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The Akan ethnomathematics as pedagogical tool under the context of technology integration in promoting conceptual understanding in mensuration

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ABSTRACT

The objective of the study was to use mortar to teach the concept of the surface area of a cylinder. The target group included knowledgeable Akan traditional artists, seasoned mathematics teachers, and senior high school students from the Ashanti Region in Ghana. Data collection tools included Focus Group Discussions and interviews, with informed consent, privacy, and ethical clearance from the School of Graduate Studies, AAMUSTED. We pre-planned, taught, and assessed two 60-minute lessons on deriving the formula for the surface area of a cylinder. The session utilised technology tools such as: a laptop, projector, cylindrical object images, a tape measure, a cardboard metre rule, activity cards, and the mortar, as a local tool. The analysis of the interview data and the FGD revealed that the Akan culture has connections with school geometry that can enhance relational understanding. We concluded that this approach, aside from improving academic achievement, can also increase student interest, creative skills, critical thinking, innovativeness, help students overcome fear, and, above all, become creative problem-solvers.

Keywords: Akan ethnomathematics, artefact, fufu, mortar.

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INTRODUCTION

There have been several studies among mathematics educators aimed at finding ways of providing realistic mathematics instruction for all students (Atta and Brantuo, 2021). This is due to the realization of the increasing importance of mathematics and its applications for society, and the availability of new insights in the teaching and learning of mathematics. One of the mathematics pedagogies that is gaining currency among mathematics educators is Ethnomathematics. Albanese (2021) also describes ethnomathematics as a kind of mathematics practiced among specific cultural groups. Ethnomathematics aims to foster both the understanding of culture and the understanding of mathematics in a way that can lead to an appreciation of the two (Meaney et al., 2021). The term "ethnomathematics" entered the world of education around 1997 by Brazilian educator and mathematician Ubiratan D'Ambrosio during a presentation for the American Association for the Advancement of Science. *Ethno* refers to people of a cultural group characterised by their traditions, codes, symbols, myths, and distinctive ways to reason and infer (Rosa and Orey, 2007) as cited in (Atta and Bonyah, 2023a). *Mathema* means to explain and understand the world so that cultural groups can transcend, manage, and cope with reality. *Tics* refers to processes such as counting, ordering, sorting, measuring, weighing, ciphering, categorising, inferring, and modelling.

When ethnomathematics first appeared as a field of study, it was a reaction to historical evidence of a conscious devaluing of the mathematics produced and advanced by non-European civilizations (Atta et al, 2024). That was the era when people thought that the only path to understanding mathematics was to come from Western civilization. Researchers who believe in ethnomathematics and mathematics education believe that it is essential to recognize the cultural context of mathematics for students through teaching culturally relevant mathematics (Rosa, 2020; Rosa et al., 2016). In order for mathematics education to influence the political and social dynamics of culture, mathematics instruction must be founded on cultural relevance and personal experiences that help students get a deeper understanding of reality, culture, society, and themselves (Atta and Bonyah, 2023a).

Traditional teaching methods are still prevalent in Ghanaian education, characterized by teacher-centred approaches that prioritize rote learning and memorization over critical thinking and problem-solving as prescribed by the curriculum (Asare and Afriyie, 2023). Meanwhile, most of these students are exposed to technology and are familiar with social media outlets like WhatsApp, Facebook, TikTok, among others. Most recent is the introduction of ChatGPT and others that students make use of and sometimes abuse. Since mathematics is a core subject at all pre-tertiary levels in Ghana, it will be easier to use it as a medium to enlighten the young ones through the lens of culture and technology in this artificial era. Culture provides a unique identity, and it is a binding force that brings people together to foster unity, cohesion, collaboration, peace, and national development. Studies have shown that students grasp mathematics concepts better when taught in context, and AI has also been identified as a catalyst in education. Blending the two, therefore, will provide desirable results, hence the need for the current study.

According to the ethnomathematics viewpoint, mathematics is a part of every culture, and everywhere humans go, their cultural practices are embedded with mathematical concepts. Thus, the ethnomathematics programme promotes the idea that mathematics is innate to many. Cultures ought to be studied and covered in mathematics curricula in schools. More so, studies have demonstrated that Akan culture has so many applications in mathematics, especially mensuration. One of the widely used kitchenware items that this study used as a pedagogical tool to teach mensuration is the mortar (Waduro), as a cylinder. Mortar is curved from a piece of cylindrical wood.

