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Effect of Ethnomathematics Approach on Senior High School Students' Achievement in Geometry

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ABSTRACT

This study investigated how ethnomathematics approach influences senior high school students' achievement in geometry. Ethnomathematics approach in this study is conceptualized as a culturally anchored, cognitively scaffolded, historically and socially mediated framework for teaching geometry. Bishop's concept of mathematical enculturation and the sociocultural theory of learning served as the study's foundations. Explanatory sequential mixed approaches were employed in the investigation. This study also employed a quasi-experimental pretest-posttest control group design. We employed a multistage sampling technique to select 140 General Art mathematics teachers and 422 General Arts students from 18 Senior High schools (SHS) to participate in the study. The Geometry Achievement Test (GAT) was used to collect data from the students, while a semi-structured interview guide was used to collect data from both mathematics teachers and students. We analysed the quantitative data using both descriptive and inferential statistics. We used thematic content analysis followed by a narrative discussion to analyse the qualitative data. The study demonstrated that teachers' ethnomathematics approach has a major impact on how they teach geometry. The Ministry of Education should give teachers professional development opportunities to strengthen their knowledge of ethnomathematics approaches and their implications for teaching and learning.

Keywords: efficacy, enhancing, ethnomathematics approach, geometry, senior high schools

Introduction

Mathematics is widely recognized for its role in fostering logical reasoning and problem-solving skills across various fields. Despite its significance, conventional methods of teaching mathematics often fail to engage students, particularly within culturally diverse classrooms. Ethnomathematics, defined by D'Ambrosio (1985) as the study of mathematical practices rooted in cultural contexts, has emerged as a promising pedagogical approach, especially for teaching geometry in senior high schools (SHS). So, emphasizing the connection between culture and mathematics, this approach seeks to make instruction more culturally relevant and meaningful (Davis, 2017a).

Bishop (1988) identified six universal mathematical activities: measuring, counting, locating, designing, explaining, and playing that offer practical entry points for integrating ethnomathematics into instruction. Geometry, in particular, provides fertile ground for this integration, with its principles evident in architectural designs, artistic patterns, and cultural artefacts (Prahmana & D'Ambrosio, 2020). However, conventional teaching methods often prioritize procedural fluency and rote memorization, overlooking the contextual and cultural dimensions of the subject (Davis, 2017b; Sevgi & Erduran, 2020). This detachment can contribute to student disengagement and underperformance, particularly in multicultural environments like Ghana.

In contrast, the ethnomathematics approach seeks to contextualize geometric concepts, making them more relatable and engaging. Studies have shown that linking geometric ideas such as symmetry, transformations, and tessellations to indigenous African patterns like Adinkra symbols and kente designs enhances students' understanding and retention (Boaler, 2016; Davis, 2010, 2016). Empirical evidence supports the effectiveness of this method in improving student achievement and problem-solving skills (Davis, 2010; Kyeremeh et al., 2023; Rosa & Orey, 2011), with positive outcomes reported in Ghanaian classrooms (Davis, 2017b; Kyeremeh et al., 2023; Opoku-Asare & Agbenatoe, 2016).

Moreover, the ethnomathematics approach fosters critical thinking, creativity, and collaborative learning by encouraging students to explore and analyse cultural experiences through mathematical lenses (Gbormittah, 2022; Gerdes, 1996; D'Ambrosio, 2001). Nevertheless, challenges persist, as teachers often lack the necessary resources and expertise to implement culturally responsive strategies effectively (Davis, 2010; Kyeremeh et al., 2023). Additionally, standardized curricula and assessment systems that favour procedural knowledge over conceptual understanding further hinder the widespread adoption of this innovative approach (Anthony & Walshaw, 2009). Addressing these barriers requires systemic reforms, including culturally responsive teacher training and the development of appropriate instructional materials (Davis, 2016).

Theoretical Framework

Sociocultural Theory of Learning

Sociocultural Theory of Learning, proposed by Lev Vygotsky in 1978, emphasizes the central role of social interaction, cultural tools, and language in the development of human cognition. Vygotsky challenged conventional views that framed learning as an isolated, internal process, arguing instead that knowledge is constructed through engagement with others within a cultural and social context. According to Vygotsky, cognitive development first occurs on the social plane (inter-psychological) before it is internalized within the individual (intra-psychological).

A central construct in Vygotsky's theory is the Zone of Proximal Development (ZPD), which refers to the range of tasks that a learner can perform with the guidance and support of a more knowledgeable other but cannot yet accomplish independently. This concept highlights the importance of scaffolding, wherein teachers or peers provide temporary support structures that are gradually removed as the learner becomes more competent. Through guided participation and dialogue, students internalize strategies and knowledge, leading to deeper and more autonomous learning.

Language plays a particularly vital role in Vygotsky's framework. It is not merely a communication tool but a fundamental mechanism through which thinking and learning are mediated. As students engage in social interactions and verbal exchanges, they appropriate cultural meanings and practices that shape their cognitive processes. In the context of Mathematics Education, Sociocultural Theory suggests that learning should be situated within culturally meaningful activities. Students' understanding of mathematical concepts can be enriched when instruction draws upon their prior experiences, cultural backgrounds, and collaborative problem-solving activities. Rather than treating mathematics as a culturally neutral or purely abstract discipline, Vygotsky's theory encourages teachers to recognize and harness the diverse cultural resources students bring to the classroom. Thus, Sociocultural Theory of Learning offers a powerful lens for examining how culturally relevant teaching approaches, such as ethnomathematics, can foster deeper mathematical understanding. Therefore, situating learning within familiar cultural frameworks and emphasizing social interaction, educators can bridge gaps between students' everyday experiences and formal mathematical knowledge, leading to enhanced engagement, comprehension, and achievement.

