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Towards an Anti-Colonial Turn in Science and Mathematics Education: Centering Indigenous Ghanaian Knowledge

Kenneth Gyamerah

Introduction

In the past three decades, Ghana's educational system has faced significant challenges in addressing the learning crisis in mathematics and science (Fletcher, 2018; Mereku, 2013). Within this period, national data on student success and international assessment benchmarks, such as the *Trends in International Mathematics and Science Study* (TIMSS), reported poor academic performance of Ghanaian students in these core subjects (Mensah & Baidoo-Anu, 2022). Research has shown that the learning crisis began in 2003 when Ghanaian eighth-grade students ranked 44th among 45 participating countries in TIMSS (Fletcher, 2018; Mensah & Baidoo-Anu, 2022). It is worth highlighting that Ghana's mathematics and science problems did not improve in subsequent years. For instance, in 2007, Ghana's eighth graders were ranked 47th out of 48 participating countries in TIMSS, once again scoring low in both mathematics and science (Gonzalez et al., 2009). This downward trend continued until 2011 when Ghana occupied the lowest position in mathematics.

Similarly, in the most recent *National Standards Examination* for primary school students, barely 50% of sixth grade pupils in Ghana achieved the foundational proficiency level in mathematics and science, with just 10.9% reaching the maximum level (Ministry of Education Ghana, 2022). Also, for both third and sixth grades, approximately 40% of students failed to meet the minimum competency level in these subjects (Ministry of Education Ghana, 2022). While acknowledging that these types of assessments may be problematic in the ways they evaluate learning, they can, to some extent, provide an important national and international baseline to understand the academic performance of students. These learning opportunity gaps in mathematics and science education in Ghana, especially in primary and high school levels, demonstrate the pressing need for transformational approaches to mathematics and science education in Ghanaian schools.

Although in recent times, there have been significant policy interventions, such as the introduction of universally free education from primary to high school (Asante, 2024; Chanimbe & Dankwah, 2021), the Capitation Grant (including free meals for schoolchildren in low-income communities in Ghana), substantial investments in Science, Technology, Engineering, and Mathematics (STEM), and the expansion of educational infrastructure in Ghana, the anticipated improvement in student learning outcomes in mathematics and science remain unrealized. Mathematics and science are very crucial for the transformative development of every country, as they are often considered the bedrock of learning (Armah, 2021) and key determinants of upward mobility.

Yet in Ghana, student interest in these subjects has declined significantly. These concerns raise questions about the effectiveness of the current educational policies and curricula and the extent to which they align with the lived experiences and cultural contexts of learners. Extant scholarly work within the Ghanaian context has argued that the persistent poor performance in mathematics and science, despite increased investment in STEM education, could potentially be

attributed to the theoretical and didactic nature of teaching and learning in mathematics and science within Ghanaian schools (Mereku, 2013; Owusu & Obuo Addo, 2023). Some scholars have also argued that this potential learning crisis in mathematics and science might be linked to the Eurocentric nature of education in Ghana and the neglect of Indigenous Ghanaian knowledge (IGK) in formal schooling, which has contributed to students' lack of engagement with curricula content (Gyamerah, 2024). Despite research confirming the presence of mathematical and scientific concepts embedded in IGK and cultural practices (Okyere, 2022; Owusu & Obuo-Addo, 2023), policymakers and teachers in Ghana have yet to integrate these into their teaching, particularly in mathematics and science (Mereku & Mereku, 2013).

In Ghana, policymakers often frame student achievement from a deficit perspective, perceiving them as the problem (Baidoo-Anu et al., 2023) without recognizing the challenges posed by the colonial modes of assessment, teaching, and learning that portray them as underachievers (Baidoo-Anu & De Luca, 2023). Given that formal education plays a crucial role in preparing individuals for society, there are concerns that Ghana's socio-economic developmental challenges may partly stem from the formal education system, the pedagogies employed by teachers, and the forms of knowledge they promote (Adjei & Dei, 2008; Adzhalie-Mensah, 2013). Consequently, mathematics and science teaching and learning in Ghana have failed to utilize homegrown knowledge and pedagogical practices grounded in students' Indigenous ways of knowing. This study thus argues that Ghana is missing an opportunity to benefit from the youthful and vibrant population and contribute to emerging technologies such as Artificial Intelligence (AI), scientific innovation, and the global knowledge economy if they continue to undermine the transformative potential of Indigenous Ghanaian mathematical and scientific knowledge systems which have been present among different cultural groups in Ghana since time immemorial. While previous studies have explored the role of African Indigenous Knowledge Systems (AIKS) in science education, we know little about Ghanaian primary school teachers' current understanding, knowledge, and general perspectives regarding the integration of IGK in mathematics and science learning.

