. The students and teachers also identified topics in science subjects that can be used to easily integrate IKS and AI to enhance learning. One of the strategies in leveraging IKS involves incorporating traditional ecological knowledge and weather prediction methods, utilizing AI for validation and analysis of medical plant properties and farming techniques to bridge the gap between modern farming techniques and contemporary techniques. Respondents also indicated the need to integrate cultural knowledge and local knowledge in science education, such as medicine, agriculture, and food preservation methods. The conclusion is that there is a need for a curriculum review of the science syllabi to incorporate IKS and AI since there is huge potential in transforming the science education of Eswatini, just like in other countries.

5.3 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

1. Enhance digital infrastructure in schools and communities to ensure reliable access to AI technologies and internet for all learners. This can be achieved by allocating funds to upgrade existing computer labs and internet connections in schools. The ministry can partner with Mtn and Swazi mobile companies to provide affordable or subsidized internet packages for educational institutions. Additionally, they can implement a program to distribute tablets or laptops to students, especially in rural areas.
2. 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.

3. Ensure all students, regardless of their background or location, have equal access to AI-enhanced educational opportunities. This can be achieved by developing a comprehensive plan to address the digital divide in rural and urban areas. The ministry can implement mobile learning units that bring AI technologies to remote schools. They can also create online learning platforms that are accessible even with low bandwidth and provide training for teachers in these areas on using AI tools effectively.
4. 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. They should address issues such as data privacy, cultural sensitivity, and fair use of AI in assessments. Regular reviews and updates of these guidelines should be scheduled to keep pace with technological advancements.

For School Administrators and Parents

1. 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 IKS 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.
2. Support and encourage the use of AI technologies and indigenous knowledge integration in classrooms. 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.

3. Parents can support schools by buying technological gadgets for their children such as iPads, of cell phones , they can also assist in making science education easier as each learner can have their own personal gadget, and there would not be any need for losing the gadgets in schools. Schools can work with parents to create a "bring your own device" (BYOD) policy, ensuring that all students have access to necessary technology. For families unable to afford devices, schools can establish a fund or seek corporate sponsorships to provide tablets or laptops. Parents can be involved in workshops on maintaining and effectively using these devices for educational purposes.

For Teachers and Teacher Development Institutions: UNESWA, William Pitcher

1. 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 IKS integration. These courses should include hands-on training with various AI tools and platforms. Regular workshops and seminars can be organized to keep teachers updated on the latest developments in AI and IKS. Online learning modules can be created to allow teachers to learn at their own pace and convenience.

2. 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. They can organize competitions or grants for teachers to develop innovative AI-based lessons that incorporate IKS. Mentorship programs can be established where experienced teachers guide others in creating culturally relevant, AI-enhanced content. Collaborations with local elders and knowledge keepers can be facilitated to ensure authentic representation of indigenous knowledge in AI-powered educational materials.

For Science Subjects Curriculum Developers

1. 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 firsthand. 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.

2. Implement a curriculum that explicitly integrates AI, scientific principles, and IKS, ensuring an improved educational approach. Developers can create a comprehensive framework that outlines how AI and IKS should be incorporated into each science subject and grade level. They can design lesson plans and teaching resources that demonstrate the practical integration of these elements. Pilot programs can be implemented in select schools to test and refine the new curriculum before nationwide rollout. Regular feedback sessions with teachers, students, and community elders can be held to ensure the curriculum remains relevant and effective.

3. Develop AI-powered educational content that incorporates local language and cultural contexts to make learning more relatable and accessible. Curriculum developers can collaborate with local language experts and cultural practitioners to create AI-powered learning modules in Siswati and other local languages. They can develop virtual reality or augmented reality experiences that showcase local environments and cultural practices relevant to science education. AI-powered chatbots or virtual assistants can be created to help students learn scientific concepts using local examples and contexts. Regular updates to this content should be scheduled to ensure it remains current with both scientific advancements and cultural practices.

5.4 RECOMMENDATIONS FOR FURTHER RESEARCH

1. Investigate the long-term impacts of AI-enhanced IKS integration on student achievement and cultural preservation.

2. Explore the development of culturally-specific AI algorithms for educational purposes in Eswatini.

3. Examine the potential of AI in facilitating cross-cultural collaborations in science education on a global scale.

4. Assess the effectiveness of different AI tools in preserving and disseminating indigenous knowledge.

5. Investigate how AI can be used to facilitate collaboration between students from different regions across the globe to encourage creativity and practicality in science education.

6. Study the ethical implications and potential biases in AI-driven educational tools when integrating indigenous knowledge.7. Evaluate the impact of AI-enhanced IKS integration on teacher workload and pedagogical practices.