Mathematical Enculturation

Mathematical enculturation, as proposed by Bishop (1988), refers to the process by which individuals are inducted into the practices, values, and modes of thinking associated with mathematics as both a discipline and a cultural phenomenon. Bishop contended that mathematics is not a culturally neutral or purely abstract body of knowledge; rather, it is a human activity deeply embedded in cultural contexts. Learning mathematics, therefore, is not merely about acquiring procedures and formulas but about participating in the broader cultural practices that define mathematical thinking.

Central to Bishop's argument is the idea that every culture engages in certain fundamental mathematical activities. He identified six universal mathematical activities common to all human societies: counting, locating, measuring, designing, playing, and explaining. These activities represent ways in which humans have historically organized and interpreted their world through mathematical reasoning. Therefore, recognizing these universal practices, Bishop emphasized that mathematical ideas are developed and transmitted culturally and that learning mathematics involves adapting to the norms, values, and problem-solving methods that a society associates with mathematics.

Mathematical enculturation has significant implications for education. It suggests that teaching mathematics should not be confined to transmitting decontextualized knowledge but should actively involve students in mathematical practices that are meaningful within their cultural contexts. Through this lens, effective Mathematics Education requires acknowledging and building upon the cultural experiences that students bring to the classroom. Rather than viewing students' cultural backgrounds as obstacles, they are seen as rich resources that can support mathematical learning.

In the context of geometry education, mathematical enculturation implies that students can better grasp abstract concepts when instruction connects to culturally familiar artefacts, patterns, and spatial reasoning contexts. When students engage with geometry through activities rooted in their own cultural environments such as analysing indigenous designs, structures, and symbols they are not only learning mathematical content but also participating in the cultural practices of mathematical thinking. Thus, Bishop's notion of mathematical enculturation supports the argument that Mathematics Education must be both culturally responsive and socially situated. It offers a theoretical basis for approaches like ethnomathematics, which seek to contextualize mathematical learning within students lived cultural realities, promoting deeper understanding, motivation, and achievement.

The Sociocultural Theory of Learning (Vygotsky, 1978) and the concept of Mathematical Enculturation (Bishop, 1988) align closely in their emphasis on the social and cultural foundations of learning. Both perspectives reject the notion of knowledge as fixed and context-free, highlighting instead that learning is a dynamic, socially mediated, and culturally situated process. Vygotsky's emphasis on the role of cultural tools, language, and guided social interaction in cognitive development complements Bishop's view of mathematics as a human cultural activity into which learners must be gradually initiated. In the context of this study, which explores the effect of the ethnomathematics approach on students' achievement in geometry, the two theories provide a coherent and powerful framework. They collectively support the idea that embedding mathematical instruction within students' cultural experiences not only enhances conceptual understanding but also fosters deeper engagement and motivation. Hence, situating mathematics learning within familiar cultural practices and promoting social interaction, the study leverages both theoretical perspectives to argue for more inclusive, meaningful, and effective geometry education.

Empirical research demonstrates the efficacy of the ethnomathematics approach in enhancing students' geometry proficiency. For example, children who were taught using culturally appropriate examples outperformed those who were taught using conventional techniques in geometry tests (Gay, 2010). Owusu-Mensah et al. (2022) asserted that including cultural artefacts in geometry classes also enhanced students' ability to think spatially and solve problems. These results demonstrate how ethnomathematics can revolutionise geometry education and improve students' academic performances.

Over the years, West African Examinations Council (WAEC) Chief Examiners’ reports on Core Mathematics at the senior high school (SHS) level in Ghana have consistently highlighted students’ under-achievement in geometry-related concepts (WAEC, 2018, 2020, 2021, 2023). The reports from 2018, 2020, 2021, and 2023 particularly point to persistent difficulties in symmetry, transformations, and tessellations. This pattern of low achievement underscores the need for pedagogical interventions that are both innovative and contextually relevant. One such approach gaining traction within Mathematics Education discourse is ethnomathematics, which integrates learners’ cultural backgrounds and lived experiences into the teaching and learning process. The Ghanaian educational landscape is characterised by a strong oral tradition, a rich repository of indigenous knowledge systems, and an abundance of cultural artefacts and practices that inherently embody mathematical ideas. Geometry, in particular, is deeply embedded in Ghanaian cultural expressions such as kente weaving, adinkra symbolism, bead-making, indigenous architecture, and floor patterns. These cultural artefacts offer intuitive and tangible representations of geometric principles, often more relatable to students than abstract textbook illustrations. However, such indigenous knowledge systems are frequently marginalised in mainstream classroom instruction, which tends to rely heavily on expository methods and decontextualised content.

This study draws on the Ghanaian context not only as a backdrop but as a foundational element for reimagining geometry instruction. The ethnomathematics approach adopted involves the deliberate integration of cultural practices and artefacts in the teaching of geometry. For example, lessons on symmetry were connected to adinkra symbols, and studies of tessellations and transformations were based on kente patterns and indigenous floor designs. These culturally relevant resources served as cognitive bridges, helping students visualise and internalise abstract geometric concepts through familiar and meaningful contexts. So, embedding geometry in the cultural realities of Ghanaian students, the study aimed to foster deeper conceptual understanding, greater engagement, and improved academic performance. Preliminary findings suggest that students exposed to instruction infused with cultural elements demonstrated not only enhanced comprehension of geometric ideas but also increased motivation and participation in class activities (Bishop, 1988; D’Ambrosio, 1985, 2001; Davis, 2010, 2016; Davis & Chaiklin, 2015; Gbormittah & Yarkwah, 2025). This points to the value of grounding Mathematics Education in learners’ socio-cultural contexts, particularly in areas where achievement has historically been low.

