

The impact of integrating Ghanaian ethnomathematical practices on students' achievement in trigonometry

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ABSTRACT

This study examined the impact of integrating Ghanaian ethnomathematical practices into the teaching and learning of trigonometry among Senior High School students in the Bono Region of Ghana. Anchored in the pragmatist paradigm, the study adopted a sequential explanatory mixed methods design. The quantitative phase involved a quasi-experimental approach and survey, while the qualitative phase used semi-structured interviews to explain students' learning experiences. A sample of 368 students was selected from four Senior High Schools using multi-stage sampling. Data were collected through a Trigonometry Achievement Test, a structured questionnaire, and a semi-structured interview guide. Quantitative data were analysed using Analysis of Covariance (ANCOVA) and one-sample *t*-tests, while qualitative data were analysed thematically. The ANCOVA results showed that ethnomathematical instruction had a statistically significant and large effect on students' posttest achievement in trigonometry, $F(1, 364) = 71.99, p < .001$, partial $\eta^2 = .165$, after controlling for pretest scores. Students reported moderate but consistent challenges, particularly around limited prior knowledge of traditional practices and difficulty translating cultural examples into formal mathematical procedures. The qualitative findings revealed that cultural examples such as kente weaving, roofing construction, basketry, traditional measurement, and farming layouts made trigonometry more practical, visual, and engaging. The study concludes that incorporating Ghanaian ethnomathematical practices into the classroom can improve students' achievement and learning experiences in trigonometry when instruction is carefully planned, well-resourced, and explicitly connected to formal mathematical concepts.

Keywords: Ethnomathematics, trigonometry, culturally responsive pedagogy, Ghanaian cultural practices, Senior High School mathematics.

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INTRODUCTION

Mathematics is central to scientific thinking, technological advancement, problem-solving, and national development. At the Senior High School level, it serves as a foundation for further studies in science, engineering, technology, economics, and other fields that require logical and quantitative reasoning. However, despite its importance, many students continue to experience difficulty in learning mathematics, particularly abstract

topics such as trigonometry (Nanmumpuni and Retnawati, 2021; Owusu et al., 2025). Trigonometry involves concepts such as angles, ratios, bearings, elevation, depression, sine, cosine, and tangent. These ideas are useful in real-life activities such as construction, navigation, surveying, roofing, design, and measurement. Yet, in many classrooms, trigonometry is often taught mainly through formulas, rules, and repeated textbook

exercises. This approach may help students practise procedures, but it does not always help them understand the meaning behind the concepts. As a result, learners may memorise trigonometric ratios without being able to apply them meaningfully to practical situations (Owusu, 2023; Sayster, 2023).

In Ghana, students' performance in trigonometry has remained a concern in both school-based and national assessments. Obeng et al. (2024) identified persistent errors in problem interpretation and procedural selection among Ghanaian Senior High School students, while Owusu et al. (2025) documented widespread academic struggles across student programmes of study. These difficulties are not merely procedural; they reflect a deeper disconnect between the way trigonometry is typically taught and the cultural and experiential world students inhabit. Ghanaian communities contain rich mathematical resources in practices such as kente weaving, Adinkra symbol design, roofing construction, carpentry, land measurement, farming layouts, and basketry, activities that involve angles, ratios, slopes, direction, symmetry, and spatial reasoning. Yet these resources are rarely drawn upon systematically in mathematics classrooms.

Ethnomathematics, as introduced by D'Ambrosio (1985), offers a principled basis for bridging this gap. The field recognises that mathematical reasoning is embedded in cultural practices and that learners may develop stronger conceptual understanding when instruction draws on familiar cultural contexts. While several Ghanaian studies have examined ethnomathematics in relation to geometry, general mathematics, or teacher attitudes, few have tested its effect on students' achievement in trigonometry through a rigorous quasi-experimental design (Asare, 2026; Gbormittah et al., 2025; Kusi and Bonyah, 2025). This study examines whether integrating Ghanaian ethnomathematical practices improves students' posttest achievement in trigonometry after controlling for prior knowledge, identifies the specific challenges students face during such instruction, and explores students' perceptions and experiences of learning trigonometry through culturally grounded approaches.