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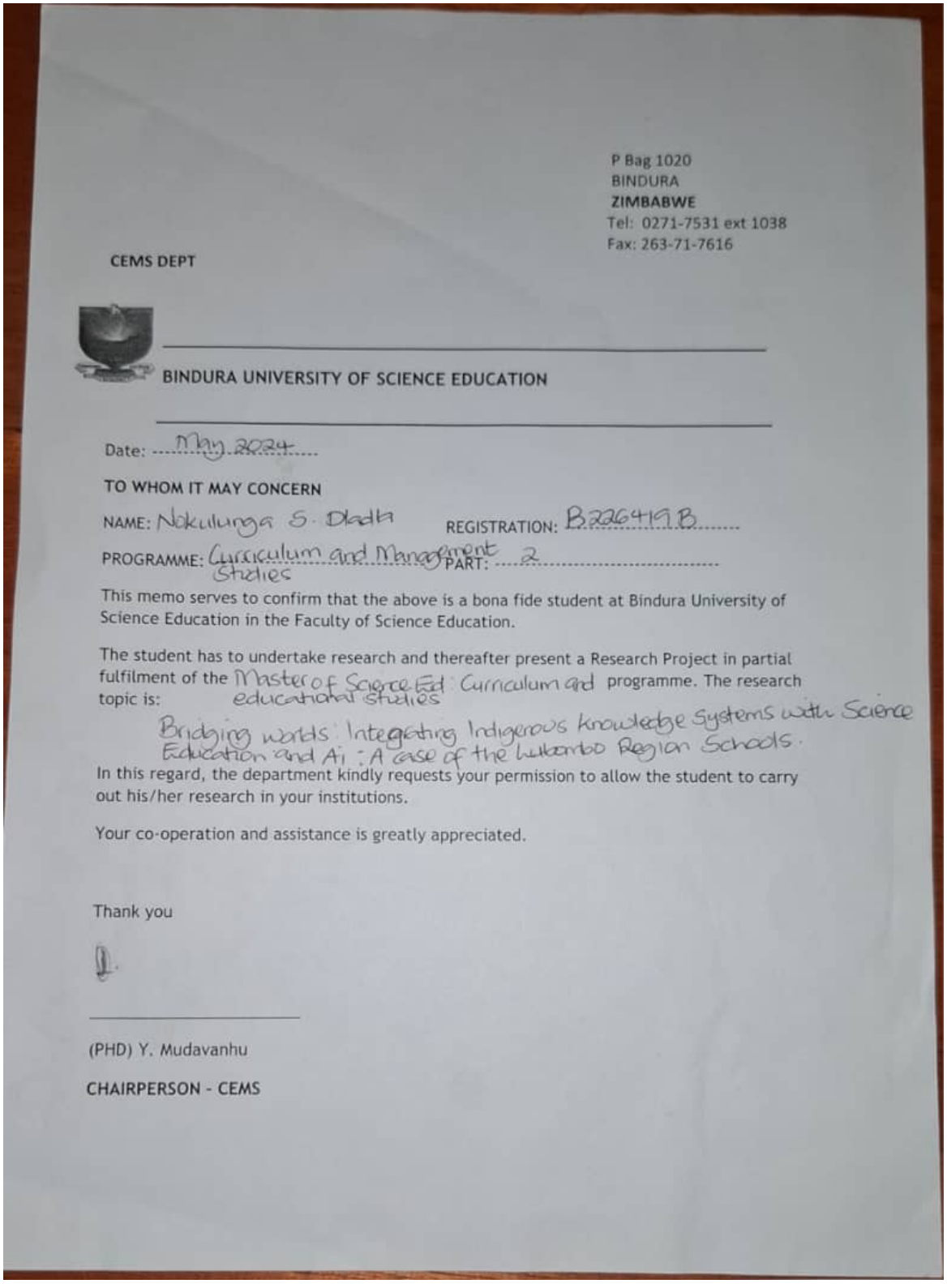
APPENDICES

Appendix A

Clearance letter from Bindura University of Science Education



P Bag 1020
BINDURA
ZIMBABWE
Tel: 0271-7531 ext 1038
Fax: 263-71-7616

CEMS DEPT

BINDURA UNIVERSITY OF SCIENCE EDUCATION

Date: May 2024

TO WHOM IT MAY CONCERN

NAME: Nokuluŋga S. Dladla REGISTRATION: B226419B

PROGRAMME: Curriculum and Management Studies PART: 2

This memo serves to confirm that the above is a bona fide student at Bindura University of Science Education in the Faculty of Science Education.

The student has to undertake research and thereafter present a Research Project in partial fulfilment of the Master of Science Ed: Curriculum and programme. The research topic is: educational studies

Bridging worlds: Integrating Indigenous knowledge Systems with Science Education and AI: A case of the Lukambo Region Schools.

In this regard, the department kindly requests your permission to allow the student to carry out his/her research in your institutions.

Your co-operation and assistance is greatly appreciated.

Thank you

(PHD) Y. Mudavanhu

CHAIRPERSON - CEMS

Appendix B

Permission letter form the Eswatini Ministry of Education and Training

The Government of the Kingdom of Eswatini

Ministry of Education & Training

Tel: (+268) 2 4042491/5
Fax:(+268) 2 404 3880

P. O. Box 39
Mbabane, Eswatini

18 July 2024

The Principal

Entandweni High School, Mpaka High School, School for the Deaf, Lusoti High School, Mafucula High School, Siteki Nazarene, Good Shepherded, KaLanga, U-Tech, Siphofaneni and Duze

Dear Madam

RE: REQUEST FOR PERMISSION TO COLLECT DATA FOR THE BINDURA UNIVERSITY OF SCIENCE EDUCATION - NOKULUNGA SANELISIWE DLADLA

1. The Ministry of Education and Training has received a request from Ms. Nokulunga Sanelisiwe Dladla, a student at the Bindura University of Science Education that in order for him to fulfill his academic requirements at the University she has to collect data (conduct research) and her study or research topic is: **"Bridging Worlds: Integrating Indigenous Knowledge Systems with Science Education and AI.** Data will be collected from students in Form 3,4 and 5, Science teachers and Head teachers. All details concerning the study are stated in the participants' consent form which will have to be signed by all participants before Ms Dladla begins her data collection.

2. The Ministry of Education and Training requests your office to assist Ms Dladla by allowing him to use the College as his research site. Data collection period is **one month**.

MINISTRY OF EDUCATION & TRAINING
DIRECTORS OFFICE
18 JUL 2024
P.O. BOX 39
MBABANE H100
ESWATINI

CHARLES HLATSHWAKO
FOR: PRINCIPAL SECRETARY

APPENDIX C

QUESTIONNAIRE

I am Nokulunga Sanelisiwe Dladla, a Masters student at BUSE University. My research focuses on bridging the gap between indigenous knowledge systems and formal science education in the Lubombo region of Eswatini by integrating AI technologies. This project aims to explore how indigenous knowledge can be effectively incorporated into science curricula, making learning more culturally relevant and inclusive. Throughout this research, I am committed to upholding ethical principles, including utmost respect for indigenous communities, their knowledge systems, and cultural practices. I will ensure the full consent and participation of all stakeholders, including educators and learners, while safeguarding their confidentiality and privacy. Additionally, I will carefully evaluate the integration of AI technologies to ensure it does not compromise the integrity and authenticity of the indigenous knowledge being represented. Kindly answer the following questions.

Section A: Demographic Information

Teacher or Principal

Teacher ☐
Principal ☐

What is your age?