The Ghanaian context, therefore, plays a dual role in this research: it highlights a persistent educational challenge while simultaneously offering rich pedagogical opportunities. The study contributes to the growing body of literature on culturally responsive Mathematics Education and provides a context-sensitive model for improving geometry achievement among SHS students. Through an ethnomathematics lens, the research affirms the potential of culture as a powerful resource for transforming mathematics teaching and learning in Ghana and beyond.

Research Question /Hypotheses

The study was guided by the following research question and hypotheses:
1. How do SHS teachers and students perceive the effectiveness of the ethnomathematics teaching approach in geometry instruction after its implementation?

$H_0$1: There is no statistically significant difference between the achievement of the SHS 2 students in the control and experimental groups in the pretest.
$H_0$2: There is no statistically significant difference between the achievement of the SHS 2 students in the control and experimental groups in the posttest.
$H_0$3: There is no statistically significant difference between the pretest and posttest scores of the control group and the pretest and posttest scores of the experimental group among SHS 2 students in geometry.

Research Methods

This study adopted an explanatory sequential mixed-methods approach, employing a quasi-experimental pretest-posttest design to investigate the research questions (Cohen et al., 2011). The population comprised all Senior High School (SHS) mathematics teachers and their students in Ghana's Savannah Region. A multistage sampling strategy was implemented to ensure representativeness and feasibility. The Savannah Region was selected for convenience, primarily due to the third author's residence in the area, which facilitated access to participants and reduced logistical costs (Davis & Gbormittah, 2023).

Districts within the region were selected using simple random sampling, followed by the identification of 18 SHSs through census sampling. All 140 SHS 2 mathematics teachers and intact General Arts student classrooms in the selected schools were invited to participate. Recruitment emphasized transparency, fairness, and voluntary participation, with clear communication regarding the study's purpose, procedures, and participants' rights, including the freedom to withdraw at any stage without consequences.

Out of 430 students invited, 422 agreed to participate, while eight declined due to health reasons. These decisions were respected without coercion. For the qualitative component, 22 students and 10 teachers from the experimental group were purposefully selected for interviews, considering factors such as teaching experience, gender, and district representation. This purposive sampling ensured a diverse and balanced range of perspectives, enriching the depth and contextual understanding of the qualitative findings.

Experimentation and Data Collection Instruments

We designed this study's experimental procedure to investigate the impact of the ethnomathematics method on the geometry proficiency of senior high school students. This quasi-experimental study design included pre- and post-tests for both the experimental and control groups. This design was selected to assess how well the intervention improved students' geometry comprehension and achievement while accounting for potential outside influences.

We randomly selected the schools to ensure an equal distribution of genders and intellectual aptitudes in the experimental and control groups. Prior to the intervention, we administered a geometry achievement test (GAT) to each participant to assess their baseline geometrical knowledge. This pretest served as a standard by which to measure the efficacy of the ethnomathematics approach in comparison to conventional teaching techniques. The GAT's questions evaluated both procedural and conceptual knowledge of geometry concepts, including symmetry, transformations, and tessellations. The GAT assigned 30 marks to both the pretest and posttest.

In the experimental group, teachers participated in an intensive 12-week professional development program designed to enhance their understanding and application of ethnomathematics in geometry instruction. The training focused on equipping teachers with culturally responsive pedagogical strategies, emphasising the integration of local cultural artefacts such as Adinkra symbols, kente patterns, and indigenous architectural designs into the teaching of geometric concepts. Workshops during the training introduced the foundational principles of ethnomathematics and demonstrated practical approaches to integrating these principles into classroom instruction. Facilitators provided in-depth illustrations on how Adinkra symbols could be used to teach symmetry and reflection, how kente patterns exemplify tessellations and repetitive motifs, and how indigenous Ghanaian architectural designs can be employed to explain geometric transformations such as translation, rotation, and reflection. Participants collaboratively engaged in lesson planning sessions where they developed culturally relevant lesson plans aligned with national curriculum standards. These sessions provided opportunities for teachers to co-construct meaningful learning experiences that resonated with students' cultural backgrounds. In mock teaching segments, teachers practised delivering these lessons and received constructive feedback from peers and facilitators to refine their approaches.

The instructional intervention in the experimental schools was meticulously designed to immerse students in culturally resonant, activity-based geometry lessons that bridged abstract mathematical concepts with tangible elements from their lived environments. Central to the intervention was the use of Ghanaian cultural artefacts (i.e., Adinkra symbols, kente patterns, and indigenous architectural forms) as instructional anchors for exploring core geometry concepts such as symmetry, reflection, tessellation, translation, rotation and area of geometrical shapes. This approach was grounded in the ethnomathematics framework, which emphasizes the integration of students' cultural knowledge systems into formal mathematical learning.

In practice, teachers initiated each lesson by contextualizing a geometric concept within a culturally familiar artefact. For example, during explorations of symmetry, students engaged with the Adinkra symbol 'Nkyinkyim', whose alternating curves and straight lines provided a rich context for identifying lines of symmetry, rotational properties, and reflective balance. Teachers scaffolded this process by guiding students to draw, fold, and trace the symbols, encouraging them to articulate their reasoning and justify the geometric features they identified. These hands-on activities made abstract ideas visually and kinaesthetically accessible, promoting conceptual clarity and retention.

To teach tessellation and spatial patterns, teachers introduced kente cloth as a mathematically rich text. Students examined recurring ideas and patterns in kente designs, mapping translations and identifying congruent shapes and tiling structures. This was followed by guided design tasks in which students created their own tessellation patterns inspired by indigenous weaving principles, applying their understanding of geometric rules in a creative context. These exercises not only deepened spatial reasoning but also fostered cultural appreciation, as students recognized the mathematical sophistication embedded in artisanal practices.