LITERATURE REVIEW

Theoretical framework

The study is grounded in three complementary theoretical perspectives: Ethnomathematics Theory, Constructivist Learning Theory, and Culturally Responsive Pedagogy. Ethnomathematics Theory, developed by D'Ambrosio (1985), challenges the assumption that legitimate mathematical knowledge exists only in formal schooling. It recognises that cultural communities engage in mathematical reasoning through everyday activities such as measuring, designing, constructing, and organising

space. Bishop's (1988) concept of mathematical enculturation extends this argument by identifying counting, locating, measuring, designing, playing, and explaining as mathematical activities found across cultures (Bishop, 2002). For trigonometry, practices involving roofing, land measurement, navigation, and construction offer particularly appropriate contexts because they involve measurable relationships among angle, direction, height, distance, and inclination.

Constructivist Learning Theory, drawing on Piaget's cognitive constructivism and Vygotsky's (1978) social constructivism, views learning as an active process in which new knowledge is constructed through prior experience, guided interaction, and reflection. Culturally familiar contexts can serve as starting points for the construction of meaning, enabling students to move from practical observation to formal trigonometric representation when the teacher provides appropriate scaffolding (Chand, 2024; Vintere, 2018). Culturally Responsive Pedagogy, as articulated by Gay (2013) and Ladson-Billings (1995), holds that teaching becomes more meaningful when it reflects learners' cultural backgrounds and ways of knowing, and requires that teachers move beyond cultural awareness towards deliberate and explicit connections between cultural examples and formal mathematical structures (Gbormittah et al., 2025).

Ethnomathematics and mathematics achievement

The theoretical foundations of ethnomathematics were established by D'Ambrosio (1985), who argued that every cultural group develops its own mathematical practices. Gerdes (2001) demonstrated that African artefacts and construction processes embody sophisticated mathematical reasoning concerning pattern, measurement, and spatial organisation. More recent reviews have confirmed that cultural games, weaving, buildings, and indigenous measurement practices can function as meaningful resources for mathematics instruction (Batiibwe, 2024; Howlader and Sarkar, 2025; Owusu-Darko et al., 2023). Batiibwe's (2024) review of 61 studies concluded that ethnomathematics can serve as a pedagogical, learning, and assessment approach, but emphasised that its effectiveness depends on the quality of instructional planning and the explicitness of connections drawn between cultural practice and formal mathematical concepts.

Within Ghana, Asare (2026) found that ethnomathematics-based instruction was positively associated with students' attitudes towards mathematics and their ability to connect mathematical ideas to real-life cultural contexts. Owusu-Darko et al. (2023, 2024) demonstrated connections between Akan informal ethnomathematics and school-based mathematics in mensuration and geometry. Gbormittah et al. (2025) documented a gap

between Senior High School teachers' stated recognition of culturally responsive pedagogy and its actual integration into instruction and assessment. Gbormittah et al. (2026) reported that an ethnomathematical approach had a meaningful positive influence on students' geometry achievement. Kusi and Bonyah's (2025) systematic review found that culturally responsive and ethnomathematical approaches were associated with gains in performance, engagement, and conceptual understanding. Despite this growing body of evidence, the existing literature is concentrated in geometry and general mathematics, and its applicability to trigonometry cannot be assumed without subject-specific investigation.

Student challenges in ethnomathematical instruction

The literature also identifies challenges that accompany ethnomathematical instruction. Atta (2024), Atta et al. (2025) and Okyere (2022) noted that cultural examples may create confusion when they are unfamiliar to learners. Lerman (2012) identified the transfer problem, the difficulty students face in moving from contextualised knowledge to formal, decontextualised mathematical procedures, as a fundamental concern. Ghaemi and Boroushaki (2025) argued that culturally relevant teaching requires adequate instructional support and teacher preparation. Students' perceptions of ethnomathematical instruction are also important because an intervention may influence learning through mechanisms that achievement scores alone do not capture. When students recognise mathematical relationships in familiar cultural activities, they may perceive trigonometry as useful and attainable, contributing to participation, confidence, and persistence (Nasir et al., 2008; Marshall et al., 2017).

MATERIALS AND METHODS

Research design and paradigm

The study is grounded in the pragmatist paradigm and adopted a sequential explanatory mixed methods design (Creswell and Plano Clark, 2023). Quantitative data were collected and analysed first, followed by qualitative data collection to explain and deepen the interpretation of the quantitative findings. The quantitative phase employed a quasi-experimental design and a structured questionnaire, while the qualitative phase used semi-structured interviews guided by a phenomenological approach. This design was chosen because the study sought both to measure the effect of ethnomathematical instruction and to understand the experiential and contextual reasons behind the observed outcomes (Ivankova and Wingo, 2018; Thornberg et al., 2022).