This paper seeks to address this gap by examining Ghanaian teachers' knowledge and understanding of IGK and their perspectives and approaches towards IGK integration in these two subjects. Exploring how teachers conceptualize and integrate Indigenous Ghanaian knowledge into their teaching practices can lay the groundwork to develop a culturally relevant education system that aligns with Ghana's diverse socio-cultural, economic, and political landscape. Given the declining interest of students in mathematics and science in Ghana, integrating Indigenous Ghanaian knowledge presents a promising avenue for learning transformation. The paper begins by outlining the research questions and a review of the literature. It then situates the study within its methodological framework, followed by an analysis and presentation of the findings. The paper concludes by discussing the implications of these findings for both policy and practice.

Research Questions

This study was guided by the following interrelated questions:

1. What is the current knowledge and understanding of Ghanaian primary school teachers regarding Indigenous Ghanaian knowledge?

2. To what extent do Ghanaian primary school teachers perceive the relevance of Indigenous Ghanaian knowledge and its integration into mathematics and science?
3. What barriers and challenges do Ghanaian primary school teachers face regarding the integration of Indigenous Ghanaian knowledge into their mathematics and science teaching?

Literature Review

African Indigenous Knowledge Integration into Mathematics and Science Learning.

African Indigenous Knowledge Systems (AIKS) encompass holistic, dynamic, and resilient ways of knowing that have evolved through centuries of interaction with nature and human life (Dei, 2012). Despite their marginalization by colonially dominated curricula policies, AIKS remain adaptive and relevant in addressing societal challenges (Acharibasam, 2021). Defined broadly, AIKS reflect how local communities understand, interact with, and manage their environments. This includes philosophies, ecological knowledge, spiritual practices, and linguistic traditions, forming a culturally grounded framework for sustainable development (Wane, 2014). AIKS integration in education is integral as it challenges linear notions of knowledge production. AIKS provide holistic, community-centred approaches aligned with cognitive justice and human rights (Odora Hoppers, 2021; Tikly, 2023).

Globally, there is growing recognition of Indigenous knowledge in addressing biodiversity, conservation, poverty alleviation, and educational inequities (Singh & Major, 2017). In Sub-Saharan Africa (SSA), integrating AIKS into curricula has the potential to address socio-cultural diversity and foster inclusivity in teaching (Mehta et al., 2023; Mpofu, 2016). Pedagogically, research has shown that aligning curricula with local contexts increases student engagement, reduces alienation, and improves educational outcomes (Le Grange, 2011; Shizha, 2015). In mathematics and science education, AIKS provide a foundation for place-based learning and links students to local ecological and cultural contexts (Handayani et al., 2018). Recent studies have indicated the relevance of Indigenous ecological knowledge in addressing global sustainability challenges (Bol & Niekerk, 2024; Ogunniyi & Iwuanyanwu, 2024). Despite its relevance in transforming teaching and learning in mathematics and science, the integration of AIKS faces significant challenges in Africa. Western-dominated curricula in African countries often marginalize Indigenous knowledge systems which makes it difficult for students to move between their Indigenous knowledge and the content they are exposed to in the classroom. Scholars argue that AIKS can bridge these gaps by providing culturally relevant, contextually grounded educational experiences (Gorecki & Doyle-Jones, 2021).

Moreover, AIKS provides important insights for rethinking mathematics and science education. For instance, African Indigenous mathematical concepts such as patterns and symmetry in traditional crafts such as adinkra symbols provide engaging contexts for teaching geometry and algebra (Okyere, 2022). Similarly, integrating African Indigenous ecological practices into science curricula promotes sustainability literacy, enhancing cognitive skills, and fostering a sense of identity and belonging (Kim et al., 2017). Research suggests various strategies for AIKS integration in science classrooms, including embedding Indigenous knowledge into existing lessons, merging them with Western frameworks, or treating both as equally valuable systems of understanding (Naidoo & Vithal, 2014). Moreso, in Africa, extant research has emphasized the

significance of integrating AIKS into education due to their potential to promote culturally responsive and inclusive learning environments (Radebe, 2019; Seehawer, 2018). While existing literature has focused on the indigenization of education at the level of curriculum content (Shizha, 2015), relatively few studies have examined other critical aspects such as pedagogical approaches, curriculum processes, and subject-specific teaching methods, especially at the primary school level. In addition, while extensive global scholarship underscores the value of Indigenous knowledge in promoting culturally responsive education (Battiste & Henderson, 2021; Garcia & Shirley, 2012; Kimmerer, 2012), studies within the Ghanaian context have largely overlooked the practical implications of AIKS for primary school teaching. Also, a few empirical studies have investigated how AIKS and African Indigenous Pedagogies (AIP) can serve as tools for transforming classroom practices in mathematics and science given the increasing emphasis on decolonization as part of the broader educational reform agenda. As societies experience rapid socio-political and technological shifts, the responsibility of educators to design and implement curricula that integrate both Indigenous and Western knowledge systems becomes increasingly complex (Garcia & Shirley, 2012). Despite this, schools often fail to utilize Indigenous ways of knowing and pedagogies as foundational elements in teaching, limiting students' engagement with their cultural heritage and its application to contemporary challenges (Gyamerah, 2024). Although research on teacher attitudes and perspectives on Indigenous pedagogies exists in the literature (Mhakure & Otulaja, 2017; Shizha, 2015). In Ghana, we know little about teachers' knowledge and understanding of Indigenous Ghanaian knowledge and their potential role in improving mathematics and science learning. This study sought to address this gap by investigating how primary school teachers in Ghana comprehend and utilize their distinct Indigenous knowledge systems in teaching mathematics and science.