Figure 1. A piece of wood in a form of cylinder.

Figure 2. Finished Mortar (Waduro) used in the homes of the Akan.

Mortar is a tool mostly used to pound fufu across the Akan communities. Fufu is a popular local food in Ghana and other West African countries such as Nigeria, Togo, the Ivory Coast, and Benin. However, it is commonly eaten among the Akan people in Ghana (Adu-Gyamfi, 2022). (Figure 3)

The main nutrient in fufu is carbohydrate, which is broken down into sugar and absorbed into the bloodstream. This raises blood glucose levels, prompting the pancreas to produce insulin. It is made from ingredients like cassava, plantain, cocoyam, and yam. (Figure 4)

Figure 3. Fufu from Akan in Ghana.

Figure 4. Cassava and plantain used to prepare fufu.

Fufu is typically eaten with different soups and is a delicacy in the region. The process of making fufu involves peeling, boiling, and pounding the ingredients in large wooden mortars with wooden pestles (Adu-Gyamfi, 2022). The pounding is a demanding exercise that not everyone can handle. Different ethnic groups have their preferences for fufu. Some prefer fufu made from a mixture of cassava and plantain, while others prefer only cocoyam fufu. The type of fufu and soup consumed can vary depending on the region and cultural traditions. Fufu is typically swallowed, not chewed, and the softer it is, the better it is on the stomach. However, some people prefer their fufu to be hard. Fufu brings people together and has cultural significance, since it is associated with communal eating and is often eaten at fufu chop bars or restaurants. Fufu has various connotations in different fields of study and is seen as a symbol of national unity. It can also influence marriages and relationships. Fufu has economic implications, with retailers and marketers making a living by selling fufu-making ingredients. Women entrepreneurs play a major role in the fufu business. Overall, fufu is a beloved and culturally significant food in West Africa (Sakyi, 2017).

Ethnomathematics has not been fully utilized in Ghana due to several reasons. According to research conducted in Israel, geometry was perceived by instructors as an abstract subject and should be taught as such (Katsap and Silverman, 2016). Furthermore, Rosa (2013), cited in Alangui (2017), discovered that teachers in California had unfavourable attitudes toward the use of ethnomathematics methodologies. Some teachers are of the view that students' cultural backgrounds have little impact on their academic achievement. Teachers' opinions about the employment of ethnomathematics methods in geometry instruction and learning are impacted by a variety of issues, including their perspectives on geometry learning. It is worth noting that there has been abundant research in Ghana on the integration of technology in teaching geometry with favourable outcomes (Adu et al., 2017; Arkoful et al., 2021; Atta and Brantuo, 2021), yet the Chief Examiners' Report for the West Africa Examination Council (WAEC) has sighted mensuration as one of the areas students fail to answer questions (https://waecgh.org/chief-examiners-report/#flipbook-df_3213/5/). There was therefore the need to use local material to teach the concept of mensuration to help the learners build conceptual understanding. The objective of the study was to use Mortar to teach the concept of the surface area of a cylinder, utilising technological tools.

Research questions

1. How does the Senior High School geometry apply the Akan culture?
2. How does the Akan culture influence student conceptual understanding of geometry?

Social constructivism

The study is in line with the Social constructivists' theory. This theory considers how people's interactions with others impact their understanding of the world. Social constructivists recognize that different people can have different reactions and develop different understandings from the same events and circumstances, and are interested in how factors such as identity, family, community, and culture help shape those (Altaftazani et al., 2020; Bada and Olusegun, 2015; Ertmer and Newby, 2013). Vygotsky, for instance, believes that adults in a society provide the cognitive development of children in a desired and systematic way. According to Vygotsky, it is important that adults put the children into meaningful activities that strengthen them mentally and help them to succeed in performing these activities. Social Constructivist Theory emphasizes that when working together, the meaning is understood better than when working alone (Pathan et al., 2018). This assertion demonstrates how to bridge the Zone of Proximal Development (ZPD).