Participants and sampling

The target population comprised all Senior High School (SHS) students in the Bono Region of Ghana. The accessible population consisted of SHS 2 students from four selected schools: Sunyani Senior High School (SUSEC), Berekum Senior High School (BESS), Dormaa Senior High School (DORMASS), and Drobo Senior High School (DROSEC), with a total student population of approximately 4,542. A multi-stage sampling procedure was employed. The region was stratified into five educational zones of which one school in Wenchi zone (Wenchi senior high school) was selected for a pilot study and one school from the remaining four educational zone was purposively selected from each zone based on the accessibility and performance classification. The sample size of 368 was determined using Yamane's (1967) formula at a 5% margin of error (Hasan and Kumar, 2024): $n = N / (1 + N(e)^2) = 4,542 / (1 + 4,542(0.05)^2) \approx 368$. Proportionate stratified sampling allocated students across schools in accordance with enrolment size. Within each school, two intact SHS 2 classes were assigned to either the experimental or control condition. For the qualitative phase, four students were randomly selected for interviews. The sample distribution is shown in Table 1.

Table 1. Distribution of student sample across selected schools.

School	Population	Sample
Sunyani SHS (SUSEC)	1,520	123
Berekum SHS (BESS)	1,048	85
Dormaa SHS (DORMASS)	1,050	85
Drobo SHS (DROSEC)	924	75
Total	4,542	368

Note. n = sample size; e = margin of error. Source: Field data (2026).

Instruments

Three instruments were used. A Trigonometry Achievement Test (TAT), developed by the researchers, served as both pre-test and post-test and assessed students' understanding of angles, trigonometric ratios, and their applications. A structured questionnaire, scored on a five-point Likert scale (1 = strongly disagree to 5 = strongly agree), collected data on students' perceived challenges. Internal consistency was strong, with Cronbach's $\alpha = .872$ for the challenges subscale. A semi-structured interview guide explored students' perceptions and experiences. Content validity was established through expert review (Cheung et al., 2024).

The Trigonometry Achievement Test was treated separately because its items were scored with partial credit, awarding full, partial, or no marks according to the

completeness and accuracy of each response, rather than on a rating scale. For polytomously scored items of this kind, the appropriate index of internal consistency is Cronbach's alpha, and the twenty-item test returned a coefficient of .827, which falls within the range conventionally regarded as good and indicates that the items functioned coherently as a single measure of trigonometric achievement. Because partial-credit marking involves an element of marker judgement, a detailed marking scheme was prepared in advance, specifying the marks to be awarded for each acceptable response and the partial credit due for incomplete or partially correct solutions. The scheme was applied uniformly across all scripts to standardise scoring and reduce subjectivity in the award of marks. Both reliability coefficients are reported in Table 2.

Content validity of the instruments was established through the researcher's two supervisors (a Professor and a Doctor) and three experienced mathematics education lecturers, all of whom held doctoral qualifications. The experts independently evaluated each instrument item for relevance, representativeness, clarity, and alignment with the study objectives and research questions. Their recommendations informed the refinement and modification of the instruments prior to the main data collection exercise.

Reliability was assessed using Cronbach's alpha coefficient to determine the internal consistency of the instruments. Following the recommendation of Kusi et al. (2025), a minimum coefficient of .70 was established a priori as the criterion for acceptable reliability.

Table 2. Reliability of the study instruments.

Instrument	No. of items	Cronbach's α
Trigonometry Achievement Test	20	0.827
Students' challenges in applying ethnomathematics	15	0.872

Note. Source: Field Survey (2026).

Intervention

An eight-week ethnomathematics-based intervention was implemented in the experimental schools. Prior to the intervention, selected teachers participated in a two-day training workshop on ethnomathematics principles, culturally responsive lesson design, and the connection of Ghanaian cultural practices to trigonometric concepts. Teachers designed and delivered lessons incorporating kente weaving, roofing construction, basketry, traditional land measurement, Adinkra symbols, farming layouts, and indigenous carpentry as instructional contexts for teaching angles, trigonometric ratios, right triangles, angles of elevation and depression, and bearings. Visual and hands-on materials were used throughout. Control group teachers delivered the same content using conventional teacher-centred instruction. Classroom observations were conducted periodically to ensure implementation fidelity. Post-intervention reflection sessions were also held with the experimental-group teachers to support implementation.