Instruction extended beyond the classroom into the architectural layout of indigenous Ghanaian compounds, which provided authentic models for understanding transformations, scale, and orientation. Through field-based learning and image analyses, students identified examples of reflectional and rotational symmetry in housing layouts, circular designs in courtyards, and proportional reasoning in room arrangements. This situational learning bridged formal geometry with local environmental literacy, enhancing relevance and contextual grounding.

Group projects were an integral component of the intervention, requiring students to either analyse existing artefacts or generate original geometric designs rooted in cultural contexts. These collaborative tasks fostered peer dialogue, cooperative problem-solving, and critical thinking. Teachers served as facilitators, prompting learners to make connections between mathematical vocabulary and cultural symbolism, and encouraging iterative thinking through feedback and peer evaluation. Regular

reflective discussions were held to consolidate learning, allowing students to express their interpretations and insights, thus reinforcing both cognitive and affective dimensions of learning.
The instructional sequence was carefully structured to build from recognition to analysis and then to application, ensuring a coherent learning trajectory. Tasks were differentiated to accommodate diverse readiness levels, with formative assessments embedded in the learning cycle to monitor progress and provide timely support. The lessons were not merely illustrative; they were grounded in rigorous mathematical inquiry framed within familiar cultural settings, which enhanced motivation, sense-making, and long-term understanding.

In this study, the ethnomathematics-based instruction was not an additive enrichment but a transformative reorientation of mathematics teaching. It positioned students as active participants in knowledge construction, empowered by the validation of their cultural experiences. The instructional design demonstrated how cultural artefacts can function as authentic mathematical tools, bridging the gap between classroom abstraction and everyday reality, thereby reconfiguring Mathematics Education as a culturally sustaining and intellectually robust endeavour. Figure 1 illustrates geometric elements in Ghanaian cultural artefacts: Adinkra symbols, kente patterns, and indigenous architecture that guided instruction in the experimental group.

Figure 1

Geometry in Ghanian Cultural Designs

In contrast, the control group received instruction through conventional teaching methods that emphasized procedural fluency and rote memorization, in alignment with the Ministry of Education's (MOE, 2010) mathematics curriculum for senior high schools. Teachers in this group introduced geometry to their students mainly by presenting two-dimensional and three-dimensional shapes, etc., prompting students to identify and label them. This approach is repeated for learning other complex geometrical concepts. The instruction focused on demonstrating how to calculate areas and volumes of these shapes, using examples with specified dimensions. The approach lacked contextual or culturally responsive elements and was primarily centred on mechanical repetition and formulaic problem-solving. To maintain the effectiveness of the experimental design, the researchers observed the teaching process during the intervention period. The 12-week intervention involved SHS teachers delivering three geometry lessons per week, each lasting 40–60 minutes, consistent with standard classroom practice in Ghana. Rather than conducting formal lesson observations, the research team employed routine monitoring strategies to track the integration of ethnomathematics. This included regular reviews of lesson materials, teaching aids, and student outputs. The monitoring process confirmed that teachers consistently incorporated relevant cultural artefacts into instruction and that students were meaningfully engaged throughout the program. Teachers participated in biweekly feedback meetings, where they shared challenges, received additional guidance, and discussed strategies for improvement. We developed the Geometry Achievement Test (GAT) based on the Ghanaian national curriculum (MOE, 2010), cultural artefacts in the Ghanaian context (see Figure 1), and validated international assessment frameworks, such as Trends in International Mathematics Science Study [TIMSS], (2007, 2011) and National Council of Teachers of Mathematics [NCTM], (2007). Conducting a pilot test with a similar group of students to assess the reliability and clarity of the instruments. Few items that were not clear to the students on GAT were reviewed to elicit valid responses. The GAT achieved a Cronbach's alpha of 0.82, indicating high internal consistency. The GAT was designed to assess both procedural and conceptual understanding of geometry topics relevant to the curriculum as shown in appendices C and D.

We also conducted semi-structured interviews (see appendices A and B) for teachers and students from the experimental group to understand the benefits and challenges of implementing the ethnomathematics approach in the classroom. The experiment aimed to comprehensively evaluate the effectiveness of the ethnomathematics approach while adhering to all ethical guidelines. All participants gave their informed consent before the study started, and we upheld confidentiality at all times.

Data collection and analysis procedures

To find out how the ethnomathematics method affected how well students did in geometry, the data collection process for this study was carefully designed to make sure that the data collected was valid and reliable. We used both quantitative and qualitative methodologies to thoroughly understand the effects of the intervention. We carried out the process in stages, beginning with preparation work and concluding with the examination of data from multiple sources. The initial stage of the data-gathering procedure included a pretest for all participants in the experimental and control groups. We created the geometry achievement test (GAT) based on literature (NCTM, 2007; TIMSS, 2007, 2011) to assess students' foundational geometry knowledge and abilities. In line with the national curriculum, the test comprised a combination of procedural and conceptual questions on subjects like symmetry, transformations, and tessellations. We administered the pretest under uniform circumstances to ensure consistency and impartiality.

After the pretest, the experimental group received the intervention. We trained the experimental group's teachers in the use of the ethnomathematics approach, focusing on integrating relevant cultural practices and artefacts into geometry instruction. Throughout the 12-week intervention, researchers maintained close communication with teachers to support implementation, address emerging challenges, and reinforce the consistent use of culturally grounded strategies. This collaborative engagement ensured that the incorporation of ethnomathematical elements remained both contextually relevant and pedagogically effective, contributing to sustained student engagement and alignment with the study's goals. A direct comparison between the two approaches was made possible by the control group's teachers continuing to use conventional teaching techniques, which mirrored those of teachers in the field. The intervention period concluded with a post-test for all participants. Because the posttest and the pretest were identical, the researchers were able to compare the achievement of the experimental and control groups and measure changes in the students' achievement in geometry. To ensure uniformity, the test was administered in the same standard setting as the pretest. The effect of the ethnomathematics method on students' achievement was ascertained using a quantitative analysis of the pretest and posttest data.