ZPD is the difference between a child's development level as determined by independent problem solving and the child's potential development as determined through problem solving under the guidance of an adult or in collaboration with a capable peer (Pathan et al., 2018). This is the gap between what a child can do on their own and what a child can do with support. As individuals and groups interact with each other, they contribute to the common trove of information and beliefs. This helps them to reach consensus with others on what they consider as the true nature of identity, knowledge, and reality (Lasmawan and Budiarta, 2020; Qiquan, 2021).

Cooperative and collaborative learning

Cooperative and collaborative learning are two key instructional approaches derived from social constructivism, coming out of a problem-solving approach. Research has documented that cooperative learning results in greater effort to achieve, more positive relationships, and greater psychological health than competitive or individualistic learning efforts. Adding their voice to the benefits of cooperative learning, Adu et al. (2017), assert that, when learners are encouraged and required to communicate mathematically with other learners, with the teacher, and with themselves, they have opportunities to explore, organize, and connect their thinking.

Collaborative learning has been described as the use of small groups through which learners work together to accomplish shared goals and to maximize their own and others' potential (Ardiyani et al., 2018). Collaborative learning is also explained as the learners are responsible for one another's learning as well as their own, and that the success of one student helps other learners to be successful. It has been found that students who participated in collaborative learning performed significantly better on the critical-thinking test than students who studied individually. It is also established that both groups did equally well on the drill and practice test. The peer support system makes it possible for the learner to internalize both external knowledge and critical thinking skills and to convert them into tools for intellectual functioning (Abramczyk and Jurkowski, 2020; Amir MZ et al., 2021; Okumus et al., 2020). This, therefore, alludes to the fact that when students are provided with the opportunity to work together using local materials like mortar, among others, they tend to construct knowledge by themselves and for themselves. The ultimate aim of every lesson is to give students intuitions that could be applied in solving problems in other subject areas and real life.

METHODOLOGY

The study employed a qualitative case study to obtain in-depth information on the perception of mathematics educators and artisans on how the Akan traditional art contributes to students' mathematical understanding of concepts. Case study design is a popular methodological technique for a number of reasons (Kothari, 2017). A case study is a reliable resource that facilitates the comprehension and investigation of complex phenomena when a thorough and comprehensive investigation is required (Sileyew, 2019). Furthermore, Yin (2009) pointed out that a case study is a qualitative approach that tackles the how and why questions in situations where the researcher lacks control over the variables. A collective case study, which entails a thorough examination of a specific circumstance, event, schedule, or activity protocol, was used.

The third-largest region in Ghana, the Ashanti Region, served as the study's location. The region, which is part of the country's central belt, is well-known for its abundant gold and cocoa output. The targeted group for the study includes both knowledgeable Akan traditional artists, seasoned mathematics teachers, and senior high school students. In order to make sure that every member of the intended population has enough experience and expertise, purposeful and snowball sampling techniques were used (Hu and Chang, 2017). The criteria for selecting the teachers were based on their teaching experience and their knowledge of ethnomathematics. To qualify for selection, the participant should have a minimum of five years' work experience and a proven track record, especially for artisans. Ten participants were enlisted, consisting of three artisans who are knowledgeable about Akan cultural customs and seven seasoned mathematics teachers, in addition to 20 final year Senior High students.

Focus group discussions and Interviews were used to get participant responses in order to collect data. The study investigated the potential integration of Akan cultural practices into mathematics education, with a specific focus on geometry instruction, using a semi-structured interview guide. This approach makes sure that everyone contributes knowledge on the same subjects and delves deeply into intriguing problems. Informed consent, privacy during interviews, and appropriate ethical clearance and permission all contributed to upholding ethical standards.

Pre-presentation

Two lessons, of 60 minutes each, were pre-planned, delivered, and evaluated. Learners were informed in advance of the materials needed for the lesson. They were conscientious about the lesson as a learning activity for research purposes, but not for examination, promotion, or certification. The lesson was on how to derive the formula for finding the total surface area of a cylinder. Students had already been introduced to the formula for finding the area of a circle. The materials for the lesson were a laptop, a projector, images of cylindrical objects, a tape measure, a mortar, a cardboard metre rule and activity cards.