Data analysis

Quantitative data were screened for completeness, missing values, and outliers before analysis. The

ANCOVA assumptions of normality, homogeneity of error variances, homoscedasticity, and homogeneity of regression slopes were tested using descriptive statistics, graphical methods, Levene's test, an F test for heteroskedasticity, and a Group by Pretest interaction term. ANCOVA assessed the effect of instructional group on post-test achievement after controlling for pre-test scores. One-sample t -tests (test value = 3) examined perceived challenges. Effect sizes were reported as partial η^2 for ANCOVA and Cohen's d for t -tests. Qualitative interview data were transcribed verbatim and analysed thematically through iterative coding and categorisation. Trustworthiness was enhanced through member checking, peer review of codes, reflexive note-taking, and the trustworthiness criteria of credibility, transferability, dependability, and confirmability (Enworo, 2023).

Ethical considerations

Permission was obtained from relevant educational authorities and school administrators before data collection. Participants were informed about the study's purpose, and written consent was obtained. Confidentiality and anonymity were maintained throughout, and all data were used solely for academic purposes.

RESULTS

Participant demographics

A total of 368 SHS 2 students participated in the study. Of these, 220 (59.8%) were male and 148 (40.2%) were

female. The majority (53.3%) were aged 16–17 years. Students were drawn from five programmes: General Science (31.5%), General Arts (22.0%), Visual Arts (20.4%), Business (13.9%), and Home Economics (12.2%). The full demographic distribution is presented in Table 3.

Table 3. Demographic characteristics of students.

Category	Variable	Frequency	Percent (%)
Gender	Male	220	59.8
	Female	148	40.2
	Total	368	100
Age	14–15 years	45	12.2
	16–17 years	196	53.3
	18 years and above	127	34.5
	Total	368	100
School	Sunyani SHS	123	33.4
	Berekum SHS	85	23.1
	Dormaa SHS	85	23.1
	Drobo SHS	75	20.4
	Total	368	100
Programme	General Science	116	31.5
	Business	51	13.9
	General Arts	81	22.0
	Visual Arts	75	20.4
	Home Economics	45	12.2
	Total	368	100

Note. Source: Field Survey (2026).

Research question 1: Impact of ethnomathematical integration on achievement

Before conducting the ANCOVA, all underlying assumptions were examined. Normality of the posttest distribution was assessed for the combined sample. The Kolmogorov-Smirnov and Shapiro-Wilk tests were both significant, $D(368) = .081$, $p < .001$, and $W(368) = .978$, $p < .001$, but these results carry little inferential weight at this sample size, where normality tests reliably flag trivial departures (Knief and Forstmeier, 2021). The graphical diagnostics were more informative. The histogram was broadly unimodal and centred near the mean with a mild positive tail, the Q-Q plot tracked the diagonal closely through the central range and deviated only modestly at the tails, the boxplot showed a compact interquartile range with no flagged outliers, and the scatterplot indicated a broadly linear covariate-outcome relationship. The distribution departed from normality only at the extremes, which has little practical consequence for ANCOVA at this

sample size.

Levene's test of equality of error variances was non-significant, $F(1, 366) = .125$, $p = .724$, and a formal heteroskedasticity test was likewise non-significant, $F(1, 366) = .491$, $p = .484$, confirming stable residual variance across groups and across the range of fitted values. The homogeneity of regression slopes was examined by adding a Group by Pretest interaction term to the model. The interaction was non-significant, $F(1, 364) = 3.53$, $p = .061$, partial $\eta^2 = .010$. Although the p value approached the conventional threshold, it did not cross it, and the associated effect size was negligible, so the assumption was treated as met and the adjusted group effect was interpreted in the standard way. All assumption tests are summarised in Table 4.

Table 5 reports the posttest descriptive statistics by group. Students in the control schools, taught through conventional instruction, obtained a mean posttest score of $M = 16.30$ ($SD = 7.95$, $n = 160$), while students in the experimental schools, taught through Ghanaian

ethnomathematical practices, recorded a substantially higher mean of $M = 22.63$ ($SD = 7.22$, $n = 208$). The overall sample mean was $M = 19.88$ ($SD = 8.16$). The raw difference of 6.33 marks is about 15.8 percentage points

on the 40-mark instrument, and the experimental group showed slightly lower variability, suggesting more consistent outcomes across the students exposed to it.

Table 4. Summary of ANCOVA assumption tests.

Assumption	Test	Statistic	df	p	Interpretation
Normality	Kolmogorov-Smirnov	.081	368	< .001	Read with graphical evidence; acceptable
Normality	Shapiro-Wilk	.978	368	< .001	Read with graphical evidence; acceptable
Homogeneity of variance	Levene's test	$F = .125$	(1, 366)	.724	Assumption met
Homoscedasticity	Heteroskedasticity test	$F = .491$	(1, 366)	.484	Assumption met
Homogeneity of regression slopes	Group × Pretest	$F = 3.53$	(1, 364)	.061	Assumption met (negligible effect)

Note. Source: Field Data (2026).