To analyze the qualitative data, we employed thematic analysis, following Braun and Clarke's (2006) six-phase framework: familiarization with the data, generating initial codes, searching for themes, reviewing themes, defining and naming themes, and producing the final report. Transcripts from the focus group discussions were read multiple times to ensure immersion and understanding. The first codes were created based on what participants said and then grouped into larger themes that showed common experiences and views about the ethnomathematics approach. We employed several strategies to enhance trustworthiness. Credibility was established through member checking that selected participants reviewed summarized findings to verify accuracy and resonance with their experiences. We supported transferability by providing detailed descriptions of the context and participants. So, keeping an audit trail of coding decisions and analytical memos, reliability was guaranteed. Confirmability was addressed by triangulating the qualitative data with the quantitative findings and involving multiple researchers in the coding process to minimize bias. These measures collectively contributed to a rigorous and trustworthy analysis of the qualitative data, providing rich insights into how the intervention influenced participants' educational experiences.

Generally, we coded and analysed the collected data using descriptive and inferential statistics specifically, an independent samples *t*-test, a paired samples *t*-test, and a two-way ANOVA test. The biographical data underwent analysis using frequency counts and percentages. Research Question 1 was addressed through thematic content analysis followed by narrative discussion. Hypothesis 1 was tested using an independent samples *t*-test. A one-way ANCOVA was applied for Hypothesis 2 to account for potential covariates. Hypothesis 3 was examined using a paired samples *t*-test. We conducted the inferential analysis at 0.05 error margin, as the presentation of the results will reveal.

Results

The respondents' biographical information is displayed in Table 1.

Table 1

Biographical Data of the Respondents

	Teachers		Students	
Variable		N%		N%
Gender	Male	97 (69.3)	Male	176(41.7)
	Female	43(30.7)	Female	246(58.3)
	Total	140(100.0)	Total	422(100.0)
Age (in years)	18 – 25 years	19(13.6)	Less than 10 years	0(0)
	26 – 33 years	81(57.9)	11 – 18 years	402(95.3)
	Above 33 years	40(28.6)	Above 19 years	20(4.7)
	Total	140(100.0)	Total	422(100.0)
Teaching Experience	Below 5 years	37(26.4)	0	0
	5 – 8years	54(38.6)	0	0
	9 – 12 years	41(29.3)	0	0
	Above 12 years	8(5.7)	0	0
	Total	140(100.0)	0	0
Academic Qualification	Bachelor Degree	117(83.6)	0	0
	Master’s Degree	23(16.4)	0	0

	Total	140(100.0)	0	0
Group	Control	81(57.9)	Control	216(51.2)
	Experimental	59(42.1)	Experimental	206(48.8)
	Total		Total	422(100)

Table 1 shows the discrepancy between the gender distribution of the student body (58.3%) and the teacher population (69.3%) may have an effect on classroom dynamics. Students were mostly in the typical high school age range of 11 to 18 years, while teachers were comparatively young, with the majority (57.9%) being between 26 and 33 years old. A balance between early-career and mid-career professionals is suggested by this teacher age profile, which may help to explain a range of teaching philosophies and experiences. With 38.6% having taught for 5–8 years and 29.3% for 9–12 years, the majority of teachers had moderate experience. Only 5.7% of teachers had more than 12 years of experience, and fewer teachers (26.4%) had less than 5 years, suggesting that there aren't many highly experienced teachers. The teaching workforce is highly qualified, as seen by the fact that the majority of teachers (83.6%) had bachelor's degrees and only 16.4% had master's college degrees. Additionally, the participants were split almost equally between the experimental and control groups; 51.2% of students and 57.9% of teachers were in the control group.

$H_0$1: There is no statistically significant difference between the achievement of the SHS 2 students in the control and experimental groups in the pretest.

Table 2 presents the independent samples t-test for equality of means between the experimental and control groups in the pretest.

Table 2

The Independent Samples T-test For Equality of Means for the Control and Experimental Groups in the Pretest

	Levene's Test for Equality of Variances		t-test for Equality of Means			95% confidence interval of the difference	
	F	Sig.	T	Df	Sig. (2-tailed)	Lower	Upper
Equal variances not assumed	15.607	0.00	1.253	406.603	0.21	-0.1298	0.5865

The assumption of homogeneity of variances was broken in Table 2, according to the findings of the independent samples t-test, which focuses on the scenario in which equal variances are not assumed. Levene's Test for Equality of Variances yielded a F value of 15.607 at a significance level of 0.00, $p < 0.05$ which served as the foundation for this conclusion. The *t*-test results must be interpreted under the "Equal variances not assumed" condition since the equal variances assumption cannot be maintained because this significance level is less than the conventional alpha value of 0.05. The independent samples t-test produced a t-value of 1.253 with 406.603 degrees of freedom and a two-tailed significance level of 0.21 under these circumstances. This result means that the achievement of students in geometry did not differ between the control and experimental groups in the pretest.

$H_0$2: There is no statistically significant difference between the achievement of the SHS 2 students in the control and experimental groups in the posttest.

Table 3 shows one-way ANCOVA test for equality of means for the control and experimental group in the posttest. Preliminary checks confirmed that the assumptions of homogeneity of regression slopes and normality of residuals were met with F value of 4.152 and p = 0.07 (Tabachnick & Fidell, 2013).