	☐
	☐
	☐
	☐
	☐
	☐

Gender

Male ☐
Female ☐
Other ☐

Years of teaching experience

	☐
	☐
	☐
	☐

Qualifications

Advanced Teachers Diploma	☐
Bachelor's Degree	☐
Honors Degree	☐
Master's Degree	☐
PDH	☐

Educational level you teach (e.g., secondary, high school)

Secondary	☐
High school	☐
Both	☐

Section B: Indigenous Knowledge and Child Development in Eswatini

1.1. What do you think is the role of indigenous knowledge in the overall development of children in Eswatini?

1.2. In what ways do you believe indigenous knowledge influences academic achievement in Eswatini's educational system?

1.3. Can you provide examples of indigenous knowledge that are relevant to child development and learning in Eswatini?

1.4. On a scale of 1 to 5, how important do you think indigenous knowledge is in the development of children in Eswatini? (1 - Not important at all, 5 - Extremely important)

Section C: Utilization of AI Technologies in Science Curricula

2.1. Are you familiar with AI technologies and their potential applications in education? (Yes/No)

2.2. If yes, how do you think AI technologies could be used to recognize and incorporate indigenous knowledge within science curricula? (Open-ended response)

2.3. Which aspects of indigenous knowledge do you believe AI could effectively present within science education? (Open-ended response)

2.4. On a scale of 1 to 5, how confident are you in the ability of AI to accurately represent indigenous knowledge in science curricula? (1 - Not confident at all, 5 - Extremely confident)

2.5. Can you suggest any topics in the Science curriculum where indigenous knowledge and AI can be integrated?

Section D: Challenges and Opportunities of Integrating AI and Indigenous Knowledge

3.1. What challenges do you foresee in integrating AI and indigenous knowledge in science education? (Open-ended response)

3.2. What opportunities do you see in the use of AI to enhance the teaching of indigenous knowledge within science curricula? (Open-ended response)

3.3. How important is it to address the challenges associated with integrating AI and indigenous knowledge in science education? (1 - Not important at all, 5 - Extremely important)

3.4. How likely are you to support initiatives that aim to integrate AI and indigenous knowledge in science education? (1 - Not likely at all, 5 - Extremely likely)

Section E: Educators' Perceptions and Attitudes Towards AI

4.1. What, if any, AI tools or platforms are you currently using in your teaching?

4.2. How do you perceive the use of AI in bridging the gap between indigenous knowledge systems and formal science education? (Open-ended response)

4.3. What are your thoughts on incorporating AI technologies and indigenous knowledge in teaching science?

4.4. On a scale of 1 to 5, how comfortable are you with the use of AI in your teaching practices? (1 - Not comfortable at all, 5 - Extremely comfortable)

4.5. Would you be interested in professional development opportunities that focus on the use of AI in education? (Yes/No)

Thank you for your participation

APPENDIX D

Focus Group Discussion Guide

Focus Group Discussion Guide for Students

Good morning/afternoon, everyone. Thank you all for taking the time to participate in this focus group discussion. My name is Miss Nokulunga Sanelisiwe Dladla, and I am a researcher conducting a study at Bindura University on Integrating indigenous knowledge systems with science education and AI.

The purpose of this focus group is to gather your insights and perspectives on how we can better integrate indigenous knowledge and practices into formal science education and the development of AI systems. Your feedback will be invaluable in helping us understand your knowledge, the challenges, opportunities, and best practices in this important area of research.

This is an informal discussion, so please feel free to share your thoughts and opinions openly. As learners, your experiences and understanding of indigenous knowledge, Ai and science education will be crucial in shaping the direction of this study.

Ground Rules:

Before we begin, let's go over a few ground rules to ensure our discussion is productive and respectful:

1. Confidentiality: Everything discussed in this room will remain confidential. Please do not share any information outside of this group.

2. Respect for Indigenous Knowledge: We acknowledge the importance and validity of indigenous knowledge systems. Please be respectful when discussing and sharing your perspectives on this topic.

3. Open and Honest Communication: We encourage open and honest dialogue. Feel free to express your views, even if they differ from others.

4. Respect: Be respectful of each other's opinions and perspectives. Listen actively and avoid interrupting.

5. Participation: We want to hear from everyone, so please do not dominate the conversation. I may call on you if you've been quiet to get your input.

6. Timing: We have a limited amount of time, so I may need to move the discussion along at times to cover all the topics.

7. Electronics: Please silence your phones and avoid using laptops or tablets during the discussion, as they can be distracting.

Does everyone understand and agree to these ground rules? Great, let's get started.

1. What is your understanding concerning indigenous knowledge?

2. How do you feel about learning science through incorporating indigenous knowledge in science topics?

3. Are there any countries you know where they use indigenous knowledge and Ai in teaching science? If so, give examples on how they do it?

4. Suggest which topics best can incorporate indigenous knowledge to make your learning easy.

5. Which aspects of your culture or local knowledge do you think should be included in your science education?

6. What is your understanding concerning Ai?

7. Which Ai tools are you familiar with or have you used before to assist you in learning?

8. What are some advantages and challenges of using the Ai tools in learning?

9. Do you use Ai tools in school to assist you in your learning or during lessons?

10. What are your suggestions for making science education more fun, practical and engaging with the help of Ai and indigenous knowledge?