Table 5. Descriptive statistics for posttest scores by instructional group.

Group	M	SD	n
Control	16.30	7.95	160
Experimental	22.63	7.22	208
Total	19.88	8.16	368

Note. M = mean posttest score; SD = standard deviation; n = group sample size. Maximum score = 40. Source: Field Data (2026).

Table 6 presents the full between-subjects effects for the ANCOVA model. The corrected model was statistically significant, $F(3, 364) = 73.25$, $p < .001$, partial $\eta^2 = .376$,

with instructional group, pretest performance, and their interaction together explaining 37.6% of the variance in posttest scores ($R^2 = .376$, Adjusted $R^2 = .371$). The pretest covariate was a strong predictor in its own right, $F(1, 364) = 129.07$, $p < .001$, partial $\eta^2 = .262$. The central result concerns instructional group. After adjusting for prior knowledge, the effect of group on posttest achievement was significant, $F(1, 364) = 71.99$, $p < .001$, partial $\eta^2 = .165$, a large effect indicating that about 16.5% of the variance in posttest achievement was attributable to the instructional approach once prior knowledge had been accounted for. Students taught through Ghanaian ethnomathematical practices clearly outperformed those taught conventionally.

Table 6. Tests of between-subjects effects for posttest trigonometry achievement scores.

Source	SS	df	MS	F	p	Partial η^2
Corrected Model	9,207.53	3	3,069.18	73.25	< .001	.376
Intercept	17,218.81	1	17,218.81	410.96	< .001	.530
Groups	3,016.29	1	3,016.29	71.99	< .001	.165
Pretest	5,408.06	1	5,408.06	129.07	< .001	.262
Groups × Pretest	147.90	1	147.90	3.53	.061	.010
Error	15,251.21	364	41.90	—	—	—
Total	169,904.00	368	—	—	—	—
Corrected Total	24,458.74	367	—	—	—	—

Note. $R^2 = .376$ (Adjusted $R^2 = .371$). SS = Type III sum of squares; MS = mean square. Partial η^2 benchmarks: .01 small, .06 medium, .14 large (Cohen, 1988). The Groups × Pretest interaction was included to test the homogeneity of regression slopes assumption. Source: Field Data (2026).

Research question 2: Challenges in ethnomathematical trigonometry instruction

Normality of the challenge scores was assessed using the

Kolmogorov–Smirnov test, $D(208) = .080$, $p = .003$, and Shapiro–Wilk test, $W(208) = .967$, $p < .001$. Both were significant, but at $n = 208$ these tests are highly sensitive to minor departures (Knief and Forstmeier, 2021). The

mean ($M = 3.62$) and 5% trimmed mean (3.64) were virtually identical. Skewness was $-.162$ and kurtosis was $-.782$, both within acceptable limits (George and Mallery, 2010; Kim, 2013). The data were therefore suitable for parametric analysis. The one-sample t -test results are presented in Table 7. All fifteen items produced mean scores significantly above the neutral midpoint of 3.00. The

overall mean of 3.62 ($SD = 1.35$, $CV = 37.29\%$, Cohen's $d = 0.45$) indicated a moderate but consistent level of perceived challenge. The two most prominent challenges were lack of prior knowledge about traditional practices ($M = 3.97$, $d = 0.83$) and difficulty relating cultural practices to trigonometric concepts ($M = 3.83$, $d = 0.75$), both producing large effects.

Table 7. One-sample t -test on students' challenges in learning trigonometry through ethnomathematics (test value = 3).