Presentation

Table 1. Lesson one.

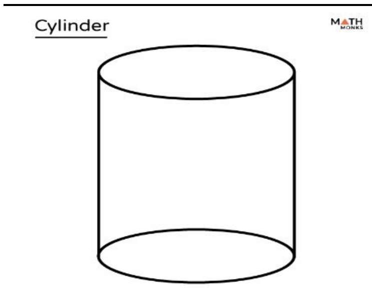
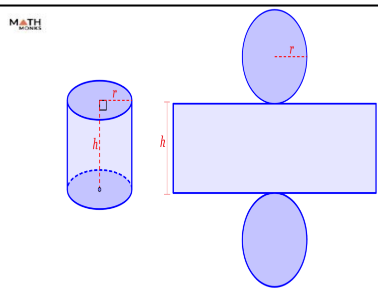
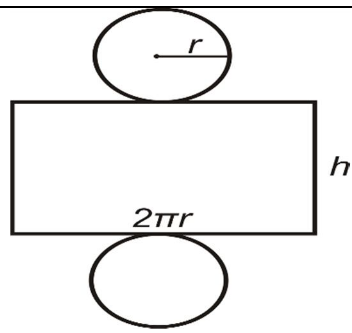
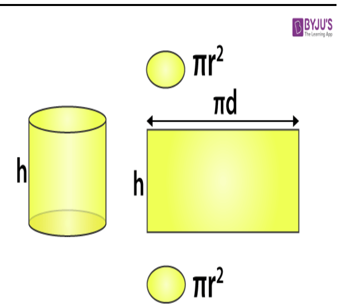
	Class activity	Time minutes
1	Students answer a few questions on finding the area of a circle.	10
2	Introduction of the concept of a Cylinder was introduced focusing on items students use in their homes.	6
3	Asked students to mention the objects used in their homes that have the shape of a cylinder. Student responses were: mortar……………., bucket, milo tin, milk tin, barrel, among others	4
4	Discuss the images of some of the objects mentioned using the projector	5
5	Students worked in groups of 4 to draw the mortar and come out with the net of the mortar (cylinder).	10
6	Each group was then given a mortar, a long ruler, a tape measure, a cardboard, and a marker for recording findings. The teachers observed the students as they measured the circular ends of the mortar, the diameter, and the height based on the specific activity guide and presented their results within 10 minutes.	15
7	Involved students in a general discussion tasked to try a similar activity using different objects in their homes before the next lesson.	5

Table 2. Lesson two.

S/n	Class activity	Time minutes
1	Students presented their findings from the assignment.	10
2	With the concept of the area of a circle and a rectangle, students working in their groups find the area of each component of the net of the mortar already measured	10
3	The teacher guides students to add the various sections to get the total surface area of the cylinder and derive the general formula	10
4	Students work some try questions on the total surface and curved surface area of a cylinder	15
5	Involved students in a general discussion tasked to try a similar activity using different objects in their homes before the next lesson. Next lesson will be on finding the volume of a cylinder. Until then, bye-bye.	10

Takeaways

Table 3. Finding the total surface area of a cylinder.

			
A cylinder is a 3-D object that has two circular ends and a hollow surface	The hollow surface, when cut open, looks like a rectangle with *h* as the height *(length)* and the circular ends as the *breadth*	The circular end is the *circumference* of the circle, which is $C = \pi d \text{ or } C = 2\pi r$	LSA or CSA = $2\pi r \times h = 2\pi rh$ TSA = $2\pi rh + 2\pi r^2 = 2\pi r(h+r)$

Source: Class activities.

RESULTS

The participants were of the view that if students get the concept of geometry very well, they can later apply it in real life in diverse ways, since geometry itself has so many real-life applications. Geometry they observed has existed since creation, and these learners have been involved in activities that make use of geometric shapes. Touching on the relationship between Akan traditional art and geometry, participants indicated that the Akan traditional art has a lot of geometric shapes, like lines, angles, rectangles, squares, spheres, among others.

