A Study of Mathematical Patterns and Cultural Symmetry in Traditional Weaving, Beadwork, and Basketry

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Abstract

Traditional weaving, beadwork, and basketry from diverse Indian cultures exhibit mathematical patterns and cultural symmetry that coexist with a variety of mathematical principles. This research paper explores the geometrical structures that are present in the form of tessellations and symmetry in the crafts of Double Ikat of Patan Patola, symmetric motifs in Kanchipuram silk, and radial symmetry in Naga beadwork. The researchers also examine the mathematical ideas behind Banjara embroidery, Toda basketry, and Khasi bamboo weaving, and show how some fundamental concepts, including permutations, combinations, tessellations, and geometric transformations can be applied in some of their creations. The analysis concludes that ethno mathematics is essential in maintaining indigenous knowledge, especially in its application of mathematical principles in a way that artisans naturally employ in the process of producing visually balanced and structurally precise designs. This paper aims to establish ethno mathematics as both a valid cultural epistemology and a pedagogical tool for culturally responsive mathematics education.

Keywords: *Weaving, Beadworks, Basketry, Mathematical patterns, Cultural symmetry.*

Introduction

In the pattern of certain traditional handicrafts, mathematics is deeply embedded in the form of intricacy in patterns and symmetry in design (Firdaus & Nasution, 2023). Within practices such as weaving, beadwork, and basketry, cultural knowledge bearers intuitively apply mathematical principles to produce artefacts that are both aesthetically appealing and structurally precise. Aside from being aesthetic and functional objects, these crafts constitute a large repository of indigenous mathematical ideas that have been transmitted from generation to generation.

Ethno mathematics is an interdisciplinary field that studies the link between cultural practices and mathematical concepts, which is based on mathematical patterns in typical craftsmanship (Khalil, 2023). Since the researchers study only geometric arrangements, tessellations, and symmetric designs in textiles and handicrafts, they gained insight into how the artisans incorporate the theory of symmetry, proportions, and numbers without any formal mathematical training (Firdaus & Nasution, 2023).

The present research paper focuses on the mathematical structures found in traditional weaving, beadwork, and basketry among various Indian communities and examines how the art forms employ geometric shapes, permutations, and symmetrical patterns

as an expression of ethno mathematics, reflecting both cultural meaning and mathematical reasoning.

The researchers reviewed the secondary sources, such as ethnographic studies, museum archives, and scholarly articles, and identified the major art forms where mathematical ideas are visibly present. On this basis, weaving, beadwork, and basketry were selected as representative examples for ethno mathematical analysis. This research demonstrates how mathematical ideas are already embedded within cultural heritage, showing that indigenous activities express mathematical concepts through practices such as weaving, beadwork, and basketry, and how this knowledge can be applied in the present-day situation.

Ethno mathematics: A Cultural Epistemology

Ethno mathematics, as understood by D'Ambrosio (2006), is more than the traditional sense of mathematics being an ahistorical, culturally neutral discipline. Rather, it puts greater emphasis on human sources of mathematical innovation and locates mathematics within the everyday activity of specific cultural groups. Through such multiplicity, the field recognizes the existence of multiple forms of mathematical thinking as a result of problem-solving in daily life, symbolic representations, and artistic work (Khalil, 2023). Mathematics, as developed through this understanding, is not only a tool of abstraction but a culturally embedded practice of any human activity, which develops according to human wants, aesthetic ideals, and socio-cultural interaction, such as in Patan Patola weaving, community guilds transmit symmetry-based grid patterns across generations, embedding mathematical order within cultural rituals of cloth-making. In Kanchipuram silk, triangular motifs reflect both the social value of temple architecture and the artisan's mathematical

reasoning about stability and proportion. Similarly, Naga beadwork encodes clan identity through combinatorial colour arrangements, where mathematical choices are inseparable from social affiliation. These examples illustrate how mathematical structures emerge directly from cultural practices and community life.