Item	<i>M</i>	<i>SD</i>	<i>CV (%)</i>	<i>t</i>	<i>df</i>	<i>p</i>	95% <i>CI</i>	<i>d</i>
Difficult to relate cultural practices to trigonometric concepts	3.83	1.11	28.87	10.85	207	< .001	[0.68, 0.98]	0.75
Lack of prior knowledge about traditional practices limits understanding	3.97	1.17	29.49	11.96	207	< .001	[0.81, 1.13]	0.83
Use of local languages sometimes confuses content	3.23	1.54	47.76	2.16	207	.032	[0.02, 0.44]	0.15
Need more visual aids to understand cultural artefacts	3.67	1.36	37.13	7.08	207	< .001	[0.48, 0.85]	0.46
Struggle to apply traditional knowledge to solve problems	3.82	1.27	33.33	9.27	207	< .001	[0.64, 0.99]	0.64
Lessons with cultural elements move too slowly	3.28	1.32	40.18	3.10	207	.002	[0.10, 0.46]	0.20
Limited resources explaining culture–trigonometry links	3.53	1.40	39.58	5.46	207	< .001	[0.34, 0.72]	0.38
Teaching sometimes feels less structured	3.66	1.34	36.68	7.08	207	< .001	[0.48, 0.84]	0.46
Difficult to generalise to standard trigonometric problems	3.70	1.28	34.56	7.87	207	< .001	[0.52, 0.87]	0.55
Discussions dominated by a few students	3.72	1.36	36.47	7.62	207	< .001	[0.53, 0.90]	0.53
Prefer standard problems to cultural ones	3.70	1.36	36.67	7.46	207	< .001	[0.52, 0.89]	0.52
Lack confidence on tasks involving traditional knowledge	3.63	1.32	36.32	6.94	207	< .001	[0.45, 0.81]	0.44
Do not understand relevance of traditional examples	3.51	1.48	42.29	4.95	207	< .001	[0.31, 0.71]	0.34
Limited exposure affects engagement	3.62	1.46	40.39	6.08	207	< .001	[0.42, 0.82]	0.42
Problems feel unrealistic or outdated	3.42	1.43	41.66	4.28	207	< .001	[0.23, 0.62]	0.29
Overall	3.62	1.35	37.29	—	—	—	—	0.45

Note. Test value = 3.00. *M* = mean; *SD* = standard deviation; *CV* = coefficient of variation; *CI* = confidence interval. Cohen's $d \approx 0.20$, 0.50, and 0.80 represent small, medium, and large effects, respectively. $N = 208$. Source: Field Data (2026).

Research question 3: Students' perceptions and experiences

Thematic analysis of the four student interviews produced six themes: (1) improved conceptual understanding through familiar contexts; (2) real-life relevance and familiarity; (3) increased interest, motivation, and participation; (4) visualisation and practical application of abstract concepts; (5) challenges in connecting cultural examples to mathematical formulas; and (6) the need for better instructional support.

On conceptual understanding, one participant explained:

“When the teacher uses examples from our culture, like kente patterns or the way carpenters measure roofing angles, it makes trigonometry easier to understand. It feels less difficult because I can relate it to things I already know.”

A second student noted:

“Before, the topic looked too abstract, but when the teacher connected it to things like traditional building styles and weaving designs, it became clearer and more practical to me.”

On real-life relevance, one participant observed:

“When roofing is used to explain slope and angles, it becomes easier for me to follow because I can relate it to actual buildings.”

Students also described increased motivation and participation:

“It motivates me because I no longer see trigonometry as something too foreign or difficult. The cultural examples make me feel that I can understand it.”

Despite these positive accounts, students identified real difficulties. One explained:

“Sometimes I understand the cultural example, but connecting it to the actual trigonometry formula can be difficult. It takes extra explanation before I fully understand the mathematics part.”

Another noted:

“Not everyone is familiar with the same cultural practices. Some examples make sense to some students, but for others it can be hard to follow.”

Students recommended clearer step-by-step explanations, more practical activities, more widely familiar examples, and more visual and physical teaching materials.

DISCUSSION

The ANCOVA results provided strong statistical evidence that integrating Ghanaian ethnomathematical practices into trigonometry instruction improved students' posttest achievement. After controlling for pretest differences, students in the experimental group scored significantly higher than those in the control group, with a large effect (partial $\eta^2 = .165$). The overall model explained 37.6% of the variance in achievement, and the pretest was a significant predictor ($\eta^2 p = .262$), confirming that prior mathematical knowledge shaped subsequent achievement (Hattie, 2009; Siegler et al., 2012).

This finding aligns with a growing body of evidence in the ethnomathematics literature. D'Ambrosio (2001) argued that learning becomes deeper and more durable when formal mathematics is connected to learners' cultural environments. Bishop (1988) maintained that mathematical understanding is fundamentally a cultural activity. Batiibwe (2024) reviewed evidence showing that cultural artefacts can serve as effective teaching resources. Kusi and Bonyah's (2025) systematic review reported that culturally responsive and ethnomathematical approaches were associated with gains in performance, engagement, and conceptual understanding when cultural contexts

were deliberately incorporated. Gbormittah et al. (2026) reported that ethnomathematical instruction had a meaningful influence on students' geometry learning, a finding paralleled here in trigonometry.