Thank you for your time and participation

APPENDIX E

Sample Data Audit Trial / Code Book

Page	Line		Comment scope	Comment text	Author	Date
1	32		most indigenous knowledge is undocumented so AI will have a problem getting reference on most information	Recognition and Validation	Nono	11-Aug-2024
1	2		Cybercrime	Data Privacy and Security	Nono	11-Aug-2024
1	32		Lack of infrastructure	Digital Divide	Nono	11-Aug-2024
1	32		Funding of the equipment needed for learners and teachers	Sustainability	Nono	11-Aug-2024
1	4		People don't understand AI and its importance...so that would hinder its integration	Technological Literacy	Nono	11-Aug-2024
1	32		Lack of proper sources of information and knowledge, misrepresentation of facts and misconceptions, inconsistencies in knowledge and information, highlighting the bad side of the indigenous knowledge and information	Cultural Sensitivity and Appropriation	Nono	11-Aug-2024
1	5		Lack of infrastructure	Digital Divide	Nono	11-Aug-2024
1	5		proper training of officers	Capacity	Nono	11-

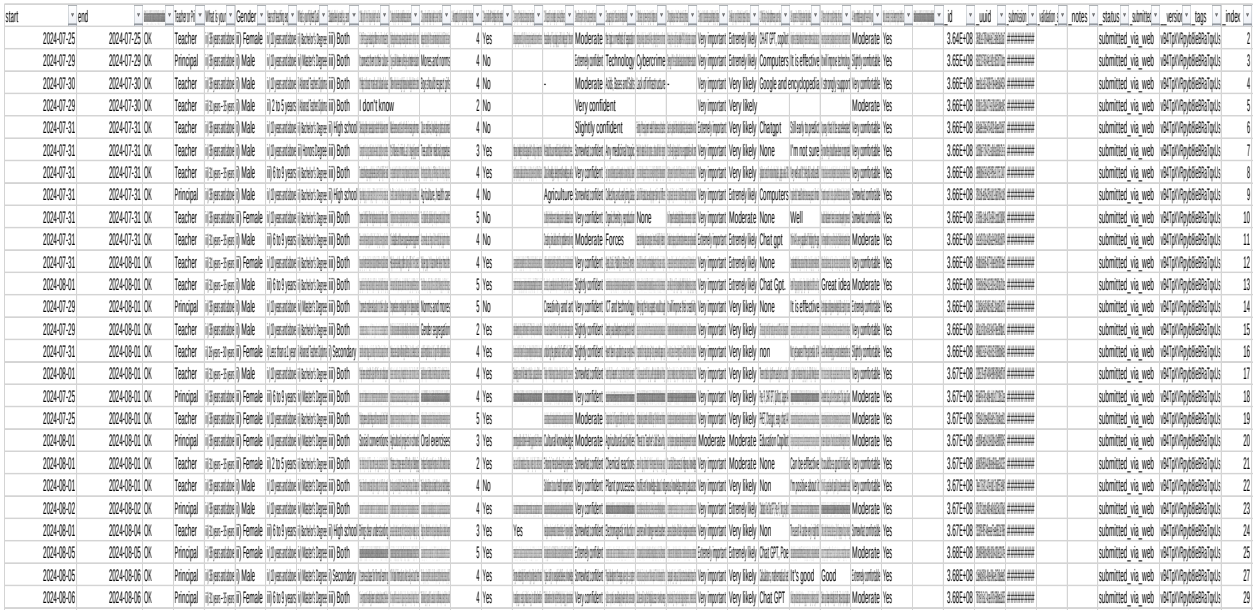
Page	Line		Comment scope	Comment text	Author	Date
				Building		Aug-2024
1	6		Access to technology such as computers, internet. Availability of electricity	Digital Divide	Nono	11-Aug-2024
1	32		Limited availability of documented indigenous mathematical knowledge and potential inaccuracies in existing data.	Recognition and Validation	Nono	11-Aug-2024
1	7		Most Modern items and things dont have indigenous names and specific names. Ai developers do not have our indigenous knowledge hence making it difficult for our learners to probe using their indigenous knowledge to find solutions. for an example an eye is just an eye we do not have names for the parts of the eye but with AI you may probe the get the formal name hence the need to adopt and incorporate AI	Recognition and Validation	Nono	11-Aug-2024
1	13		On another the accuracies and lack of documentation makes such knowledge too mythological and hence easily doubted and can be easily discredited	Recognition and Validation	Nono	11-Aug-2024
1	16		The lack of proper resources and text needed for integrating., as well the the gadgets and reliable networks within the regoin	Digital Divide	Nono	11-Aug-2024
1	32		: Indigenous knowledge is often embedded within complex cultural, spiritual, and linguistic frameworks. Translating and digitizing this knowledge for AI systems risks stripping away	Cultural Sensitivity and Appropriation	Nono	11-Aug-2024

Page	Line		Comment scope	Comment text	Author	Date
			important contextual nuances			
1	32		: There may be concerns about the ownership, control, and commercialization of indigenous knowledge when it is documented and used in AI applications, requiring careful negotiations with local communities	Policy and Regulation	Nono	11-Aug-2024
1	32		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	Digital Divide	Nono	11-Aug-2024
1	32		Building sustained trust and partnerships between indigenous knowledge holders, educators, and AI developers will be crucial, but may be hindered by historical power imbalances and misunderstandings.	Interdisciplinary Collaboration	Nono	11-Aug-2024
1	18		most of indigenous knowledge is undocumented hence it would be difficult to integrate AI fully there will be no reference for the information	Recognition and Validation	Nono	11-Aug-2024
1	21		AI technologies and the necessary infrastructure may be limited in some indigenous communities. L	Digital Divide	Nono	11-Aug-2024
1	22		Few educators may have the necessary expertise to effectively integrate AI and indigenous knowledge into science curricula	Technological Literacy	Nono	11-Aug-2024
2	6		It is important to approach indigenous knowledge with respect and cultural sensitivity,	Cultural Sensitivity and	Nono	11-Aug-2024