Methodology

This study utilized Indigenous research methodology. Owusu-Ansah and Mji (2013) highlight the importance of African researchers developing and employing Indigenous research methods when conducting studies within the continent. While these scholars do not dismiss conventional methods of inquiry, they emphasize culturally responsive and contextually appropriate approaches that focus on transformation, empowerment, and healing within Indigenous communities (Chilisa, 2020). Similarly, Kovach (2020) argues that research rooted in Indigenous epistemology must adhere to Indigenous research methods, ethical standards, and relationality. Indigenous methodologies reflect polycentric worldviews, multiple perspectives, and a community-oriented focus in research (Wilson, 2020). This study involved n=20 primary school teachers (grades 1-6) in Ashanti and Northern Ghana. The sample included teachers from different public primary schools in these two regions. Purposive sampling was employed to select teachers who are specifically working in primary schools within the two regions. Ethical clearance for this study was granted by Queen's University's General Research Ethics Board. The audio recordings from the three data sources were transcribed verbatim.

Data Collection

Data for this study was from a larger study that explored the role of Indigenous Ghanaian knowledge in decolonizing and transforming STEM learning. Data collection occurred in three phases. In phase 1, I conducted four (4) sharing circle conversations with teachers in the two

regions. Sharing circle is an Indigenous ceremonial data-gathering method (Lavallee, 2009). This method was ideal for co-generating knowledge with the teachers. Each sharing circle session lasted approximately four (4) hours and comprised five teachers in each session. Teachers sat in a circle and took turns sharing their knowledge and experiences related to AIKS, their integration into curricula, the barriers and challenges they face in applying AIKS in teaching mathematics and science, and the factors influencing their pedagogical decisions. All sessions were audio-recorded and notes were taken to ensure detailed documentation of the discussions.

During phase 2, I employed a conversational inquiry (Kovach, 2020) to gather data from the teachers. Conversational inquiry is built on the knowledge shared by the teachers in Phase 1. The conversational inquiry served as a follow-up to unpack and further explore the teachers' knowledge and understanding of IGK and how they apply it in their mathematics and science teaching. Each conversational inquiry lasted between 30 and 45 minutes. All the conversations were audio recorded, and notes were taken to ensure detailed documentation of the discussions.

In phase 3, I organized two co-creation workshops with all the teachers to provide avenues for them to collaboratively explore actionable strategies for integrating IGK into primary school mathematics and science lessons. These workshops promoted collective problem-solving and encouraged the teachers to share practical lessons on how they can authentically weave Indigenous Ghanaian knowledge into mathematics and science teaching.

Data Analysis and Meaning-Making

During the meaning-making process, I intentionally avoided coding the data or fragmenting them into thematic “chunks.” This helped preserve the integrity and flow of the stories shared by the teachers. I approached meaning-making in a way that honoured both the individual and collective voices of the teachers. Given the interconnected nature of the data generation strategies, the meaning-making process unfolded concurrently across all phases of the study. Each session (Phases 1–3) was audio recorded with the explicit consent of the participating teachers. To center their voices within the stories, I listened to the audio recordings multiple times to deepen my understanding of the ideas and knowledge that emerged throughout the process. I conducted manual transcription of the recordings from all the data sources. These transcripts were accompanied by detailed field notes and personal reflections. Rather than coding the transcripts, I engaged in a close, line-by-line reading and took extensive notes during the analysis. My goal was to make meaning from what the teachers shared without imposing external judgments (Osibodu, 2020). I intentionally resisted over-analyzing their narratives and focused on amplifying the individual and collective voices of the teachers. In this way, the teachers’ perspectives remained central to the analysis, rather than being overshadowed by my interpretations. From this iterative and reflective process, I organized the findings into four broader themes that captured the core ideas and insights shared across the data generation phases: 1) teachers’ understanding and knowledge of Indigenous knowledge; 2) the dilemmas of integrating IGK into teaching mathematics and science; 3) the search for an inclusive framework for Indigenous knowledge integration in mathematics and science learning; and 4) weaving knowledge: practical examples of how teachers integrate IGK into their classrooms.

Findings

Teachers Understanding and Knowledge of Indigenous Ghanaian Knowledge. Teachers' understanding of Indigenous knowledge plays a central role in their ability to integrate these systems into mathematics and science education. The findings reveal a significant disparity in the knowledge and application of Indigenous Ghanaian knowledge among teachers in the two regions. Teachers in Northern Ghana demonstrated a critical understanding of Indigenous Ghanaian knowledge and their applicability to teaching mathematics and science. In contrast, teachers in the Ashanti region were aware of the various Indigenous knowledge systems and perspectives within their culture, but most of them lacked the expertise to effectively integrate them into their teaching practices.