The qualitative interview data helped explain why this achievement advantage emerged. Students consistently described ethnomathematical instruction as making trigonometry feel more accessible and less threatening. Cultural grounding appeared to reduce extraneous cognitive load (Sweller, 1988) and redirect learners' attention toward mathematical relationships. Students described how roofing angles, kente patterns, basket weaving, and traditional land measurement allowed them to form mental images of trigonometric relationships that would otherwise have remained purely symbolic, consistent with constructivist theories (Devi, 2019; Vygotsky, 1978). Students also reported becoming more willing to answer questions and seek clarification, consistent with Gay's (2013) argument that culturally responsive teaching activates learners' existing knowledge and identity resources.

The challenge findings add necessary nuance. The most prominent challenges, lack of prior knowledge about traditional practices ($d = 0.83$) and difficulty relating cultural examples to formal mathematical procedures ($d = 0.75$), reflect a foundational tension in ethnomathematical pedagogy: the approach assumes cultural familiarity that is not uniformly distributed (D'Ambrosio, 2001; Rosa and Orey, 2011). The difficulty of generalising from culturally contextualised problems to standard trigonometric formats ($d = 0.55$) reflects the well-documented transfer problem in mathematics education (Kamii and Dominick, 1998; Sfard, 1991). The high coefficients of variation on several items, particularly language confusion ($CV = 47.76\%$) and perceived unrealism ($CV = 41.66\%$), indicate that students' experiences of challenge were far from uniform, pointing to the need for differentiated instructional strategies (Tomlinson, 2001).

Integrated discussion

Because the study followed a sequential explanatory design, the two phases are best read together rather than in isolation. The first, quantitative phase established that students taught through Ghanaian ethnomathematical practices outperformed their peers on the posttest (partial $\eta^2 = .165$) while also reporting a moderate but consistent level of challenge. These results showed that the intervention worked and that it was not without friction, but on their own they could not explain why the gains emerged or what lay behind the difficulties. The second, qualitative phase supplied that explanation. The student interviews accounted for the achievement advantage by tracing it to improved visualisation, greater perceived relevance, and increased motivation, and they accounted for the

challenge scores by pointing to uneven cultural familiarity and the effort of translating cultural examples into formal procedures.

The qualitative findings therefore did three things in relation to the quantitative results. They explained them by identifying the cognitive and affective mechanisms (reduced cognitive load, mental imagery, and confidence) through which cultural grounding raised achievement. They corroborated them, since the students who described trigonometry becoming clearer and less threatening were drawn from the same experimental group whose posttest scores rose. And they extended them, by surfacing the conditions under which the approach succeeds or falters,

namely the need for explicit bridging from cultural practice to formal mathematics and for examples that are widely shared rather than locally specific (Nasir et al., 2008). Across both phases, the integration portrays ethnomathematical instruction in trigonometry as a genuinely promising but inherently demanding approach whose measured benefits depend on deliberate pedagogical design, which is the explanatory outcome the sequential explanatory design was intended to produce (Creswell and Plano Clark, 2023).

Table 8 sets out this integration directly, mapping each qualitative theme to the quantitative finding it speaks to and the function it serves in the joint interpretation.

Table 8. Integration matrix mapping qualitative themes to quantitative findings.

Qualitative theme (Phase two)	Related quantitative finding (Phase one)	Integration function	Joint interpretation
Improved understanding through familiar contexts	Higher experimental posttest mean ($M = 22.63$ vs 16.30); group effect, partial $\eta^2 = .165$	Explanation	Familiar cultural contexts gave students a route into abstract ideas, helping account for the achievement advantage.
Real-life relevance and familiarity	Significant group effect on posttest achievement	Explanation and corroboration	Perceived relevance of practices such as roofing and building sustained the engagement that fed into attainment.
Increased interest, motivation, and participation	Achievement gain with lower variability in the experimental group ($SD = 7.22$ vs 7.95)	Explanation	Higher motivation helps explain both the mean gain and the more consistent outcomes.
Visualisation and practical application of abstract concepts	Group effect on posttest scores; pretest a strong predictor	Explanation	Visualising angle, ratio, and slope through artefacts supported the conceptual grasp seen in posttest scores.
Challenges in connecting cultural examples to formulas	Difficulty relating cultural practices to trigonometric concepts ($M = 3.83$, $d = 0.75$) and generalising to standard problems ($d = 0.55$)	Corroboration	The transfer difficulty described in interviews matches the largest challenge effects, explaining why gains coexisted with friction.
The need for better instructional support	Moderate overall challenge level ($M = 3.62$, $d = 0.45$); items on resources, visual aids, and structure	Extension	Students' calls for clearer bridging and materials specify the conditions under which the approach works.

Note. Phase One = quantitative findings; Phase Two = qualitative findings. Source: Field Data (2026).