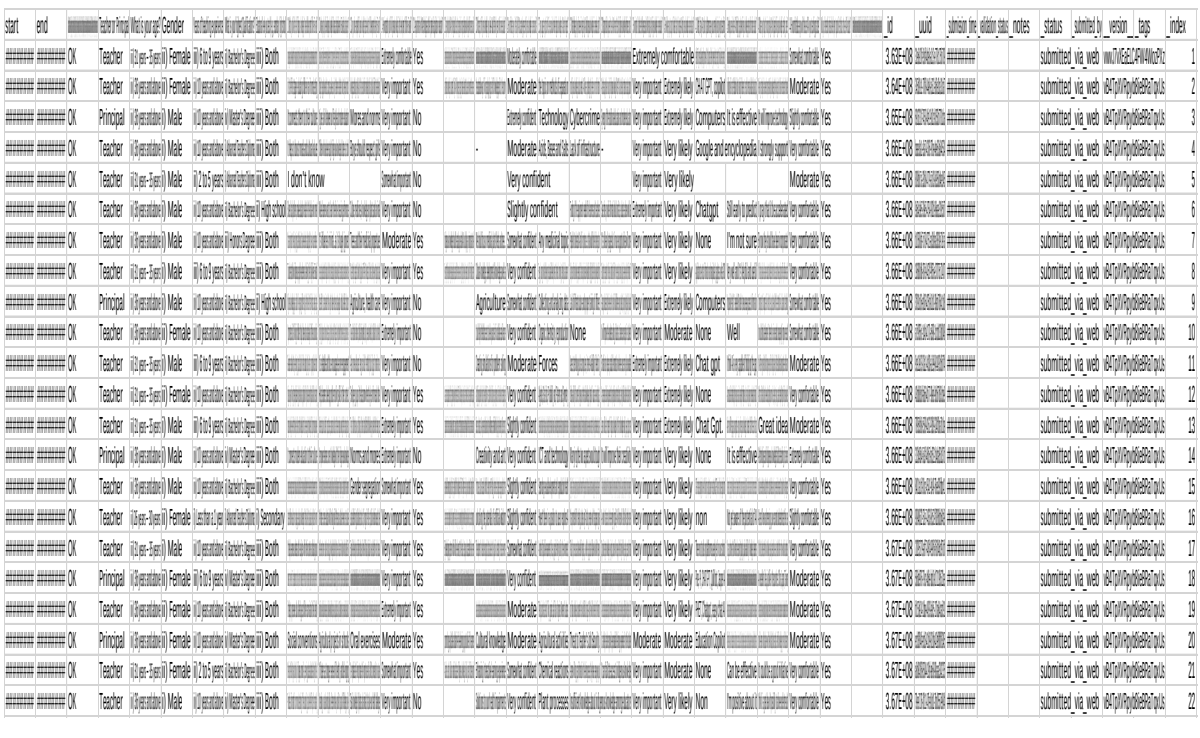
Page	Line		Comment scope	Comment text	Author	Date
			and to ensure that indigenous communities are consulted and involved in the development of educational materials that incorporate their knowledge	Appropriation		
2	6		Access to AI technologies and the necessary infrastructure may be limited in some areas of Eswatini, making it difficult to incorporate these technologies into the educational system.	Digital Divide	Nono	11-Aug-2024
2	6		Cultural sensitivity	Cultural Sensitivity and Appropriation	Nono	11-Aug-2024
2	6		technological access or network coverage	Digital Divide	Nono	11-Aug-2024

online questionaaire.pdf

Focus Group Responses from the selected schools



SAMPLE DATA IN EXCEL SPREAD SHEET



Mafucula high school (A)

1. Indigenous Knowledge is local knowledge that is not learned at school through formal setting, it is passed from one generation to the next. In most cases it comes from the communities' traditional practices and beliefs

2. Happy, because it would be easy to understand scientific concepts and make learning easy

3. Yes, Japan, China, America

China: Chinese medicine, based on traditional Chinese knowledge, has been incorporated into medical education. Artificial intelligence is being used to study medicinal herbs and their potential applications in healthcare.

Japan: The Japanese have incorporated traditional farming techniques such as rice cultivation, which requires a deep understanding of the environment, into their agricultural science education. AI is used to optimize crop yields and water usage.

4. Topics which can best incorporate IKS are:

Agriculture:
-crop rotation
- irrigation systems
Consumer science:
-Nutritional value of traditional diets
Geography
-Weather patterns
Science:
-Energy
-Reproduction system
-Digestive system
5. Aspects of swazi culture or local knowledge which can best incorporate IKS are:
-Medicine (eg using plants) for example when you have a tummy ache you can use ash and water, then drink. That aspect of local knowledge can be included in science education
-Food preservation methods
6. AI are machines or technologies which act as human like and makes life easy for human beings.
7. No idea
8. Advantages of using Ai tools in learning are:
-Make work easy
-Reliable
-Convenient

-Offers 24/ 7 assistance

Challenges of using Ai tools in learning

-Expensive as they require electrical gadgets in order to be used and requires Wi-Fi or data

-May lead to over reliance as learners may end up not wanting to think

-They can be bias

9. No, we do not use Ai tools in schools to assist us in learning

10. Suggestions:

-Children should be taught on how to use Ai tools so that they are able to use it for their benefits.

-There should be continuous training for teachers on how to use Ai tools in teaching science and how to use technological tools effectively during the process of teaching and learning

(ii) School for the Deaf (B)

1. Indigenous Knowledge refers to the body of knowledge, skills, and practices that have been passed down from generation to generation within a particular community or culture. It is the wisdom and experience that has been shaped by the community's history, culture, and interaction with the natural environment.

2. Mixed feelings, but it can make understanding easy on Students though there may be a clash between the historical and model ways of learning science.

3. Yes, Japan, America, China, Taiwan

Japan: Students might learn traditional farming techniques such as rice cultivation, which requires an understanding of water management and pest control. AI could be used to help optimize crop yields and water usage.

United States: Students might study how Native American communities used plants for medicinal purposes. AI could be used to analyze the chemical makeup of these plants and their potential health benefits.

China: Students might study traditional Chinese medicine, which includes acupuncture and herbal remedies. AI could be used to understand the effects of these remedies and their potential applications in modern medicine.

4. Topics which can best incorporate IKS to make learning easy are:

Agriculture:

-Crop cultivation

-Conservation

-Animal husbandry

Geography

-Weather patterns

-Landmarks

Consumer:

-Food preservation methods

-Food processing

-Home management

5. Aspects of culture that we think should be included in science education are:

- **Medicine**: how to use plants to make medicine.
- **Food preservation methods** especially on traditional food and amarula brew
- **How to cremate dead bodies**

6. Ai refers to technological or computer systems that perform specific tasks to make life for human beings easy.

7. Ai tools: Chart GPT, Poe

8. Advantages of using Ai tools in learning are:

- convenient and fast
- you get personalised assistance that suits your needs
- you get help at any time and you learn at your own pace

Challenges of using AI tools:

- Requires knowledge and skills on how to operate it
- Expensive: you need to have a phone, WiFi or data in order to be able to use it.