A key outcome from my conversation with the teachers highlights that teachers' knowledge and understanding of Indigenous knowledge as well as their applicability to teaching and learning were shaped by their upbringing, connections to local communities, and engagement in cultural practices. Also, in terms of their utility and applicability, teachers from Northern Ghana had an in-depth understanding of their Indigenous knowledge and recognized their relevance not only in teaching mathematics and science but also in their everyday life. In other words, these teachers mostly viewed their Indigenous knowledge as integral to their existence. For instance, Zack a teacher based in the Northern region, emphasized the intrinsic role of Indigenous knowledge that is central to his cultural identity. According to Zack, "In my Dagomba culture, this knowledge has been passed down from generation to generation through our stories and ceremonies. It is part of my existence." Similarly, Jamilah, another teacher from the Northern region, echoed this perspective. She revealed, "We have come to learn so much about ourselves as people, our traditions, practices, and life lessons through our Indigenous knowledge systems."

On the other hand, while teachers in the Ashanti region acknowledged the importance of Indigenous knowledge, they reported infrequent application of this knowledge in their personal or professional lives. Esi and Agyeman, who are teachers from the Ashanti region, reported they were distanced from the practical application of Indigenous Ghanaian knowledge in their lives but acknowledged their importance in mathematics and science learning education. Esi, a primary one teacher, remarked that although she had learned about Indigenous knowledge growing up, the changing dynamics of her community had limited her engagement with this knowledge. She explained:

> I grew up in an Indigenous community, and my grandparents were very much rooted in the traditions and teachings. This knowledge was important as it taught us many lessons about ecology and sustainable development. I think the problem is that in my generation, most of us feel these practices are archaic, and so we have moved from using them in our lives. In terms of teaching, I think not much is seen in our books or [teaching] syllabuses.

Agyeman, another teacher from the Ashanti region, also admitted that, "I feel I need to learn more about the cultural significance of these teachings and practices because I think they are important." From the above, it is evident that there were distinct levels of knowledge and understanding of Indigenous knowledge among the teachers in the two regions.

The Dilemmas of Integrating Indigenous Ghanaian Knowledge into Mathematics and Science. Teachers in this study identified several challenges with integrating Indigenous Ghanaian knowledge into mathematics and science education. A critical issue raised by teachers in the two regions was the lack of opportunities within the current mathematics and science curricula to integrate this knowledge meaningfully and authentically. While Indigenous Ghanaian knowledge has historically contributed to scientific innovations as emphasized by the teachers, they remain underrepresented in the formal education system. This marginalization reflects a broader trend of colonial legacies in education. Teachers from both regions noted the constraints imposed by the mathematics and science curricula, particularly the lack of a guiding framework for integrating Indigenous knowledge into teaching and learning. Efua, a primary six mathematics teacher from the Ashanti region, captured this tension:

> I know about the educational lessons in my culture and some Indigenous knowledge, but the challenge is how to effectively apply them in teaching mathematics and science. The curriculum does not show how this knowledge can be included. I think that the curriculum doesn't see any value in our Indigenous knowledge, which is very unfortunate.

Efua's perspective highlights the epistemic injustice perpetuated by the mathematics and science curricula. From the conversations, it appeared that the current curricula reflect the coloniality of knowledge that contributes to devaluing Indigenous knowledge as lacking scientific rigour. This exclusion perpetuates what anti-colonial theorists describe as epistemic violence which is the deliberate or systemic marginalization of non-Western ways of knowing within curricula. Asare, who is another teacher from the Ashanti region, highlights the significance of Indigenous scientific knowledge, citing innovations in traditional medicine as a powerful example. He observed:

> Traditional medicine in Ghana shows how valuable our Indigenous scientific knowledge can be. Our elders and ancestors have developed these herbs over centuries, and they can cure many ailments, yet our education system ignores this. What is interesting to me is that while we overlook herbal medicine in Ghana, countries like China have embraced similar knowledge systems to innovate in scientific medicine. Our curriculum doesn't even prioritize local knowledge, and that is a big loss for our country.

Asare also re-echoes the anti-colonial critiques of Eurocentrism which argue that non-Western societies might undervalue their intellectual and cultural capital and would more keenly look outwards for knowledge and ideas. This disconnect demonstrates how education systems such as in the case of Ghana have been shaped by colonial histories and continual failure to equip local communities to use their knowledge systems for sustainable development. During my conversations with teachers, another teacher from the Northern region expressed a similar desire to include Indigenous Ghanaian knowledge in their classrooms but emphasized the challenges posed by the colonizing curriculum and their lack of pedagogical training to utilize them in teaching. Fatima, a primary three science teacher expressed her frustration:

> I think the Indigenous ones we have discussed are very important too; but unfortunately, I don't know where to start. We don't have any education or background in teaching Indigenous knowledge and applying it in science and math. I can see a lot of potential for this and its benefits to the students, but where do we start from?