Table 3

Test of Between Subject Effects

Source	Type III Sum of Squares	df	Mean Square	F	Sig.	Partial Eta Squared
Corrected Model	9843.974[a]	2	4921.987	441.303	0.00	.68
Intercept	10396.057	1	10396.057	932.105	0.00	.69
Pretest	22.616	1	22.616	2.028	0.20	.01
Group	9842.362	1	9842.362	882.461	0.00	.68
Error	4673.239	419	11.153			
Total	80730.000	422				
Corrected Total	14517.213	421				

a. R Squared = .678 (Adjusted R Squared = .677)

After adjusting for pretest scores, the analysis in Table 3 showed a significant main impact of group on posttest scores ($F(1, 419) = 882.46$, $p < 0.05$, partial $\eta^2 =.68$), suggesting a substantial effect size. This figure indicates that 68% of the variation in the posttest results was explained by the treatment group, indicating a strong influence on the students' posttest achievement in geometry. $F(1, 419) = 2.03$, $p = 0.20$, and partial $\eta^2 =.01$ indicated that the relationship between the pretest and posttest scores was not statistically significant. This conclusion suggests that the students' posttest scores were not much influenced by their pretest performance. The whole model had a substantial effect size (partial $\eta^2 =.68$) and was significant ($F(2, 419) = 441.30$, $p <.05$). The intercept term, which reflected the baseline difference in scores, was likewise significant, $F(1, 419) = 932.11$, $p < 0.05$. The group factor and other controlled variables accounted for the majority of the variance in posttest scores as shown by the corrected total variance (Total Sum of Squares = 14,517.213). The results demonstrate how well the therapy intervention improved the geometry posttest scores of SHS students. The significant impact of the treatment on learning outcomes is highlighted by the huge effect size for the group component (partial $\eta^2 =.68$). The non-significant contribution of the pretest suggests that prior knowledge, as measured by it, did not substantially predict posttest achievement once the group effect was accounted for.

$H_0$3: There is no statistically significant difference between the pretest and posttest scores of the control group and the pretest and posttest scores of the experimental group among SHS 2 students in geometry.

Table 4 shows the paired samples test for the control and experimental group.

Table 4

Paired Samples Test for the Control and Experimental Group

		Paired Differences							
					95% Confidence Interval of the Difference				
		M	SD	Std. Error Mean	Lower	Upper	T	df	Sig.(2-tailed)
Pair 1	Exp.	13.40	4.10	0.2834	12.8393	13.9568	47.279	205	.00
Pair 2	Cont.	3.50	3.40	.2285	3.0682	3.9688	15.401	215	.00

The paired samples *t*-test results in Table 4 indicate significant improvements from pretest to posttest for both the experimental and control groups. For the experimental group, the mean difference between posttest and pretest scores was 13.3981, with a standard deviation of 4.0673. The paired samples t-value of 47.279 and a p-value of 0.00, $p < 0.05$ indicate that this improvement is statistically significant with Cohen's d of 3.29. The 95% confidence interval for the mean difference, ranging from 12.8393 to 13.9568, confirming the significance of the result. Similarly, the control group also showed a statistically significant improvement, with a mean difference of 3.5185 and a standard deviation of 3.3577 with Cohen's d of 1.05. The paired samples t-value of 15.401 and a p-value of 0.00, $p < 0.05$ support this conclusion, with the 95% confidence interval for the mean difference (3.0682 to 3.9688) further affirming the result. These findings demonstrate that both groups improved significantly, though the experimental group experienced a much larger mean improvement compared to the control group.

RQ1: How do SHS teachers and students perceive the effectiveness of the ethnomathematics teaching approach in geometry instruction after its implementation?

The ability of the ethnomathematics method to enhance geometry education and learning has been praised by both teachers and students. Both groups acknowledged its benefits, which are consistent with modern pedagogical concepts while also pointing out some implementation-related challenges. Teachers stressed that the ethnomathematics approach was learner-centred and in line with the demands of the new curriculum. A teacher commented, "*This approach shifts the focus from a teacher-dominated instruction model to a student-centred learning process.*" One student said, "*I feel like I have more control over my learning because I get to work through the problems myself, with my teacher guiding me only when needed.*" Students also experienced empowerment. It adds excitement and enjoyment to the lessons.

The activity-based character of the ethnomathematics approach was another widely acknowledged advantage. "*The practical activities spark students' interest and keep them engaged in ways I've not seen before,*" one teacher said, describing how the hands-on activities created a vibrant classroom environment. One student shared, "*The activities make mathematics feel like play.*" Other students agreed. "*I no longer fear making mistakes, and I like fixing issues.*" As one teacher put it, "*I've noticed that my students approach geometry problems with less fear and more curiosity.*" Teachers also emphasised how this strategy promoted creative thinking while lowering students' anxiety. One student concurred, stating, "*I feel more confidence after doing the actual tasks.* " Understanding how formulas operate is much more important than simply memorising them.

Teachers and students both cited the teaching and learning resources' flexibility as another important strength. Teachers found that employing culturally relevant materials, such Adinkra symbols, greatly improved their students' comprehension of mathematical ideas. A teacher said, *"When I use Adinkra symbols in my lessons, students suddenly understand that mathematics isn't just something in their textbooks but part of their daily lives."* Students found these symbols especially important, as one student put it: *"It was amazing to see mathematics in our* indigenous *icons. I realised that mathematics has applications beyond the confines of the classroom.* Students' understanding of geometry and its practical uses was enhanced by this link between cultural heritage and classroom instruction.

Teachers particularly valued how students were able to connect mathematical ideas to their cultural backgrounds through reflection using the ethnomathematics approach. According to a teacher, "*Students find geometry more relevant and meaningful because they see how it relates to their culture." "I was surprised to learn that mathematics is part of our cultural heritage,"* one student said, echoing this attitude. It has made me proud of my culture and altered my perspective on the matter.

Notwithstanding its many benefits, the ethnomathematics approach presented challenges to both teachers and students. Teachers reported that the hands-on activities frequently took longer than conventional methods, with one teacher explaining, *"While these activities are effective, it's challenging to cover the entire curriculum within the allotted time."* Students also reported difficulties with group activities, with one student sharing, *"Sometimes, not everyone in the group participates equally, which can make it harder for the group to finish the task."* A few students initially had trouble understanding the connections between mathematical concepts and cultural symbols, but these problems were resolved with additional explanations and assistance from the teacher.