9. Only teachers use it but not students as they use smart boards in teaching and learning. Since learners have disabilities technology is mostly used to teach learners.

10. Suggestions

- learners should be taught how to use these Ai tools and technology to learn science well

- encourage science practicals and interactive learning during teaching and learning process
- provide ongoing inservice for teachers on how to use AI tools effectively in the classroom during the teaching and learning of science and other subjects

(iii) Mpaka High school (c)

1. IKS refers to local knowledge that is passed from generation to another . It involves the cultural practices, history and norms of a community.

2. Feel comfortable, as they can easily relate and understand the topic which is taught . It can also answer some of the questions that they have as they may get to experience and gain more knowledge of science concepts.

3. Yes, Japan, China, India, Russia, Taiwan

Taiwan: students may study traditional knowledge of the indigenous people of Taiwan, such as the use of plants for medicinal and food purposes. Also in Taiwan students may be taught how to use drones in agriculture to detect sicknesses in plants then use Ai to diagnose and find solutions and prescriptions to the diseases.

India: students may be taught about traditional medicine which includes herbs and lifestyle practices for maintaining health. Ai is used to analyse these herbs and their potential health benefits

Russia: students may be taught how to create nuclear weapons and bombs, Ai could be used in assisting how the nuclier weapons works

Japan: students may be taught about how to make security systems and satellites

4. Topics;

Pysics:

- transformers
- thermal phsics
- waves
- levels

Biology:

- Transportation in plants

- Biotechnology
- Species

Agriculture:

- Preparation of soil
- Inseticides
- Crop production and animal farming

Maths:

- Linear programming
- Speed
- Calculating volumes

5. Aspects of Swazi culture or local knowledge which should be included in science education:

- In consumer science: traditional food and preservation methods can be included so that we know what it does to our bodies.
- Medicine: for example, if you have a stomach ache Swazis use ash and water, make a solution and drink, this local knowledge should be included in the science education
- Agriculture: how to use drones in spraying inseticides and detecting sicknesses in plants

6. Ai refers to machines that carries complex tasks and requires a degree of intelligence. It also refers to technological and labour devices that makes life easy. It is a subfield in computer science that focuses on device intelligence computers that can do activities that need human intelligence.

7. Chart Gpt, google assistance, maths papa, mathway, Au app, Pi, Ai essay

8. Advantages of using Ai tools in learning are

- Saves time
- Offers personalised learning
- Convenient and reliable
- Offers 24/7 assistance and does not get tired

Challenges of using Ai tools in learning

- Makes learners lazy as they depent on Ai tools and become lazy to use critical thinking
- Requires skills and knowledge to operate
- Expensive as it requires electronical gadgets and devices to use aswell as wifi or data

9. At school they don't use Ai in learning but students use these ai tools at home when writing assignmenths or mathematics assignments. Most of the learners in this school seem to have more knowledge concerning the Ai tools but teachers have no idea of such.

10. Suggestions:

- In schools, learners should be provided with Ai tools and gadgets so that learning is easy
- Educate teachers and students on how to operate these Ai tools to make learning fun, practical and easy

(iv) Good Sherperd (D)

1. IKS refers to wisdom and experience of a particular community that has been shaped by their history, culture and interactions with the environment. IKS is not learned formally at school but passed from one generation to anpther in most cases through word of mouth.

2. Happy, because it would make things easier to understand. It will balance science. It will be very exciting and more relevant to them

3. Yes , China, Japan, America

China: they use IKS and AI to make greenhouses. They also use Ai robots which are exactly as the images of their gods as per their religion.

America: they use plants to make medicine and pills through the assistance of ai

Japan: they use their indigenous knowledge on foods for their healthy and Ai to analyse the benefits of such foods in their bodies and the effects.

4. Topics:

Biology

- Transplant in animals
- Classification of living organisms found in Swaziland

- Reproduction (asexual)
- Medicine and its effects
- Biodiversity and conservation

Consumer science

- Food processing and preservation

Pysics

- Natural resources
- Energy conversion models

Agriculture

- Crop production
- Soil management

Chemistry

- Natural resourses

Maths

- Geometry

5. Aspects of culture or local knowledge which should be included in science education are:

- Medicine
- Agriculture
- Traditional foods in consumer science

6. Ai refers to technology that enables machines to perform tasks that requires human intelligence, such as problem solving, learning, and decision making.

7.Chart GPT, Pi, Poe, Cymaths, photomaths,

8. Advantages of using Ai tools in learning

- Fast and easy
- Offers additional knowledge
- Offers 24/7 assistance
- Offers accurate information
- Shares confidentiality

Challenges of using AI tools in learning

- Costly as it requires electronical or technological gadgets for it to work, also data and wifi
- Promotes laziness to learners as they depend on the Ai tools hence not using their critical thinking.

9. No, teachers do not use Ai during lessons , but students use it at home not duting lessons. Teachers seem to have no ide of these tools.

10. Suggestions

- More practicals should be done during science lessons
- Montly field trips are encouraged to assist learners to observe and experience
- Teachers should be educated on Ai tools and technology so that they are able to use it effectively during the teaching and learning process.
- Learners should be educated on how to use these Ai tools at their advantage and not sorely rely on the tools

(v) Entandweni High School (E)

1.IKS refers to knowledhe that is natural, that has been passed from one generation to another. It is learnt from home and not taught at school. It is also not written and in most cases is passed through the word of mouth. It encompasses the traditions, history, beliefs, cultural practices of that community.

