Artificial Intelligence in the Study of Fractal Patterns in Ethnomathematics

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Abstract
This study investigated artificial intelligence in the study of fractal patterns in ethnomathematics. Two research questions were answered and two null hypotheses tested at 0.05 significant level. The research design employed was quasi experimental which involved intact classes, pretest and posttest control group. The design presented one experimental group and one control group. The population of the study was made up of all the level 300 undergraduate students of Mathematics education in the three universities in Rivers State. The purposive sampling technique was used to select thirty-six level 300 undergraduate mathematics education students from two universities. The instrument used to collect data was fifty multiple-choice test items named "Ethnomathematics Fractal Achievement Test" (EFAT). The instrument was content validated and Kuder-Richardson formula 21 was used to obtain an internal stability of 0.81. Students in the experimental group were taught ethnomathematical fractal pattern with Mandelbulb 3D AI software while those in the control group were taught with direct instruction. The topics taught were tree fractals, bead fractals, wave fractals, sea shell fractal, arts and design fractals. The mean and standard deviation were used to answer the research questions while analysis of covariance was used to test the null hypotheses. The result showed that students that were taught ethnomathematical fractal pattern with Mandelbulb 3D AI software had a higher performance than those taught with direct instruction with a statistically significant difference. The result also showed that the male students that were taught with Mandelbulb 3D AI software had a higher performance than their female counterpart in the same group with no statistically significance difference. Based on the findings it was concluded that the integration of artificial intelligence in the teaching of ethnomathematical fractal patterns enhanced students' performance in ethnomathematics.

Keywords: Ethnomathematics, Artificial Intelligence, Patterns, Fractals, Performance

Introduction

Ethnomathematics is the study of how mathematics is related to culture. Machaba and Dhlamini (2021) averred that ethnomathematics is an aspect of Mathematics that illuminates the parallel connection between mathematics and culture. This parallel connection thus depicts the critical role which the cultural heritage of the students play in the learning of mathematics. In as much as every classroom constitutes students of diverse culture, the mathematics teacher should endeavor to promote inclusion in the classroom by providing a range of material resources and activities that supports all students' learning styles and incorporate a variety of cultural backgrounds and perspectives. One of the 3 components culturally responsive teaching proposed by Ladson-Billings (1994) is the development of students' cultural competences to assist them in developing positive ethnic and social identities. Hammond (2015) asserted that the 3 ways to make lessons more culturally responsive is to either gamify it, make it social or storify it. Encouraging mathematical thinking among students and helping them to mathematize the world in which they live is a concern in the present society. This makes it imperative for various approaches to employed to deliver Mathematics instruction. Mathematics teacher are therefore expected to value diverse instructional approaches that feature flexibility. One of the definitions of Mathematics is that it is he study of patterns. The most occurring patterns are naturally explored. Stewart (2026) opined that mathematics is the subject that can be conveniently employed to unlock the mysteries behind these patterns and thus exhibiting the beauty of nature.

Patterns are visible regular, repeated, predictable forms or designs found in the natural world, arts, and human behavior. Patterns are classified into symmetries, spirals, fractals, tessellations, meanders, waves, foams, cracks, stripes, and mathematical sequences. Fractals in the context of ethnomathematics refers to complex geometric shapes and patterns that are self-similar across different scales and can often be observed in various cultural artifacts, natural phenomena, and traditional art forms. The study of fractals can provide insight into the mathematical understanding and aesthetic expressions of different cultures, bridging mathematics, art, and culture. Fractals can be used for cultural representation. Many cultures create artistic designs that exhibit fractal-like properties, such as repeating patterns and self-similar structures, example traditional textiles, ceramics or architectural elements. Fractals can also be found to occur in nature. Example branching trees, river networks, coastlines and snowflakes. Different cultures might interpret these natural fractal patterns in unique ways that shape their understanding of nature, environment and worldview. The present-day worldview is modern, encapsulated with technologies that can be employed to explore more sophisticated fractal patterns. One of the present-day characteristics is the integration of technologies into almost every human endeavor. The integration of Artificial Intelligence (AI) in the teaching of every school subject is sacrosanct. This may suggest why Johnson and Rajuroy (2025) asserted that the integration of AI into various discipline has opened new frontiers for research and innovation. By utilizing AI tools and platforms, educators can create an engaging, culturally relevant curriculum that deepens students' understanding of fractal patterns within the context of ethnomathematics. This approach doe not only foster mathematical understanding but also appreciation for cultural diversity in mathematical practices. The various tools which can be used to study fractal patterns are GeoGebra, ChatGPT, Gemini, Desmos, Mandelbulb 3D, OpenArt, Pixelcut, Copilot, Apophysis, Minecraft, Kahoot, Canva or Adobe Spark, Scratch. These AI tools are interactive, and can provide personalized assistance and explanations about fractal pattern. It can also help students to identify, create, visualize, analyze and compare fractal patterns from different cultures, thereby allowing students to discover similarities and differences (Adhitya & Supriyadi, 2024). Ethnomathematics explores mathematical concepts within cultural contexts, highlighting how different societies understand and utilize mathematics. By examining these cultural artifacts, it can be seen how different societies approach mathematical concepts including fractals, in their artistic and practical lies. African geometric fractals draw inspiration from traditional patterns, textiles, and cultural symbols found across the continents. These fractals can be seen in various form, such as:

1. **African Art:** Many African cultures use repetitive geometrics patterns in textiles (Kente textile design of Ghana and Akwete textile design of Nigeria), carvings, and architectural designs. These patterns often exhibit fractal properties through self-similarity and intricate repetition.
2. **Native American Patterns:** Indigenous cultures in North America create art that includes geometric designs and motifs, often reflecting fractals-like structures found in nature such as spirals and branching forms.
3. **Islamic Geometric Patterns:** Islamic art features complex geometric designs that exhibit fractal characteristics. The tessellations and repetitive motifs can be seen in tile work, textiles, and architecture, demonstrating symmetry and self-similarity.
4. **Celtic Knots:** Traditional Celtic designs often incorporate interwoven patterns that can be interpreted as fractals due to their recursive nature and complexity.
5. **Maori Patterns:** In Maori culture, intricate carvings often contain symmetrical and fractal-like designs that reflect natural forms and spiritual beliefs.
6. **Fractal Trees:** many cultures represent trees in ways that mimic fractal branching, reflecting growth and life which can be symbolic in various traditions.

Studying fractals is important because they intersect various field of study and offer deep insights into both the natural world and mathematical concepts. Fractals are prevalent in nature and appearing in structures like pineapple, weaving, mountains, clouds, trees, and coastlines. Studying fractals help to understand these complex patterns and phenomena, thus providing a mathematical framework to describe natural processes. Adeten and Faroyo (2021) asserted that fractals have applications in diverse fields including Physics, Computer science, Biology, Medicine, Art, Economics, Engineering and Meteorology. The aesthetic value of fractals cannot be over emphasized. Fractals possess intrinsic beauty due to their complex structures and patterns. They inspire artists and designers leading to new forms of creative expression and inspiring movements in digital and visual arts. Integrating Ai in ethnomathematics bridges the gap between indigenous knowledge systems and the modern technology which can aid to visualize and analyze cultural mathematical practices that exist in various cultures. The key aspect of AI in ethnomathematics is that it aids in cultural preservation and analysis of historically significant artifacts which enhance students' comprehension of Mathematics concepts and application in real-life.

This study was therefore delved into the investigation of artificial intelligence in the study of fractal patterns in ethnomathematics.

Statement of the Problem
The African environment is alive with various fractal patterns and artefacts that bear a rich mathematical endowment. For instance, in Nigeria, there are tree fractals, arts fractals, wave fractals, sea ornament fractals, bead fractal, Adire, Akwete, and Ankara fractal patterns. A cursory look at these cultural fractals reveal that each possess one form or more of measurements, geometric patterns, tessellation, transformation, rotation, ration, proportion, measurement, similarity, or estimation. It has been observed by the researcher that these cultural treasures are often absent from formal mathematics instructions. Ethnomathematics can help students to identify, recognize and value these cultural referents. This is because ethnomathematics is a learner-centered teaching approach that helps students learn mathematics from lived experiences right from their own traditions and immediate environment. Teaching students Mathematics without using it to bridge the gap between home knowledge and school knowledge becomes a problem. Now that most of the pre-service students belong to the Gen z, it becomes imperative that AI be integrated into the teaching of fractal patterns. There are different types of AI softwares that be used to teach ethnomathematics concepts in schools. This study was therefore embarked upon, to investigate the possible effect which the use of AI can have on the academic performance of students in mathematics.

Objectives of the Study
The objectives of the study were to:
1. Determine the performance of students taught ethnomathematical fractal patterns using Mandelbulb 3D AI software and those taught using the direct instruction.
2. Determine the performance of the female and male students taught ethnomathematical fractal patterns using Mandelbulb 3D AI software.

Research Questions
1. What is the difference in the mean score performance of students taught ethnomathematical fractal patterns using Mandelbulb 3D AI software and those taught using the direct instruction?
2. What is the difference in the mean score performance of the female and male students taught ethnomathematical fractal patterns using Mandelbulb 3D AI software?

Hypotheses
H_{O1}: There is no significant difference between the mean score performance of students taught ethnomathematical fractal patterns using Mandelbulb 3D AI software and those taught using the direct instruction.
H_{O2}: There is no significant difference between the mean score performance of the female and male students taught fractal patterns using Mandelbulb 3D AI software.