To sum up, the ethnomathematics approach has been a transforming teaching and learning strategy for both educators and learners. Geometry teachings are now more interesting, approachable, and significant because of its learner-centred and activity-based methodology, cultural relevance, and utilisation of flexible teaching tools. As summed up by one teacher, *"This approach has brought mathematics alive in my classroom."* One student also asserted that *"mathematics is no longer boring, it's fun and connected to my life."* Even while there are still certain challenges to overcome, the enthusiasm that both teachers and students share shows how the ethnomathematics method has the potential to completely transform mathematics teaching in geometry lessons. Both teachers and students fervently support its broader implementation to improve Mathematics Education in various school settings.

Discussion

When we shifted from conventional, textbook-driven geometry instruction to lessons grounded in students' cultural experiences, the impact was immediate and unmistakable. Students previously disengaged under rote methods began participating more confidently and understanding concepts more deeply. For example, incorporating familiar visual forms such as Adinkra symbols, market layouts, and local architecture made abstract ideas like symmetry and reflection feel accessible and relevant. What once required repeated explanation was now grasped intuitively. This transformation closely mirrors findings by Maryati and Prahmana (2019), whose Indonesian students readily understood geometric transformations through indigenous bamboo-weaving patterns, demonstrating how cultural familiarity can unlock mathematical understanding.

Our ethnomathematics approach followed a clear pedagogical arc; artefact exploration, guided discussion, and abstraction. This structure enabled students to begin with what they knew, articulate insights collaboratively, and then build toward formal understanding. It closely parallels the method used in Munthahana and Budiarto's (2020) study of the Panataran temple in Java, where geometric and probabilistic reasoning emerged from guided exploration of historical reliefs. Their results, like ours, showed that embedding learning in culturally resonant contexts reduces cognitive overload and expands the learner's Zone of Proximal Development.

Ghana-specific research strengthens this picture. For example, Opoku-Asare and Agbenatoe (2016) and Kyeremeh et al (2023) found that lessons using kente and stool geometry improved both performance and mathematical identity. Similarly, Owusu-Mensah, Kwame, and Yeboah (2022) reported gains when clay pot artefacts framed geometry lessons. Students in our experimental group not only achieved higher scores but also showed greater confidence and engagement. Crucially, they exceeded Ghana's TIMSS 2019 Grade 8 geometry average, a benchmark often linked to abstract, teacher-centred instruction (Mullis et al., 2020). These gains were not accidental. Weekly teacher planning clinics were vital for ensuring that cultural connections were explicitly maintained throughout instruction, addressing the caution raised by Nasir, Hand, and Taylor (2008) that without deliberate mediation, cultural knowledge and school mathematics remain disconnected.

In contrast, students in the control group taught through teaching by telling and textbook exercises which reflected the normal practices of teachers in the Ghanaian classroom struggled. Their lessons, lacking meaningful context or differentiation, placed the full cognitive burden on learners, echoing concerns raised by Vygotsky (1978) and Bishop (1988) that learning must not be devoid of the students' cultural, historical and social contexts. Without access to cultural referents or collaborative meaning-making, students failed to internalize concepts effectively. Instruction moved linearly and uniformly, rarely responding to students' emerging understanding, often leaving them bored, frustrated, or both. Misconceptions remained unaddressed, and individual strengths were rarely activated. As Tomlinson (2014) argued, such a lack of differentiation undermines both cognitive and affective dimensions of learning. Mathematical identity suffered, engagement declined, and learning became compliance-based.

The stark contrast in outcomes between the two groups is best understood not as a reflection of student ability, but of pedagogical design. In culturally grounded classrooms, students encountered mathematics as something connected to their world, discussed in community, and abstracted only after deep, shared understanding. These contexts provided what Bishop (1988) calls "enculturation cues," framing students as competent learners within a meaningful mathematical space. Every artefact examined and every conversation had was a mediational tool that scaffolded students' ascent into formal mathematical thought, as Vygotsky (1978) and D'Ambrosio (2001) describe.

Ultimately, our study reinforces a growing consensus that geometry taught through the lens of students lived experiences is not only more engaging but also more effective. What distinguished our work was not just the use of cultural artefacts, but the sustained teacher collaboration that ensured those artefacts remained central throughout instruction. In doing so, we kept the cultural bridge open long enough for deep understanding to form. Where conventional methods presented geometry as a distant abstraction, our approach made it a familiar, shared, and contextually meaningful journey.

Conclusion and Implications

This study affirms the transformative impact of culturally grounded instruction on students' conceptual understanding and achievement in geometry. Ethnomathematics approach enabled students to access mathematical ideas through meaningful and socially mediated experiences within familiar cultural context. The resulting gains in performance, engagement, and confidence highlight the power of pedagogy that bridges learners' informal knowledge systems with formal academic content. In contrast, the conventional method's abstract, decontextualized instruction limited both cognitive development and affective growth, underscoring the limitations of a one-size-fits-all approach to mathematics education.

Educators must reimagine mathematics as a culturally situated practice rather than a neutral set of procedures. Integrating students' cultural experiences into instruction is should not be an optional enhancement but as essential tool for equity, relevance, and deep learning. Teacher preparation programs, curriculum designers, and policymakers must prioritize culturally responsive methodologies that align with Vygotskian principles of mediation, scaffolding, and enculturation. When mathematics becomes a shared, meaningful practice rooted in the lives of learners, it fosters not only academic success but also enduring identity formation and empowerment learning outcomes that are foundational to long-term participation in STEM and lifelong learning.

