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Bridging Worlds: Integrating Indigenous Knowledge Systems with Science Education. A Case of the Lubombo Region Schools

[1]Dladla Nokulunga, [2]Makuvire Claretah, Chikuvadze Pinias
[1-3]Bindura University of Science Education, Zimbabwe
[2]https://orcid.org/ 0009-0008-5527-7898)
[3]https://orcid.org/0000-0002-8569-0009)
Email: sanelisiwenokulungadladla@gmail.com, makuvirec@gmail.com, chikuvadzepenias@gmail.com

ABSTRACT
The integration of indigenous knowledge systems with science education constitutes the central focus of this research. Indigenous knowledge is deeply rooted in the wisdom and practices of local communities and offers valuable insights into the natural world. By incorporating indigenous perspectives, we can enrich science education and foster a holistic understanding of scientific phenomena. This study explores the intersection of indigenous knowledge systems and science education within the context of Eswatini. The study objectives include: examining indigenous knowledge's influence on child development and academic achievement, identifying integration challenges and opportunities, assessing educators' perceptions and recommending sustainable implementation strategies. The study employed an exploratory case study design. Data was collected from ten schools in Libombo region using questionnaires, focus group discussions, observations and document analysis targeting principals, teachers, and students. Thematic analysis and descriptive statistics were used to analyse the data. Findings show indigenous knowledge positively influences child development and academic achievement promoting holistic learning cultural identity and engagement. Challenges include lack of documentation of indigenous knowledge systems and cultural sensitivity while opportunities include authentic integration of cultural heritage. Recommendations include enhancing digital infrastructure providing educator professional development and developing educational content incorporating local language and culture in science education. The study concludes that the integration of culture and science creates an educational system which honours cultural heritage while preparing students for future challenges. Ongoing teacher professional development is highly encouraged.
Keywords: *Indigenous knowledge system, science education, integration, child development*

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INTRODUCTION

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

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. 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 educational practices in Eswatini.

Statement of the problem

The current challenge lies in the limited integration of indigenous knowledge systems with science education in Eswatini. Existing curricula inadequately recognize or incorporate indigenous knowledge, leading to a lack of cultural relevance and inclusivity within science classrooms. This research endeavors to bridge these gaps and explore the potential of AI-supported Indigenous Knowledge integration in science education.

Research objectives

1. Explore how indigenous knowledge influence child development and academic achievement in the context of Eswatini.
2. Identify the challenges and opportunities associated with integrating indigenous knowledge in science education.
3. Recommend informed strategies to ensure the sustainable integration of IK into science curricula.

Review of related literature

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

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).

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.

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).

METHODOLOGY

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

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

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

RESULTS AND DISCUSSION

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

The influence of IK 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-structured 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.

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.

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.

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 articulated 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 echoed 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.

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.

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.

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.

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.

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.

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.

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.

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.

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.

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 *1* 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.

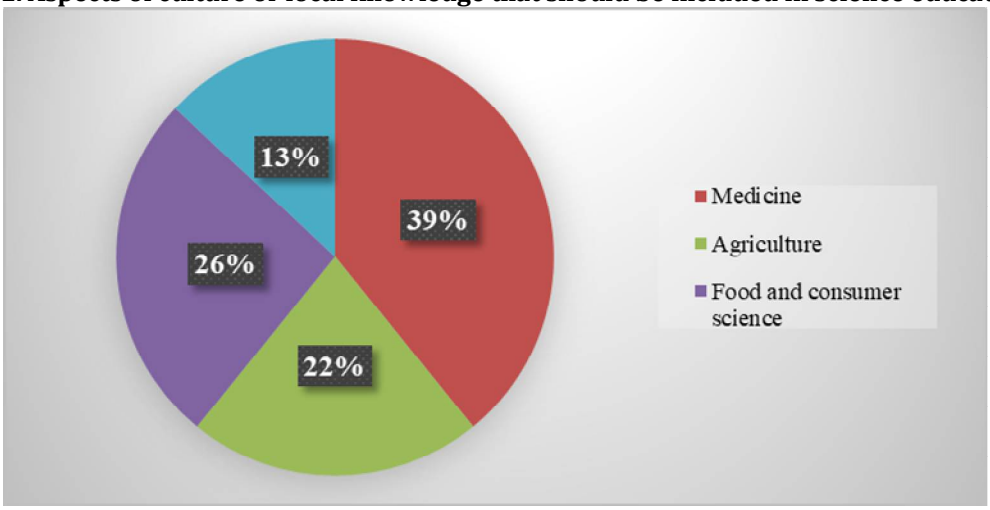
Integration of Eswatini cultural or local knowledge in science education

To address our objective 4 of this study, which seeks to develop strategies for sustainable integration of IKS into science curricula 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:

Subject area	Topics	Frequency
1. Agriculture	2. Crop production 3. Animal husbandry 4. Soil management 5. Other	48% 26% 21% 5%
2. Biology	1. Biodiversity 2. Medicine 3. Reproduction	43% 39% 18%
4. Consumer Science	1. Home management 2. Food preservation 3. Nutrition	38% 31% 31%
4. Geography	1. Weather patterns 2. Land marks Other	50% 30% 20%

Another question was asked the learners 'which aspects of your culture or local knowledge do you think should be included 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:

Fig 1. 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.

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 and learning of science subjects. Document analysis also provided a clear understanding of the current curriculum to compare with the actual teaching practices observed in the classroom. 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 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. 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.

Observation Findings

Observations were also done in order to check if the educators made use 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. The lessons relied on traditional teaching aids such as textbooks, chalkboards, and occasional multimedia presentations. 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 IKS is not being utilized in the science lessons observed across all the schools. The absence of IKS in science teaching has implications for student engagement and learning outcomes. Students miss out on the opportunity to connect scientific concepts with their cultural. In school F, students showed limited engagement during a physics lesson that could have been made more interactive and relatable with references to traditional engineering practices.
The findings from the observations indicate a significant gap in the integration of Indigenous Knowledge Systems 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.

RECOMMENDATIONS

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

1. **Policymakers and Ministry of Education** are advised to invest in research exploring the intersection 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 indigenous knowledge and science education. Creating a national database of indigenous knowledge and funding pilot projects that IKS in science classrooms would be beneficial.
2. **For School Administrators and Parents** are encouraged to 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.
3. **For Teachers and Teacher Development Institutions: UNESWA, William Pitcher**- Provide professional development for educators on effectively 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.

The institutions must also 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.

4. **For Science Subjects Curriculum Developers-** Seek ways to incorporate IKS 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 in science education first hand. They can establish partnerships with curriculum development bodies in these countries for knowledge exchange. Regular international conferences can be organized in Eswatini to discuss best practices and challenges in integrating IKS in the science curriculum. A task force can be formed to adapt successful strategies from other countries to the Eswatini context.

Implement a curriculum that explicitly integrates scientific principles, and IKS, ensuring an improved educational approach. Developers can create a comprehensive framework that outlines how 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.

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