Methodology
The research design employed was quasi experimental which involved the use of intact classes, pretest and posttest. The population of the study was made up of all the level 300 students of Mathematics Education in the three universities in Rivers State. The purposive sampling technique was used to select 2 universities for the study. The sample for the study was thirty-six level 300 students of Mathematics education. The instrument used for the collection of data was a fifty achievement test questions on ethnomathematical fractals. The test questions were multiple-choice with four options. The instrument was titled "Ethnomathematics Fractal Achievement Test" (EFAT). It measured both high and low cognitive learning outcome. EFAT was face and content validated by three mathematics educators. A set of twenty level 300 Mathematics education students that were not part of the sample was used to ascertain the reliability of EFAT. Kuder-Richardson Formula 21 (KR-21) was employed to conduct the internal consistency reliability test for the instrument EFAT, which yielded 0.81.

A pretest of EFAT was first administered to the experimental group and control group by the research assistants. This was followed by the teaching of ethnomathematical fractals to the sample students using the assigned instructional approach with respect to the study specification. The students in the experimental group were taught ethnomathematical fractals using Mandelbulb 3D AI software which was downloaded from the internet. The

students in the control group were taught same ethnomathematical fractals using the direct instructional approach in which charts were used. The topics taught were tree fractals, bead fractals, wave fractals, sea shell fractal, arts and design fractals. After the teaching, the two groups were post tested with the same EFAT thought in a modified version with regards to the rearrangement of the test items to minimize memorization of test items by the sample students. Both the pretest scripts and posttest scripts were collated, marked, graded, and subjected to statistical analyses. The mean and standard deviation were used to answer the research questions while the Analysis of Covariance was used to test the null hypotheses at 0.05 significant level.

Results

Research Question 1: What is the difference in the mean score performance of students taught ethnomathematical fractal patterns using Mandelbulb 3D AI software and those taught using the direct instruction?

Table 1: Mean and standard deviation on the performance of students taught fractal patterns with M3D AI and those taught with direct instruction

Group	n	Pretest		Posttest		Performance	Mean
		Mean	SD	Mean	SD	Mean Gain	Difference
M3D AI	17	38.52	11.53	75.67	12.36	37.15	
							21.50
DI	19	39.18	14.88	54.83	11.82	15.65	

Key: M3D AI = Mandelbulb 3D AI
DI = Direct Instruction

Table 1 showed the mean and standard deviation on performance of students that were taught ethnomathematical fractals with Mandelbulb 3D AI software and direct instruction. From Table 1, it is evident that the students who were taught ethnomathematical fractals with Mandelbulb 3D AI software in the experimental group had a performance mean gain of 37.15, and those taught with direct instruction in the control group had a performance mean gain of 15.65. The data analysed in Table 1 showed that the students that were taught with Mandelbulb 3D AI software performed better than those that were taught with direct instruction. The performance mean difference between the students that were taught ethnomatical fractals with Mandelbulb 3D AI software and direct instruction was 21.50.

Research Question 2: What is the difference in the mean score performance of the female and male students taught ethnomathematical fractal patterns using Mandelbulb 3D AI software?

Table 2: Mean and standard deviation on performance mean score of female and male students taught ethnomathematical fractals with M3D AI

Sex	n	Pretest		Posttest		Performance	Mean
		Mean	SD	Mean	SD	Mean Gain	Difference
Female	11	37.28	11.53	73.91	12.36	36.63	
							1.04
Male	8	39.76	12.50	77.43	14.71	37.67	

Table 2 showed the mean and standard deviation on the performance mean score of the female and the male students that were taught ethnomathematical fractal patterns with Mandelbulb 3D AI software in experimental group. The data in Table 2 revealed that the female students that were taught ethnomathematical fractal patterns with Mandelbulb 3D AI software had a performance mean gain of 36.63, while the male students taught with same Mandelbulb 3D AI software had a performance mean gain of 37.67. It is evident from Table 2 that the male students performed better than their female counterpart in the same experimental group. The performance mean

difference between the male and female students that were taught ethnomathematical fractal patterns with Mandelbulb 3D AI software in the same experimental group was 1.04.

H$_{O1}$: There is no significant difference between the mean score performance of students taught ethnomathematical fractal patterns using   Mandelbulb 3D AI software and those taught using the direct instruction.