The mathematical reasoning is embedded into the culture in the example of traditional weaving. The persistence of pattern designs, the rigor of repeated motifs, and the instinctive spatial thinking that is apparent in crafts with patterning, such as in Patan patola and Kanchipuram silk , are all products of indigenous mathematical logic. These activities are not scaled-down versions of modern mathematical practices that operate on various levels on their own conceptual and methodological levels. More so, ethno mathematics leads to linguistic and cultural pluralism. Different communities maintain their own symbolic systems and mathematical idioms, which reflect diverse ways of reasoning and problem-solving. In this sense, ethno mathematics supports the idea of epistemological pluralism that there are multiple valid ways of knowing mathematics. Forms of such pluralism include indigenous spatial reasoning in weaving, symbolic colour codes in beadwork, and oral traditions that transmit counting and measurement practices. These differ from the dominant epistemology of Western mathematics, which assumes universality, abstraction, and cultural neutrality. By contrast, epistemological pluralism recognizes mathematics as context-bound, situated in culture, and expressed through material practices. In pedagogy, this contrast is crucial, whereas universalist approaches often reduce cultural artefacts into decontextualized textbook problems, a popularist approach values the cultural logic embedded in traditional designs, thereby promoting inclusivity and fairness in mathematics education.
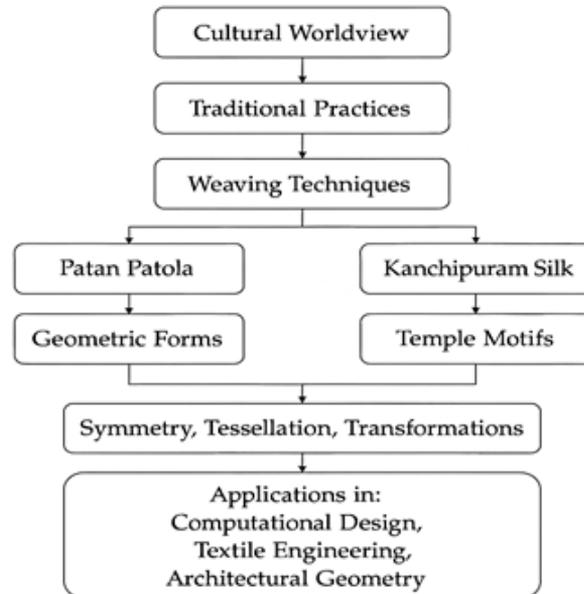
Mathematics as a Human Cultural Act

Fig. 1 Conceptual Design (Image source: Authors)

The concept of mathematics must thus be envisioned beyond the realms of abstract thinking; however, mathematics can be presented as a culturally ingrained activity rooted in material life, shared practice, and interaction with signs within the environment. In the Indian context, one can find evidence of this thesis with reference to traditional crafts (Patan Patola, Kanchipuram silk weaving), where mathematical concepts are ferociously intertwined with material culture.

The utilization of repeating squares, triangles, and tessellated patterns in these fabrics is not coincidental in the slightest: the visual language corresponds to many remotely cosmological, communal, and religious belief archetypes (Dewi Pebryani, 2018; Keerthi & Mokanaa Sri E, 2024). The geometric patterns are amazingly precise and were frequently developed by formally untrained geometric builders, thus showing a type of local mathematical literacy that is simultaneously intuitive and rigorous.

Fig. 2 Patan Patola Art
(Source: https://images.app.goo.gl/
ZBWgabUB9xf1wkBM7)

Fig.3 Kanchipuram Silk Design
(Source: https://images.app.goo.gl/
VLR9an8FM19U8BAcA)

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[2]Kanchipuram silk is a hand-woven textile from Tamil Nadu, recognized for its temple-inspired motifs, triangular borders, and cultural significance in South Indian traditions.

Balamurugan (2015) noted that such type of mathematically motivated knowledge, which is naturally developed by generations of trade practice, forms a genuine and complicated system of discourse. Such a symmetrical grid pattern found in Patola, for example, not only communicates the aesthetic values but also reflects the cultural beliefs, in terms of order and harmony. Similarly, the triangular ornamentation of Kanchipuram sarees suggests the architectural style of temple towers, and, beyond decoration, conveys ideas of stability and auspiciousness. The repeated use of triangles is not incidental in geometry, the triangle is considered the most stable polygon, since once its sides are fixed, its shape cannot be deformed without altering its length. This property of rigidity is mirrored in weaving, where triangular motifs provide visual balance and symbolic strength, while also reinforcing the structural alignment of wrap and weft threads. In this way, the design links geometric abstraction with both spiritual expression and practical stability.