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Appendix A

Interview Protocol for Teachers

Objective: To explore teachers' perceptions of the ethnomathematics approach in improving geometry instruction and learning, focusing on its benefits, challenges, and cultural relevance.

Section A. General Information

1. Participant's role: Teacher
2. How long have you been teaching mathematics?
3. What is your experience with the use of the ethnomathematics approach?

Section B: Teachers' perceptions of the ethnomathematics approach

1. How would you describe your overall experience with the ethnomathematics approach in teaching geometry?
2. In what ways do you think this approach aligns with the current curriculum?
3. Can you describe how the ethnomathematics approach changes your role as a teacher?
4. How does the learner-centred nature of this approach impact student engagement and participation? Can you share an example?
5. What effect do the activity-based components have on students' understanding and enjoyment of geometry?
6. How have culturally appropriate resources (e.g., Adinkra symbols) influenced students' understanding of mathematical concepts?
7. What challenges have you encountered in implementing the ethnomathematics approach?
    a. Time constraints?
    b. Balancing hands-on activities with curriculum coverage?
8. How do you address situations where students struggle to relate cultural symbols to mathematical concepts?
9. Have you observed any difficulties in group activities (e.g., unequal participation)? How have you managed these issues?
10. How do you think the ethnomathematics approach has changed students' attitudes toward mathematics?
11. Would you recommend this approach for wider adoption in Mathematics Education? Why or why not?

Appendix B

Interview Protocol for Students

Objective: To explore students' perceptions of the ethnomathematics approach in improving geometry instruction and learning, focusing on its benefits, challenges, and cultural relevance.

Section A. General Information

4. Participant's role: Student
5. How long have you been learning mathematics?
6. What is your experience with the learning through the ethnomathematics approach?

Section B: Students' perceptions of the ethnomathematics approach

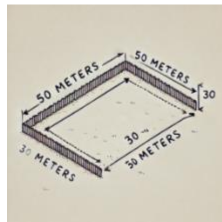
1. How would you describe your experience learning geometry through the ethnomathematics approach?
2. What is different about this method compared to conventional ways of learning math?
3. How has the learner-centred nature of this approach impacted your learning experience?
   a. Do you feel more in control of your learning?
   b. What do you like most about the activity-based lessons?
4. Can you give an example of an activity you enjoyed and why?
5. How do you feel about using cultural resources like Adinkra symbols to learn mathematics?
   a. Did this change how you view math in your everyday life?
6. What challenges have you faced when learning through the ethnomathematics approach?
   a. Were there times when you didn’t understand the connection between cultural symbols and mathematics?
7. How do you feel about group activities?
   a. Were there times when some group members didn’t participate equally? How did that affect your learning?
8. How has the ethnomathematics approach influenced your attitude toward mathematics?
9. What changes or improvements would you suggest for this approach?
10. Would you like this method to be used more often in your mathematics classes? Why or why not?
11. Is there anything else you’d like to share about your experience with the ethnomathematics approach?
12. Do you have any recommendations for improving how this approach is implemented?

Appendix C

Geometry Achievement Test (GAT)-Pretest

Answer all questions. This is only for research purposes.

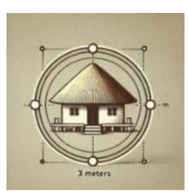
1. A farmer wants to fence a rectangular piece of land measuring 50 meters by 30 meters. What is the total length of fencing needed? If fencing costs 20 Ghana cedis per meter, calculate the total cost.



2. A kente cloth pattern has repeated triangles and squares. If the length of one side of the square is 4 cm and the base of the triangle is 6 cm with a height of 5 cm, calculate the total area covered by 3 squares and 2 triangles.

3. The Adinkra symbol 'Eban' represents safety and security. It consists of a circle with a diameter of 8 cm surrounded by a square. Calculate the area of the square if each side is equal to the circle's diameter.

4. In indigenous Ghanaian architecture, some houses have circular bases. If the radius of a house's circular base is 3 meters, calculate the area covered by the base.



5. Identify the type of tessellation shown in this kente cloth pattern. Justify your answer by describing the properties of the shapes used.

6. Using the Adinkra symbol 'Nkyinkyim,' which consists of curved and straight lines, describe how the concept of transformation (translation, reflection, or rotation) is applied to create its repetitive patterns.

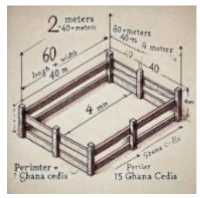
7. Design your own geometric pattern for a piece of kente cloth, using at least two different shapes (e.g., triangles and hexagons). Explain how the shapes fit together without leaving gaps."

Appendix D

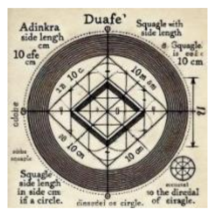
Geometry Achievement Test (GAT)-Posttest

Answer all questions. This is only for research purposes.

1. A decorative floor design includes repeated circles and rectangles. If the radius of each circle is 3 cm and the dimensions of the rectangle are 5 cm by 8 cm, calculate the total area covered by 4 circles and 3 rectangles.



2. The Adinkra symbol 'Duafe' consists of a square with a side length of 10 cm inscribed in a circle. Calculate the area of the circle if its diameter is equal to the square's diagonal.



3. A village water well has a circular opening with a radius of 2.5 meters. Calculate the area of the opening.

4. Identify the type of tessellation shown in a woven basket pattern. Justify your answer by describing the properties of the shapes used (e.g., equilateral triangles, or squares).

5. Using the Adinkra symbol 'Eban,' which consists of straight lines and repeated arcs, describe how the concept of symmetry (reflection, rotation, or translation) is applied to create its repetitive patterns.

6. Create your own design for a floor tile using at least two different shapes (e.g., pentagons and circles). Explain how the shapes fit together seamlessly without leaving gaps.