Table 3: Summary of ANCOVA on the performance of students taught fractal patterns with M3D AI and those taught with direct instruction

Source	Type III Sum of Squares	Df	Mean Square	F	Sig.	Partial Eta Squared
Corrected Model	515.80	2	171.93	15.34	.00	.55
Intercept	602.42	1	602.42	53.75	.00	.23
Pretest	.49	1	.49	.05	.47	.01
Group	112.24	2	56.12	5.01	.00	.47
Error	1087.25	33	11.21			
Total	39833.00	36				
Corrected Total	1603.05	35				

a. R Squared = .432 (Adjusted R Squared = .356)

Table 3 above showed the test of significant effect using analysis of covariance on the difference between the performance of students that were taught ethnomathematical fractal patterns with Mandelbulb 3D AI software and direct instruction. It can be deduced from Table 3 that a significant difference exists between the performance mean score of students who were taught ethnomathematical fractal patterns with Mandelbulb 3D AI software and direct instruction, (F_1, 33=5.01, p=.00 < .05, partial eta squared = .47). The null hypothesis one (H$_{O1}$) was rejected at 0.05 significant level.

H$_{O2}$: There is no significant difference between the mean score performance of the female and male students taught ethnomathematical fractal patterns using Mandelbulb 3D AI software.

Table 4: Summary of ANCOVA on the performance of the female and male students taught ethnomathematical fractal patterns using Mandelbulb 3D AI

Source	Type III Sum of Squares	Df	Mean Square	F	Sig.	Partial Eta Squared
Corrected Model	132.50[a]	2	44.17	230.30	.00	.54
Intercept	3945.39	1	3945.39	20572.61	.00	.91
Pretest	89.86	1	89.86	468.54	.00	.15
Sex	.08	1	.08	.41	.78	.04
Error	115.07	16	.19			
Total	5905.14	19				
Corrected Total	247.57	18				

a.   R Squared = .463 (Adjusted R Squared = .602)

Table 4 above showed the test of significant effect using analysis of covariance on the difference between the performance of the female and male students that were taught ethnomathematical fractal patterns using Mandelbulb 3D AI. The result showed that there was no significant difference between the performance of the female and male students who were taught ethnomathematical fractal patterns using Mandelbulb 3D AI (F1, 42 =.41, p = .78 p > .05, partial eta squared = .04). The null hypothesis two, H$_{O2}$ was retained at .05 significant level since p-value was greater than .05.

Discussion
The result showed thatstudents who were taught ethnomathematical fractals with Mandelbulb 3D AI software in the experimental group had a performance mean gain of 37.15, and those taught with direct instruction in the control group had a performance mean gain of 15.65. This indicated that the students that were taught with Mandelbulb 3D AI software performed better than those that were taught with direct instruction. When subjected to statistical test, the result showed that there was a significant difference between the performance mean score of

students who were taught ethnomathematical fractal patterns with Mandelbulb 3D AI software and those taught with direct instruction, (F_1, 33=5.01, p=.00 < .05, partial eta squared = .47). The null hypothesis one (H_{O1}) was rejected at 0.05 significant level. This result agrees with the result of Adang et al. (2024) who found that the use of digital teaching materials to teach students mathematics significantly the problem-solving abilities and also responded positively to the cultural relevance in the teaching materials. The result is in consonance with the findings of Nwoke et al. (2025) whose study found that artificial intelligence contributes immensely to the development of mathematics education of which ethnomathematics is an aspect of mathemetics. The research finding of Madu et al. (2025) agrees with this result in that it found that the ethnomathematics e-module was effective in improving students learning outcomes. The ethnomathematics e-module had the capacity to successfully integrate mathematical concepts of circles with relevant local referents which made the learning of ethnomathematics more meaningful and less difficult. This result is in agreement with the result of Atta et al. (2025) which revealed that the use of technological tools and local mortar to teach students mensuration in the Akan culture, Ghana enhanced their relational comprehension of geometrical concepts.

The result also showed that the female students that were taught ethnomathematical fractal patterns with Mandelbulb 3D AI software had a performance mean gain of 36.63, while the male students taught with same Mandelbulb 3D AI software had a performance mean gain of 37.67. This indicated that the male students performed better than their female counterpart in the same experimental group. When subjected to statistical test, the result showed that there was no significant difference between the performance of the female and male students who were taught ethnomathematical fractal patterns using Mandelbulb 3D AI ($F1$, 42 =.41, p = .78 p > .05, partial eta squared = .04). The null hypothesis two, H_{O2} was retained at .05 significant level since p-value was greater than .05. This study collaborates with that of Auuke and Uyanahan (2023) which showed that there was no significant difference in the performace of the female and male students taught ethnomathematical concepts with technological tools.

Conclusion
Based on the results of this study it was concluded that the integration of artificial intelligence and technological tools improved the academic performance of students in mathematics and ethnomathematics which is an area of mathematics than those that were taught without the intrgration of AI. It was also concluded that there was no significant difference between the academic performance of the female and male students that were taught ethnomathematics with the use of AI.

Recommendations
1. Mathematics teachers should be trained on the use of AI to teach, so that they can conveniently use it to teach thereby improving the academic performance of students in ethnomathematics.
2. Both the female and male students should be taught ethnomathematics using AI technologies.

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