> *There is a particular game common to the Akan children in which they use Turkey berries known among them as "Kwahu Nsusaa." One will kick a berry and where it reaches, he/she will use his/her fingers to measure the distance it reached. This game teaches them how to find the distance between shapes arbitrarily, which is also taught in schools under*

geometry using standard units and measuring tools ***(Boat, Mathematics Educator)***.

When you look at their pot (Ahina), the tip of the pot is circular, when you look at the earthenware is circular, when you look at even some of the symbols, the Akan symbols most of them have circular shapes, so circles are the major shapes used" ***(Rev, Mathematics Educator)***.

In the case of the Kente weaving, you have to start at a certain angle before you weave the required shape, whether a triangular shape or a parallelogram. So, they apply the kind of geometry we teach in the class, even though they may not be aware, but it makes a lot of impact ***(Pablo, Mathematics Educator).***

In order to make certain shapes and symbols among the Akan, such as "Adinkrahene", "Gyenyame", the Moon (bosome) and star (Nsoroma), circles, spheres, rectangles, and squares are drawn arbitrarily before these shapes and symbols are cut out. This indicates that there is a relationship between Akan culture and geometry ***(Doctor, Adinkra works).***

We have a pre-defined measure known as ***Kyereye****, which is what we use to set up the weaving. It comes in sizes depending on the number of holes in it: 100, 120, 130 or 140. You choose the type of* ***Kyereye*** *based on how wide you want that particular cloth to be, depending on who is who can use it, since humans have different sizes. The size of the kyereye gives one strip, and 15 stripes make one full cloth for males. All that we have done is based on indigenous knowledge. All the tools are locally made, and we do it through logical reasoning and critical thinking* ***(Vice Kente Weaver).***

Yeah, there is some kind of relationship between the Akan culture and geometry, some aspect of geometry we teach in school. A typical example I normally use in my teaching when I am talking about the circumference of a circle Mortar (Waduro). The Earthenware (Apotoyowa) that the Akan use has its edge looking like an inner circumference and an outer circumference. The calabash (Koraa), used to serve water or palm wine (Nsa fufuo), also has a spherical shape, which has something to do with the geometry that we teach in school ***(WAB, Mathematics Educator)***.

In response to the research question two, does the Akan culture have any influence on students' conceptual understanding of geometry? The Focus Group Discussion with the students was recorded and analyzed.

Table 4. Summary of FGD on the benefits of using the Akan culture to teach geometry.

Item	Always	Not always	Not at all	Total
Does learning geometry using the Akan culture make learning very interesting?	15	5	0	20
Does using the Akan culture help you to understand the concepts in geometry?	14	5	1	20
Would you like all mathematics topics taught using the Akan culture?	15	3	2	20
Geometric concepts can be found in my daily life activities	19	1	0	20
Does teaching using the Akan culture make you feel you are learning at home?	16	2	2	20
Does using the Akan culture to teach geometry make me feel proud?	17	2	1	20

Source: Focus group discussion.

Table 4 displays the summary of responses received from the Focus Group Discussions. Since the focus of the study was on conceptual understanding, we refrained from relying on tests. The discussion was conducted to find out if students really understood the concepts and how they also feel about the approach. For instance, 15 out of 20 students believe that learning is very interesting using the Akan culture. Also, 19 out of the 20 students indicated that the ethnomathematics helped them to understand the geometry concepts. Almost 18 out of the 20 students wish all mathematics topics were taught using the Akan culture, and a whopping 19 students see geometry in their daily life activities. Akan art has a lot of mathematical concepts, and I feel that I am learning at home. A resounding 18 out of the 20 students affirm this. Using artefacts and resources in the learner's environment to teach them means that students can do their independent learning at home since the materials are abound in the community. Geometric concepts can be found in my daily life activities had almost all the students responding in the affirmative.