Novel contribution

The principal contribution of this study is methodological as well as substantive. To the authors' knowledge, it provides the first quasi-experimental evidence, gathered within a sequential explanatory mixed methods design, of the effect of Ghanaian ethnomathematical practices on trigonometry achievement at the Senior High School level. Whereas earlier Ghanaian work concentrated on geometry, mensuration, and general teacher attitudes (Gbormittah et al., 2026; Owusu-Darko et al., 2023), the present study isolates trigonometry, a topic whose reliance

on angle, ratio, and spatial reasoning makes it especially suited to culturally grounded representation, and it pairs a controlled achievement comparison with student accounts that explain why the measured effect emerged.

Theoretical implications

The findings carry implications for the three perspectives that framed the study. For ethnomathematics theory, the results give empirical weight to D'Ambrosio's (1985, 2001) claim that culturally embedded reasoning can be mobilised

for formal learning, and they extend Bishop's (1988) notion of mathematical enculturation from description toward a measurable outcome. For social constructivism, the students' movement from familiar cultural observation to formal trigonometric representation illustrates the scaffolded knowledge construction that Vygotsky (1978) described, with the cultural example serving as the shared starting point. For culturally responsive pedagogy, the students' accounts show that the gains depended not on cultural reference alone but on deliberate bridging from artefact to formal structure, consistent with Gay (2013) and Ladson-Billings (1995) and with the integration gap documented by Gbormittah et al. (2025) and Kyeremeh et al. (2025). The convergence of the three lenses on the same evidence suggests they are best treated as complementary rather than competing explanations of why the intervention worked.

Policy considerations

The results also speak to policy. If culturally grounded instruction can raise measurable achievement in a topic as demanding as trigonometry, there is a case for embedding ethnomathematical content in the Senior High School mathematics syllabus, in approved teaching materials, and in the assessment items used by the West African Examinations Council, rather than leaving it to individual teacher initiative. The challenges students reported, including limited resources and a need for clearer instructional support, indicate that such a policy would need to be matched by investment in culturally relevant teaching materials and by sustained professional development, without which the approach is unlikely to be implemented consistently or equitably.

CONCLUSION

This study investigated the impact of integrating Ghanaian ethnomathematical practices on students' achievement in trigonometry, the challenges students faced during such instruction, and their perceptions and experiences of culturally grounded learning. The ANCOVA established that ethnomathematical integration produced a statistically significant and practically meaningful improvement in posttest achievement (partial $\eta^2 = .165$) after controlling for prior knowledge, with the overall model explaining 37.6% of the variance in posttest scores. These results position ethnomathematical instruction as a substantive pedagogical approach capable of improving measurable learning outcomes. The one-sample *t*-test revealed that these gains coexisted with real challenges, particularly around insufficient prior knowledge of traditional practices, difficulty translating cultural examples into formal mathematical procedures, and reduced confidence when

working outside conventional lesson formats. The qualitative findings explained both strands coherently: students described improved visualisation, greater relevance, and increased motivation as the mechanisms behind the achievement gains, while their accounts of confusion and structural unfamiliarity gave substance to the challenge data.

The study contributes to the literature by providing the first quasi-experimental evidence of the effect of Ghanaian ethnomathematical practices specifically on trigonometry achievement at Senior High School level. Ethnomathematical instruction is a genuinely promising but inherently demanding approach that delivers meaningful learning outcomes when implemented deliberately, with adequate cultural preparation of students, explicit bridging to formal mathematics, and sufficient instructional support. The study was conducted in four schools in the Bono Region of Ghana, which limits the generalisability of findings to other regions. The study also did not examine in depth whether the effect of the intervention varied by programme of study or school, and subgroup analyses of this kind are a useful direction for further work. Future research should replicate the study across different regions and curriculum areas, examine the variables that moderate the effectiveness of ethnomathematical instruction, and investigate whether achievement gains persist over time and transfer to national examination performance.

RECOMMENDATIONS

Teachers should incorporate Ghanaian cultural practices into trigonometry instruction in a structured and deliberate manner, building students' familiarity with cultural artefacts before using them as mathematical contexts, and designing explicit bridging sequences from cultural practice to formal representation. Curriculum developers and the Ghana Education Service should formally embed ethnomathematical content in the Senior High School mathematics syllabus with worked examples and assessment items that draw on Ghanaian cultural contexts. Teacher education institutions should incorporate ethnomathematical pedagogy as a substantive component of pre-service mathematics methods courses.

Conflict of interests

The authors declare that they have no conflict of interest.

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