Today, the practicality of these classical forms of mathematical expression is manifest. The logic of design incorporated in these crafts aligns with the upcoming tendencies of computational textiles, algorithmic design, and architectural geometry. According to Firdaus and Nasution (2023), integrating the indigenous knowledge of mathematics within the contemporary modelling frameworks closes the gap between indigenous and scientific knowledge systems by incorporating the indigenous wisdom of scientists. The integration is visible in the textile engineering courses where the mathematical principles of traditional crafts are used to teach concepts of design and modelling. It is also evident in sustainable practices that adapt indigenous weaving and basketry techniques for modern applications. Together, these examples illustrate how ethno mathematics is gaining recognition as both a practical knowledge system and a growing epistemology.

Literature Review

Authors	Findings
Dominikus et al. (2023)	The study findings reflect that weaving activities in Timor Island reflect various ethnomathematical characteristics, including counting, locating, measuring, designing, explaining, logical implication, and estimating. These practices suggested mathematical concepts such as multiplication, parallel lines, geometric shapes, reflection, rotation, and units of measurement. The findings highlight weaving as a source of rich cultural resources for enhancing mathematics learning.
Fauzi et al. (2023)	The researchers examined that the traditional woven fabric motifs of the Sasak people, an indigenous ethnic group from Lombok, Indonesia, incorporate mathematical concepts such as lines, angles, flat shapes, and geometric transformations, including reflection, translation, rotation, and dilation. Each motif also reflects the cultural and philosophical values such as perseverance, harmony, patience, and sincerity. These findings highlight that Sasak woven fabrics serve not only as an artistic expression but also as a valuable resource for mathematics learning.
Enmufida et al. (2021)	The researchers investigated the integration of mathematics and culture by examining Minangkabau traditional songket weaving in Pandai Sikek, revealing mathematical concepts such as counting, measuring, designing, and geometric patterns within the weaving process. Songket is a kind of traditional Minangkabau woven fabric woven by hand using gold and silver threads, especially used in the Minangkabau ceremonies. Using a qualitative ethnographic approach, it highlights how weaving embodies mathematical ideas through activities like symmetry, reflection, and pattern design. The study demonstrates that mathematics is inherently linked to cultural practices, challenging the notion that the two exist independently.

Jalalimanesh and Xun (2021)	The researchers explored the role of the golden ratio and Fibonacci number sequence in art, architecture, and design, emphasizing their aesthetic harmony and mathematical precision. The golden ratio is an irrational number characterized by the Greek letter phi. They investigated their application in textile design through restructured Ming dynasty floral motifs, generating spirals and geometric patterns as decorative elements and emphasized how mathematical models enrich textile surfaces with cultural meaning, aesthetic value, and contemporary design applications.
Subanji et al. (2017)	The research describes the mathematical ideas of Adonara people engaged in the weaving practice. These indigenous inhabitants of Adonara island belong to the large group of Lamaholot speakers in Nusa Tenggara Timor, Indonesia. They are closely related socially and culturally, sharing an important history of weaving warp-ikat sarongs, or kewatek, with other Lamaholot-speaking people living in East Flores and on the surrounding islands of Lembata, Solor, coastal Alor, Ternate, and Buaya. The researchers investigated weaving traditions through Bishop's six mathematical activities – counting, locating, measuring, designing, playing, and explaining (CMLPDE) – as a framework to identify embedded mathematical ideas (Bishop, 1988). Emphasized ethno mathematics as a research and pedagogical approach that contextualizes mathematics learning while preserving cultural knowledge systems.

Objectives of the Study

1. To synthesize theoretical insights by linking craft-based mathematical reasoning with the broader framework of ethno mathematics as a cultural epistemology.
2. To interpret the cultural significance of mathematical patterns showing how designs like squares, triangles, colours, and circles express community beliefs, idea of stability, and symbolic values.
3. To study the mathematical patterns such as symmetry, tessellation, and geometric transformation embedded in traditional Indian weaving, beadwork, and basketry.

Methodology

This study adopts a qualitative interpretive approach to understand how mathematical structures and cultural meanings are embedded within traditional Indian crafts, specifically weaving, beadwork, and basketry. The research methodology combines visual analysis, semiotic interpretation, and secondary source synthesis, grounded within the theoretical lens of ethno mathematics.