Fatima's comment was indicative of the lack of professional development and capacity building in Indigenous and culturally relevant teaching in Ghanaian schools. Like Fatima, other teachers in this study also discussed how societal misconceptions about Indigenous knowledge exacerbate these challenges. Indigenous knowledge is often misunderstood or fetishized as mystical rather than scientific worldviews thus reinforcing the coloniality of knowledge. Mohamed, a primary four teacher from the Northern region, expressed this concern:

> People in our communities sometimes treat Indigenous knowledge as though it is something exotic or magical. They don't see the science behind it. This misconception makes it harder for us to argue for its place in science education because people think it's not "real" knowledge.

Mohamed's statement unpacks the colonial construction of knowledge hierarchies that privilege Western knowledge while delegitimizing others such as Indigenous worldviews and knowledge as either primitive or overly romanticized. Such misconceptions reduce Indigenous knowledge to a mere cultural artifact rather than a dynamic system of knowledge with practical applications. These deficit notions further hinder Indigenous Ghanaian knowledge integration into mathematics and science learning in Ghanaian schools. These findings suggest that while Ghanaian teachers recognize the cultural and pedagogical value of Indigenous knowledge, they face significant structural and institutional barriers in their application. These barriers include a colonizing curriculum, insufficient training opportunities, and societal misconceptions about the relevance of Indigenous knowledge. As anti-colonial theorists emphasize, decolonizing education requires a deliberate effort to dismantle these barriers by re-centring local epistemologies such as Indigenous knowledge and providing resources and frameworks that enable teachers to bridge the gap between their understanding of Indigenous Ghanaian knowledge and their practical application in classrooms. Such efforts are critical not only for the empowerment of local communities but also for promoting science and innovation rooted in Indigenous worldviews.

The Search for an Inclusive Framework for Indigenous Knowledge Integration in Mathematics and Science. Teachers' conceptions of Indigenous knowledge are crucial for their acceptance and effective integration into teaching and learning especially in science and mathematics wherein, there has often been a deficit of perspectives regarding the place of Indigenous knowledge systems. In this study, three main conceptions emerged from teachers in both the Ashanti and Northern regions. Data from this study revealed different approaches to the integration of Indigenous knowledge into mathematics and science learning in Ghana. The analysis of the assertions of teachers from both regions reflected three key approaches to the integration of Indigenous Ghanaian Knowledge into mathematics and science learning; (1) practical inclusionist; (2) critical incorporationist; and (3) integrativist. Teachers from both regions had distinct perspectives regarding how they perceived Indigenous Ghanaian knowledge, but they mostly reflected in one of these approaches.

The Practical Inclusionists. The first approach that emerged in this study was the practical inclusionist perspective. Teachers whose perspectives reflect this approach perceived Indigenous knowledge and pedagogies as an "add-on" to existing Western scientific and mathematical content. This approach, while aiming to integrate Indigenous Ghanaian knowledge, implicitly positioned Indigenous knowledge as supplementary rather than foundational. During

conversations, teachers like Asare and Zack articulated how integrating Indigenous Ghanaian knowledge could enrich classroom experiences with a focus on practicality and complementarity. Asare a teacher from the Ashanti region highlighted:

> Bringing in Indigenous content in teaching makes the class livelier. Take multiplication, for instance. Engaging students in traditional counting methods or showing how our ancestors approached basic arithmetic adds depth to the lessons. This way, students will understand that doing arithmetic is more than just numbers. We need to find out how this knowledge fits into the current curriculum.

Similarly, Zack, a teacher from Northern Ghana, shared:

> In science, including our local Indigenous content can make topics like the water cycle more meaningful. Exploring our local rivers with students and sharing stories about their names and origins can add relevance. Let's find out how this Indigenous knowledge can be included in current topics to support students' learning from multiple perspectives.

Both teachers emphasized the pedagogical value of Indigenous Ghanaian knowledge and illustrated their ability to contextualize learning and foster deeper engagement among students. However, their framing of Indigenous Ghanaian knowledge within the confines of the existing curriculum reflects the limitations of the practical inclusionist approach. This integration strategy may inadvertently uphold colonial power dynamics by subsuming Indigenous epistemologies under Western frameworks, rather than enabling them to challenge and transform these structures. The practical inclusionist perspective also underscores a key issue regarding how the curriculum itself, shaped by colonial legacies tends to restrict the authentic integration of Indigenous perspectives into education in Ghanaian primary schools.

As the data has shown, while teachers like Asare and Zack aspired to promote learning using their Indigenous knowledge, they were mainly focused on *fitting* Indigenous knowledge into the dominant Eurocentric curriculum. From an anti-colonial standpoint, a critical transformative integration of Indigenous Ghanaian knowledge in postcolonial contexts like Ghana would require rethinking curriculum design to position Indigenous knowledge systems as central and co-equal to other bodies of knowledge rather than seeing these ways of knowing as "add-ons." In other words, while the practical inclusionist approach represents a step toward more inclusive teaching practices, it remains constrained by the limitations of a colonizing curriculum. Moving beyond this approach necessitates embracing anti-colonial approaches to knowledge synthesis and integration that disrupt epistemic hierarchies and enable Indigenous Ghanaian knowledge to reclaim its rightful place as a vital, self-sustaining system of knowledge in science and mathematics education**.**