2. It would make learning interesting since students will be able to easily understand

3. Yes, China, America, Taiwan

China: they create robots that is historically related to them like the statues, they include their language in Ai

Taiwan: they use traditional food and plants to make medicines and prolong their life span

4. Topics

Science

- Force
- Drugs

- Respiration

Agriculture

- Farming systems
- Reproduction in plants and animals

Phsics

- Electricity

Geography

- Landmarks
- Weather patterns
- Plate tectonics

Chemistry

- Electrolysis

Consumer science

- Nutrition
- Meal planning
- Hygiene and home management

5. Aspects of local culture or iks which should be included in the science education is:

- Medical aspect
- Agricultural aspects

6. Ai these are technological tools that make work easier for human beings.

7. Google assistant, Pi, Poe

8. Advantages of using Ai tools in learning:

- Gives quick feedback
- Offers 24/7 assistance
- Convenient and reliable

Challenges of using Ai tools in learning

- Expensive as it requires one to have a cellphone, or laptop and Wifi or data
- Sometimes not user friendly, it requires a skill ir knowledge in operating it
- Sometimes it can be biased
- If the network coverage is weak it won’t work

9. No, teachers don’t use Ai tools during lessons

10. Suggestions

- If teachers can be well trained on how to use the ai and technological gadgets in teaching science
- Introduce more science fares and competitions
- Students should be educated on how to use Ai tools and technological gadgets properly so that they do not become dependent on them and still use their critical thinking in problem solving
- The government should provide materials and resource to schools and ensure that ICT is compulsory in all schools
- Schools should offer more practical to the students

(vi) Lusoti High school (F)

1. IKS refers to general knowledge, local knowledge which includes the communities' cultural practices, beliefs and norms, it is passed through word of mouth mostly by old people. It is passed from one generation to another.

2. Happy because it will make learning easy

3. U.S.A, China, Uk, South Korea, Japan

Japan: Japanese high schools, students learn about traditional Japanese ecological knowledge, such as landscape management practices. Teachers use Ai-powered virtual field trips and simulations to allow students to explore these traditional land use systems. Students also use AI-assisted analysis tools to study local plant and wildlife.

South Korea: they incorporate traditional Korean medicine and herbal knowledge into their science curriculum. Students use Ai chatbots and language models to access indigenous medicinal plants and their properties.

4. topics that can best incorporate iks to make learning easy are:

Agriculture:

- Agro forestry
- Biodiversity
- Sexual and asexual in plants

Consumer science

- Nutrition
- Home management
- Food preservation

Physics

- Metals
- Energy

5.Aspects of culture or local knowledge that needs to be added in science education is:

- Medicine
- Traditional food in consumer science
- Agriculture ai methods like drones in irrigation or spraying inseticides in fields

6. Ai refers to technological devices and tools that make life easy for humans and give additional knowledge.

7. Pi, Chart GPT

8. Advantages of using Ai tools in learning

- Fast and convenient
- Personal teachers which offers personalised learning
- Offers 24/7 assistance
- Does not get tired

Challenges of using Ai tools in learning

- Can give false information, it is not 100% reliable
- It may promote laxiness and overdependence to learners
- It is expensive as it requires electronical gadgets and wifi or data inorder to operate well.
- It requires knowledge or skill on how to operate it properly

9. No, teachers don’t use it in class during the teaching and learning process

10. Suggestions

- The government should invest more and offer resources for all schools to ensure that they have gadgets and Wi-Fi for learning
- An ongoing in-service training for teachers is required in order for teachers to be abreast with Ai tools and model technology
- Learners should also be educated on how to use Ai appropriately

(vii) U- Tech High school (G)

1. IKS: skills and cultural practices that have been passed down from generation to generation in a particular community. It includes knowledge about natural world, agriculture, medicine, and other aspects of life that have been shaped by community history and experiences. It is developed over centuries without use of formal education.

2. Happy, because it will be easy to understand and master concepts

3.Yes, China, Japan, South Africa, Taiwan

Japan: Japanese high schools use AI-powered simulations to teach students about traditional landscape management practices and their sustainable ecological principles.

China: In Chinese high schools, students leverage AI visualization tools to study the flow of qi energy in traditional Chinese medicine, and use machine learning to analyze patterns in traditional diagnosis and treatment.

South Africa: South African high schools incorporate indigenous knowledge about traditional herbal remedies, and employ AI chatbots to help students access databases on the properties and uses of medicinal plants.

4. Topics that can best incorporate IKS to make learning easy are:

Physics

- Electricity

Agriculture:

- Farming systems
- Animal husbandry
- Crop cultivation

Geography

- Weather change patterns

- Landmarks and landscapes

Biology

- Biodiversity

5. Medicinal aspects

6. Ai refers to technological tools that make work easier for human beings.

7. Google assistant, Pi, Poe, Chart GPT, Quilbot, Compose Ai

8. Advantages of using the Ai tools in learning are:

- Offers 24/7 assistant
- Gives quick feedback
- Allows learners to learn at their own pace

Challenges

- Requires one to have the knowledge and skills of operationg the tools
- Expensive as it requires technological gadgets and wifi or data for it to work
- Is not 100% reliable and can be biased

9. No, teachers do not use Ai tools in school or during lessons

10. Suggestions:

- Learners should be educated on how to use Ai tools for learning and not over rely on them
- Teachers should research and go for inservice training and learn about these ai tools and technology in order for them to be able to improve learning
- The government should invest more in technological gadgets in schools and ensure that they have stable wifi inorder for smooth learning processes

(viii) Sphofaneni High school (H)

1. IKS: refers to a local knowledge that is learned in a community, in most cases through word of mouth from old people. It is knowledge that is not acquired formally but orally from members of community.

2. Happy, because it will allow students to relate and understand fast

Also, teachers can be able to create a more culturally sensitive learning experience for students

3. Yes, China, Japan, Singapore, South Korea

They develop simulations.

Australia: incorporated IKS and Ai into science educarion by using virtual and augmented reality technologies to simulate traditional hunting and gathering practices. They also use Ai to analyse traditional ecological knowledge.

4. Topics:

Agriculture

- Plants and animal management
- Soil conservation

Geography

- Landmarks

Consumer Science

- Home management
- Nutrition

5. Agriculture: traditional methods from crop cultivation, animal husbandry

Medicine: use plants and herbs

6. Ai refers to computer systems that perform specific tasks or even better than humans. Makes human life easy

7. Siri, Google assistant, chart GPT

8. Advantages of using Ai tools in learning

- Does any task fast
- Allows students to learn at their own pace
- Offers 24/7 assistance and support
- Can automate tasks such as grading and giving feedback

Challenges of using Ai tools in learning

- Not all students may have equal acess to Ai tools
- Expensive since Ai tools requires technological gadgets , wifi or data to work
- Can be bias and may lead to not reliable results
- Learners may end up being dependant on the Ai tools
- It requires skills inorder to use

9. No, teachers do not use Ai tools during the teaching and learning process

10. Suggestions

- Use songs to teach science to make it easy to remember
- Teachers should be trained on how to use Ai tools effectively in the classroom

- Provide students with resources and training on responsible Ai use such as avoiding plagiarism and maintaining a healthy balance of Ai use.