DISCUSSION AND CONCLUSION

The response to the first research question, according to the interview data, was that the Akan culture has several links with school geometry. The analysis revealed that the activities of the Akan have several applications of geometry. This is seen in their buildings, games, cooking wares, and vocations like Kente weaving, wood carving, among others. In line with the findings of Owusu-Darko et al. (2023), which demonstrated how the Akan Symbols, like Adinkra and other utensils like earthenware, the Pots mad-houses, artefacts, and some practices of the Akan are connected with mathematical concepts, especially geometry. The study observed that the Akan culture is full of geometry, and using this culture to develop geometry concepts in the classroom was in the right direction. As demonstrated by some researchers, considering students' background when it comes to mathematics education is a prerequisite for relational understanding. It is through the relational understanding that enables learners to link what they have learnt to solving practical problems. Students taught in this format become creative, innovative, and critical in their thinking and therefore become problem solvers (Arthur, 2019; Prahmana et al., 2020).

The second research question was on how the Akan culture promotes conceptual understanding in geometry. We found that integrating the Akan culture into the teaching of geometry will promote conceptual understanding and improve academic achievement through lifelong learning. Participants in the FGD revealed that linking the Akan culture to the teaching of geometry enhances learners' relational understanding, thereby equipping learners to apply what they have learnt to solving practical problems. Some studies have demonstrated that using students' background to teach mathematics concepts enhances students' creative skills, critical thinking, and innovation problem-solving strategies (Arthur, 2019; Atta and Bonyah, 2023b). It is believed that the students are already familiar with the Akan culture. Once the concept of geometry is linked to the culture, it makes the lesson so real and thereby increases student interest, removes fear, and improves academic achievement, as found by Arthur (2019) and Arthur et al. (2022). Researchers across Africa have also come up with similar studies in their jurisdictions where local practices were linked to mathematics concepts (Atta et al., 2024; Nur et al., 2020; Sharna et al., 2021; Turugari, 2022). It must be noted that, where the environment of the student becomes an avenue for learning, the learning transcends the classroom.

Even though the core mathematics curriculum was built on the tenets of constructivism, studies have shown that teachers teach through abstraction because the curriculum itself is theoretical and abstract (Oppong-Gyebi et al., 2023). The data analysis revealed that geometry teaching must be practical-oriented since it has a lot of application to real life. Similar to what Baah-Duodu et al. (2020) observed. This outcome also adds to the voice of the other researchers who have been advocating for a paradigm shift in the instructional delivery at the Senior High School (Cardona, 2023; Desai et al., 2021; Owusu-Darko et al., 2023).

More so, this study has demonstrated that if the Akan culture is integrated into the teaching of geometry, it will produce learners who are critical thinkers, innovative, creative, problem solvers, and above all, conscious about their environment (Pacheco-Muñoz et al., 2023). These are the very principles exposed in the MOE (2010) with the hope that the student at the end will become self-reliant through innovative ways of solving real-life problems like unemployment, environmental degradation, loyalty, and respect for one another. It's worth noting that the United Nations Sustainable Development Goal Four (SDG4) believes that providing lifelong learning can accelerate global peace and security, and that is exactly what this study has come up with. We therefore conclude that the Akan culture has links with school geometry and can therefore promote students' conceptual understanding in school geometry.

On the issue of conceptual understanding, it came up that, the students are already familiar with the Akan culture, once the concept of geometry is link to the culture it makes the lesson so real and thereby increase student interest, remove fear and improve on academic achievement as found by (Arthur, 2019; Arthur et al., 2022). Researchers across Africa have also come up with similar studies in their jurisdictions where local practices were linked to mathematics concepts (Nur et al., 2020; Sharna et al., 2021; Turugari, 2022). The constructivist learning comes in where the environment of the student becomes an avenue for learning. This learning does not end in the classroom, but the classroom just sets the base for self-directed learning. The egalitarian principle has it that all human beings are the same; when the right opportunities are provided, everyone will do their best.

The analysis has revealed that a culturally-responsive mathematics instruction, such as linking the Akan culture to the teaching of geometry, enhances learners' conceptual understanding. As demonstrated by some researchers (Atta and Bonyah, 2023a; Bonner, 2021), taking student background into consideration when it comes to mathematics education is a prerequisite for relational understanding. It's through the relational understanding that enables learners to link what they have learnt to solving practical problems. Students taught in this format become creative, innovative, and critical in their thinking and therefore become problem solvers. Practically, using the Akan culture as a scaffold for Senior High School students in the Ashanti Region to learn geometry concepts is a panacea to students' poor academic achievement in mathematics, as demonstrated by this study.

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