The Critical Incorporationists. The second approach identified in the study was the critical incorporationist perspective. Teachers adopting this approach advocated for the intentional integration of Indigenous Ghanaian knowledge of Eastern scientific and mathematical paradigms, emphasizing their equal importance in STEM education. Unlike the practical inclusionist approach, which frames Indigenous Ghanaian knowledge as supplementary, the critical incorporationist perspective challenges the dominance of Western knowledge and calls for a balanced representation of knowledge, pedagogies, and worldviews. My conversation with teachers who expressed this viewpoint showed they were more particular about demanding equal

recognition of Indigenous knowledge as equally valuable systems that need to be studied in schools. Dela, a teacher in the Ashanti region, remarked:

> I believe we need to use both Indigenous and foreign [Western] knowledge in teaching mathematics and science. For example, when explaining seasons in science, we can talk about global patterns and local weather tales. Teaching from both sides can provide a complete understanding among students and help them relate better to national and international issues.

Similarly, Mohamed, from the Northern region, reinforced the importance of elevating Indigenous Ghanaian knowledge within Ghana's education system:

> Developing our Ghanaian Indigenous knowledge and traditional teaching practices should be the focus of our education system, particularly in mathematics and science. We have a rich cultural knowledge that is often overlooked in favour of foreign [Western] content. It is time to appreciate our Indigenous knowledge as equally important for learning.

From the data, it appears that the critical incorporationist approach seeks to dismantle the binary markers created by colonial education systems which erroneously position Indigenous knowledge as inferior and Western knowledge as superior ways of knowing. By highlighting the collective synthesis of both knowledge systems, the critical incorporationist approach might contribute to helping teachers integrate multiple ways of knowing in a way that provides students with a holistic understanding of both local and global scientific and mathematical knowledge.

The Integrativists. Teachers who embraced the integrativist perspective emphasized a pedagogical approach that centers students' Indigenous knowledge within mathematics and science education. Integrativists advocate for centring and situating Indigenous Ghanaian perspectives as foundational to teaching and learning in mathematics and science to ensure the learning is culturally relevant to students. Adiza, a primary three teacher from Northern Ghana, explained the benefits of this approach:

> Many kids will benefit from our teaching if we integrate Indigenous content and examples into the lessons. Indigenous content should be the foundation of our teaching before we introduce another knowledge. Bringing Indigenous mathematics and science knowledge into the classroom will help students connect their home and book knowledge.

Similarly, Ajo, a teacher from the Ashanti region, articulated the importance of making Indigenous knowledge central in mathematics and science learning. She revealed that:

> While I recognize that Western examples and knowledge are important, it is crucial to place Indigenous science and mathematics at the heart of teaching. This helps students connect what they learn at home to school knowledge before transitioning to Western content.

Another teacher Jamilah, expanded on this idea by emphasizing contextual relevance:

> We must include local Indigenous knowledge in mathematics and science lessons. Our teaching should prioritize the local context so that children feel more connected to what

> they learn. For example, when teaching topics like matter and measurement in science, it shouldn't just be about textbook definitions; it should include Indigenous examples.

It is worth emphasizing that centring Indigenous Ghanaian knowledge in mathematics and science teaching in Ghana can create opportunities for students to see their Indigenous knowledge and everyday experiences reflected in their learning. This approach can enable Ghanaian students to transition more seamlessly from their prior knowledge to the lessons taught in school. Grounded in anti-colonial praxis, the integrativist approach challenges assimilationist tendencies of colonial curricula which prioritize Western worldviews and knowledge systems over Indigenous knowledge. Also, from the above, one can argue that the integrativist approach challenges the epistemic erasure perpetuated by colonially influenced education systems such as in the case of Ghana and other African countries. Ajo's argument on connecting "home and book knowledge" exemplifies how centring Indigenous practices in teaching in Ghanaian schools can help address epistemic injustices faced by students in Ghanaian classrooms.

Weaving Knowledge: Practical Examples of How Teachers Integrate IGK into their Classrooms. The co-creation sessions provided spaces for teachers to infuse Indigenous Ghanaian knowledge into selected mathematics and science lessons. This collaborative process empowered them to explore new ways of integrating Indigenous content into their teaching practices. Drawing from the insights gained from this study, teachers shared their experiences in their respective regions, collectively and individually building upon their understanding of Indigenous Ghanaian knowledge to creatively incorporate them into the curriculum. These lessons were then presented by the teachers during co-creation workshops held in both regions. Below are some individual exemplar lessons shared by teachers during the co-creation workshops.

Teaching Frictional Forces Using the Indigenous Method of Grinding. In this lesson, Zack, a teacher in the Northern region of Ghana, used the Indigenous method of grinding vegetables at home using grinding stones to model how primary school science teachers in his community can use AIKS to explain the concept of frictional forces to primary school children. He explained:

> We have grinding stones in many homes here in the northern region. I'm from Salaga, I'm a Gonja [their ethnic group]. So, when we teach the forces and movement strands in science, there's a topic on friction, right? And then when our mothers are going to grind, say, ginger or pepper on the stone or kapuye [earthenware in Gonja language], the constant movement of the stone creates this groove. Students have seen this before; they can relate to it. So, in teaching frictional forces, you can use this Indigenous method of grinding as an example by explaining that when mom grinds pepper on the stone constantly, it causes wear and tear, and over time the stone reduces in size. So, the wear and tear are a result of friction. We are already familiar with this, but we don't know if it's friction that causes it, right? So, this is a topic that can benefit from Indigenous knowledge.