(ix) Duze High School (I)

1. IKS refers to knowledge, practice
2. s and beliefs of communities which have been passed down from one generation to another. It includes experiences, traditions and knowledge of that particular community

2. Happy because it will be easy for students to understand. It will also increase engagement on the students as the topics will be relevant to students' cultural backgrounds

3. Yes, South Africa, Canada, China

South Africa; Sout Africa schools have incorporated IKS into science education by using Ai to analyse traditional medicinal plants and to developnew medicines based on these plants

Canada: schools have incorporated IKS into science by using AI to analyse migration patterns of animals to support sustainable wildlife management practices

China: use virtual teaching assistants, intelligent tutoring systems to teach science to students

4. Topics:

Consumer Science:

- Home management

Agriculture

- Crop production
- Soil cultivation and conservation

Biology

- Relationship between plants, animals and human beings

5. Traditional medicines eg bitter Aloe and rooibos, these medicinal plants have healing properties and incorporating Ai ino science education could provide students with indepth understanding of health and wellness.

Agriculture: could provide students with deeper understanding of food systems and sustainability

6. Ai refers to computer systems that perform specific tasks to make life easier and better eg language translation, image classification, facial recognition etc.

7. Google assistant, wolfram Alpha, chart Gpt

8 Advantages of using Ai tools in learning are

- Can provide personalised feedback and support
- Improves efficiency
- Offers 24/7 assistance without getting tired
- Convenient

Challenges of using Ai tools in learning are:

- Requires one to have skills on how to use it
- Not all students have equal access to Ai tools
- Students may become overly dependent on Ai tools hence decreasing the level of critical thinking and problem-solving skills
- It requires technological gadgets in order to work and wifi or data, hence it can be expensive for learners

9. No, teachers do not use Ai tools during lessons however some students use the Ai tools at home by themselves

10. Suggestions:

- Incorporate Ai tools into science lessons e.g. by using Ai powered platforms such as virtual labs, chatbots to support students learning
- Create interactive experiences: use VR and AR technologies to allow students to explore science hands-on
- Use storytelling and songs to engage students in science topics to help them to easily understand and make learning easy.
- Provide in-service training for teachers on how to use Ai effectively in class and how to monitor students use of Ai
- Educate learners on how to best use Ai tools in learning science

(x) Siteki Nazarene (J)

1. Indigenous knowledge refers to the traditional knowledge, practices, and beliefs of indigenous peoples around the world. It is often based on generations of experience living in close connection with the natural environment. Indigenous knowledge encompasses a deep understanding of ecosystems, biodiversity, and sustainable resource management practices.

2. Incorporating indigenous knowledge into science education can be highly beneficial. By learning science through the lens of indigenous perspectives, students can gain a more understanding of scientific concepts. Indigenous knowledge often emphasizes the interconnectedness of all things, which aligns well with modern scientific understandings of complex systems. Blending indigenous and western scientific approaches can lead to more inclusive, relevant, and culturally-responsive science education.

3. There are a few countries that have made efforts to incorporate indigenous knowledge and AI into science education:
New Zealand – Their curriculum integrates Māori knowledge and practices with Western science. AI tools are used to help preserve and share traditional ecological knowledge.
Canada - Several provinces, including British Columbia and the Northwest Territories, have made efforts to include First Nations, Inuit, and Métis knowledge in science curricula. AI is used to support language preservation and traditional knowledge documentation.
Australia – the peoples' knowledge is increasingly being incorporated into science subjects. AI is used to assist with monitoring environmental changes and preserving cultural heritage.

4. Some topics in the Eswatini JC and EGCSE science syllabi that could benefit from incorporating indigenous knowledge include:

- Agriculture - Traditional farming practices, crop rotation, soil management
- Biology - Traditional medicine, wildlife management
- Geography - Traditional land use, natural resource management, climate change adaptation
- Physics - Traditional building materials and techniques, renewable energy
- Consumer Science - Traditional crafts, textile production, food preservation

5. Aspects of Swazi culture and local knowledge that could be integrated into Swazi science education include:

- Traditional medicinal plants and their uses
- Sustainable land management practices, such as rotational grazing
- Indigenous weather forecasting and natural disaster preparedness
- Traditional food production, preservation, and preparation methods
- Indigenous architectural designs and construction techniques

6. AI, or Artificial Intelligence, refers to the development of computer systems capable of performing tasks that typically require human intelligence, such as learning, problem-solving, decision-making, and language understanding.

7. Some AI tools that have been used in education include:

- Chart GPT, Google assistant, Pi

8. Advantages of using AI in learning include:

- Personalized and adaptive learning experiences
- Automated grading and feedback for students
- Efficient data analysis and insights for educators
- Expanded access to educational resources and content

Challenges include:

- Ethical concerns around data privacy and bias in AI systems
- The need for significant investment in infrastructure and teacher training
- Potential for AI to replace human teachers rather than support them
- Ensuring AI tools are culturally-responsive and inclusive

9. No, teachers do not use Ai tools during lessons

10. To make science education more fun, practical, and engaging with the help of AI and indigenous knowledge, suggestions are:

- Developing interactive simulations and virtual labs that incorporate indigenous perspectives
- Using natural language processing to create AI-powered virtual tutors that can explain scientific concepts in culturally-relevant ways
- Leveraging computer vision and machine learning to create apps that allow students to identify local plants, animals, and natural phenomena
- Incorporating augmented reality to bring indigenous knowledge and traditional practices into the classroom
- Collaborating with indigenous communities to co-create curriculum and learning materials that blend traditional and scientific ways of knowing