Zack's lesson activity above demonstrates how Indigenous practices can provide tangible, relatable examples for teaching scientific concepts. Drawing on the familiar practice of grinding vegetables with stones, which is very common in his culture, he was able to use the everyday experiences of students to explain the abstract concept of friction. This exemplary lesson activity

reinforces how Indigenous Ghanaian knowledge can make complex topics like friction more accessible and meaningful to students.

Teaching Physical Change and Chemical Change Through an Indigenous Approach. In this lesson, Adama, a science and mathematics teacher in the Northern region, utilized Indigenous knowledge to teach about physical and chemical change, a topic under the materials strand in primary school science. The teacher described how cooking shea butter can be employed to teach the topic. In this lesson, Adama also employed the slash-and-burn Indigenous farming method to explain the process of chemical change in science.

> Most of the children in our class have come across materials; they know what materials are. There's a bottle of water, which is material, and food in the house, which is also material. But we have physical and chemical changes when it comes to materials. That is where the problem lies. What is a physical change? What is a chemical change? When I was starting this presentation, I said, "Every child is aware of something unless you relate it directly. The physical change, in the sense that if an object changes from one state to another and it's easily reversible, that's a physical change. So, take for instance, when we go to the farm or when Mama is cooking, she uses shea butter, right? The use of shea butter, once we're done preparing it, when it is untouched, it is so hard. So, when she cuts a portion of the shea butter and places it in a frying pan, it starts melting; that is a change. It has moved from a solid state to a liquid state. And can we get it back? Yes, that is a physical change. All physical changes are reversible." Now, when this same child follows his dad to the farm, we like doing slash and burn, [so I ask,] "When you slash the weeds or grass and burn them, can we get the logs back? It's in ashes, which means a chemical change has occurred." These examples can be brought into our lessons to help students develop a deeper understanding of these concepts.

Adama's exemplar activity amplifies the value of integrating Indigenous knowledge into science lessons to make scientific concepts culturally relevant and accessible to students. By using examples such as cooking shea butter [which is mostly known and familiar to students in Northern Ghana] and the slash-and-burn farming method, Adama connects abstract scientific principles like physical and chemical changes to the everyday experiences of his students. This approach to utilizing Indigenous Ghanaian knowledge helps to bridge the gap between students' lived realities and classroom learning as well as promotes deeper conceptual understanding by grounding scientific methods in familiar cultural practices.

African Indigenous Mythology as Pedagogy for Teaching about Climate Change. In this lesson, Esi, a science teacher from the Ashanti region, shared an Indigenous approach to teaching about environmental preservation and climate change.

> Teachers can use popular myths and taboos about forests, water bodies, and wildlife as sacred and untouchable in many communities. They can ask children about the myths and taboos they have heard regarding the preservation of forests and water bodies. In many communities, there are days when nobody goes to the farm. In towns and cities across Ghana, fish farmers are forbidden from fishing on Tuesdays. Many communities have also designated certain forest reserves as "evil forests" to scare people away from hunting and harvesting food from them. Teachers can explain to students the reasons these taboos and myths have been sustained for centuries despite Westernization, as our ancestors

> understood the importance of being environmentally conscious. These myths and taboos serve to help people respect nature and live sustainably. Through this example, students can think deeply about the importance of protecting the environment.

In the above lesson activity, Esi demonstrated the value of integrating myths and community taboos to engage students and connect them with Indigenous ecological knowledge. She explained how teachers can utilize established myths and taboos in each community to show how African Elders continue to demonstrate these as a way of preserving and conserving endangered species. Given the ecological crises we face globally, using taboos and myths as a pedagogical praxis can potentially subvert dominant Euro-Western perspectives on environmentalism and create ethical spaces for the inclusion of Indigenous-centered approaches to addressing environmental issues.

Discussion

This study investigated Ghanaian teachers' knowledge and understanding of AIKS and their integration into primary school mathematics and science education. Teachers, as cultural and knowledge intermediaries, play an essential role in advancing student success by incorporating Indigenous knowledge systems into formal education (Misco, 2018). Findings revealed that while teachers in both the Northern and Ashanti regions had some level of familiarity with their Indigenous knowledge, those in the Northern region showed deeper understanding and engagement. This disparity could stem from differing colonial histories (Aboagye, 2021; Pinto, 2019). These findings illuminate how colonial legacies manifest differently across regions within the same nation (Aboagye, 2021). The study also highlighted that teachers primarily acquired their understanding of Indigenous knowledge informally through community elders and emphasised the crucial role of African elders as knowledge transmitters (Dei, 2020; Govender & Mutendera, 2020; Heto & Mino, 2023). These findings align with Naidoo and Vithal's (2014) research in South Africa, which highlighted informal learning serves as a critical pathway for acquiring AIKS and emphasized the importance of community involvement in shaping knowledge. Although teachers in this study were familiar with Indigenous concepts, most of them initially reported they faced challenges identifying curriculum entry points for their integration. Similar barriers, including insufficient exposure to Indigenous Ghanaian knowledge in teacher education programs, underdeveloped pedagogical approaches, and limited conceptual understanding of Indigenous knowledge systems have been documented across African contexts (Cronje et al., 2015; Msila & Gumbo, 2016).

In Ghana, the formal education system has historically invalidated AIKS as legitimate knowledge within mathematics and science curricula (Adjei & Dei, 2008). This trend has been observed in other African countries by African research (Emeagwali & Shizha, 2016; Mavuru, 2022). These findings challenge the perception that mathematics and science are culturally neutral domains (Burbanks et al., 2020). They call for the development of inclusive, anti-colonial frameworks to facilitate AIKS integration in education. Acharibasam (2021) asserts that students in post-colonial societies must navigate multiple worldviews, yet the Ghanaian education system fails to adequately recognize Indigenous Ghanaian knowledge and authentic ways of knowing. To facilitate students' ability to reconcile diverse worldviews and counter cognitive imperialism, it is important to integrate both Indigenous and Western knowledge systems into curricula. While

these integration approaches have been suggested by several scholars (Battiste, 2000; Battiste & Henderson, 2021; Le Grange, 2007), a critical framework for the anti-colonial engagement of Indigenous knowledge systems remains absent, particularly in primary school mathematics and science education (Arnold, 2017). This study thus contributes to Indigenous knowledge systems integration approaches and builds on Naidoo & Vithal's earlier work in South Africa which proposed similar integration approaches (Naidoo & Vithal, 2014). The practical inclusionist approach incorporates Indigenous Ghanaian knowledge into the curriculum to complement Western knowledge.

While this strategy facilitates alignment with existing curricula, it risks reinforcing colonial power dynamics by legitimizing Indigenous Ghanaian knowledge only when it aligns with Western epistemological frameworks (Wolfmeyer, 2017). Teachers adopting this approach may inadvertently perpetuate existing hierarchies by positioning Indigenous knowledge as ancillary. The critical incorporationist approach, on the other hand, positions Indigenous knowledge as equally valid, encouraging its integration alongside Western knowledge without subordinating either system. This perspective aligns with scholars who advocate for maintaining the integrity of both knowledge systems (Battiste & Henderson, 2021). Teachers using this approach recognize the interplay of power between Indigenous and Western paradigms and aim to reflect students' cultural hybridity (Acharibasam, 2021; Anyidoho, 2018). Finally, the integrative approach centers on Indigenous Ghanaian knowledge and students' lived experiences within the curriculum, emphasizing the uniqueness of Indigenous epistemologies. By prioritizing culturally grounded pedagogy, this approach challenges the dominance of non-Indigenous knowledge in education and fosters meaningful connections between Indigenous knowledge and STEM learning (Rosa & Orey, 2016). These three approaches can contribute to a significant pathway for rethinking Indigenous knowledge integration into Ghanaian curricula. However, it is worth accentuating that any effort to integrate Indigenous knowledge into formal schooling must critically address the power dynamics within knowledge systems and ensure that Indigenous knowledge is not superficially included but authentically weaved into mathematics and science learning. This study also argues for developing anti-colonial frameworks to guide teachers in embracing Indigenous knowledge in mathematics and science education.

Conclusion and Implications

This study examined Ghanaian teachers' current knowledge and understanding of Indigenous Ghanaian knowledge and their integration into mathematics and science learning. The study argues that Indigenous knowledge should not be viewed merely as supplementary or "add-ons" to mainstream curricula. The findings underscore the critical need for teachers and policy actors to meaningfully and culturally integrate Indigenous Ghanaian knowledge into Ghana's primary school mathematics and science curricula. As the findings have revealed, efforts to integrate Indigenous Ghanaian knowledge into these subjects are hindered by a curriculum that often disregards Indigenous knowledge and continually perpetuates colonialism. The findings of this research have significant implications for both educational practice and policy in Ghana. For educators, the lack of professional development in Indigenous knowledge integration must be addressed. Also, teacher training programs in Ghana should include courses on Indigenous Ghanaian knowledge and provide actionable strategies for integrating these systems into mathematics and science curricula. This approach would help equip teachers to authentically and

effectively utilize Indigenous knowledge in their teaching and help create an inclusive and culturally responsive educational environment for diverse learners. At the policy level, the study calls for a critical re-examination of the current Ghanaian mathematics and science curricula. Curriculum reviews should involve integrating Indigenous knowledge systems through consultations with Indigenous knowledge holders, such as Elders, educational researchers, and policymakers. Furthermore, societal awareness is necessary to address key misconceptions and stigmas surrounding Indigenous knowledge systems. Such efforts can contribute to the broader goal of decolonizing education in Ghana.

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