Sample Selection and Rationale

Four traditional Indian crafts – Patan Patola (Gujarat), Kanchipuram Silk (Tamil Nadu), Naga Beadwork (Northeast India), and Toda Basketry (Tamil Nadu) – were selected for in-depth analysis. These were chosen due to their:

(a) high presence of symmetry, tessellation, and geometric motifs;
(b) regional and cultural diversity across India;
(c) documented pedagogical potential in ethnomathematics research; and
(d) availability of rich visual and textual documentation

The samples were identified from:

1. Digital museum collections (e.g., Indira Gandhi National Centre for the Arts) accessible through the digital repository, which provides high-resolution images and cultural descriptions of traditional weaving and basketry;
2. Scholarly sources, i.e., peer-reviewed research articles and books on Indian textile traditions and ethnomathematics, such as Daniel et al. (2025); Keerthi and E (2024); Mehta (2020); Ndapa Deda and Amsikan (2019); Pebryani, D.N. (2018) which provide theoretical and mathematical interpretation of craft patterns.

All patterns included were selected based on their clarity, cultural authenticity, and mathematical richness.

Visual Analysis

The mathematical elements such as types of symmetry (reflectional, rotational, and translational), tessellation rules (edge-matching, repetition), geometric transformations, and combinatoric patterns in beadwork and embroidery were first identified from chosen samples. These elements were then examined through visual pattern analysis, in which patterns were redrawn and digitally annotated to map principles such as congruence, angle measure, and repetition cycle.

Semiotic Method

A semiotic framework was applied, drawing on Roland Barthes' notion of denotation and connotation. Denotation refers to the literal level of meaning, while connotation refers to the symbolic or cultural meanings (Barthes, 1964, 1972). In this study, denotative readings identified the visible geometric forms such as triangles, squares, and circles, whereas connotative readings revealed their cultural associations with cosmology, spirituality, and community identity.

Stage 1: Identification of Signifiers

Each visual motif, such as squares, triangles, circles, spirals, tessellated grids, symmetry-based arrangements, and colour-coded bead patterns, was extracted and classified based on shape, repetition, and orientation.

Stage 2: Contextual Mapping

The motif's cultural context was identified through anthropological literature, oral narratives, and historical symbolism.

Stage 3: Interpretive Synthesis

The relationship between form and cultural meaning was established using Barthes' denotation/connotation model, resulting in layered interpretations of the pattern's role in traditional belief systems.

Secondary Source Review

Secondary data played a vital role in contextualizing visual patterns. Sources included:

1. Ethnographic studies on textile symbolism and tribal art, such as Ascher (2004) on Inca and Indian weaving traditions, and Zaslavsky (1990) on mathematical symbolism in African textiles, which show how cultural motifs encode mathematical meaning;

2. Mathematical texts explaining tessellation and geometry, such as Grünbaum et al. (1987) , who systematically classify tessellations, and Stevens (1980) , who connects geometric patterning to traditional art forms; and

3. Indigenous knowledge system documentation and oral narratives such as D'Ambrosio (1985) , who emphasizes ethnomathematics as a knowledge system, and Guru et al. (2022), who records oral traditions of craft and weaving in Indian tribal communities.

Each source was reviewed to triangulate visual interpretation, validate cultural meanings, and ground the mathematical analysis in historical practices. This approach ensured the findings were not solely observational but informed by cultural narratives and academic rigor.

Objective 1: To synthesize theoretical insights by linking craft-based mathematical reasoning with the broader framework of ethnomathematics as a cultural epistemology.

Theoretical Framework

This research work is based on the ethnomathematics framework that acknowledges the mathematical systems that are vested in cultural practices. Ethnomathematics seeks to debunk the view in the previous approach as a culturally neutral discipline because indigenous knowledge systems articulate mathematical ideas in art, craft, architecture, and ritual.

The research is embedded in such an ethno mathematical paradigm that is simultaneously decolonial and pluralistic, in the view of D'Ambrosio (1985). The paradigm argues that mathematics is a humanly constructed cultural praxis, which is guided by lived experiences within the community, material practices, and symbols of the community. Mathematics, therefore, is not a culture-independent abstraction but a contextual epistemology which arises out of continued interaction between human beings and their materiality as well as their symbolism. Ethno mathematical research has found special application in the examination of production systems based on crafts, due to their ability to incorporate mathematical concepts into sensory touch through the senses. The linkage between mathematics and culture in relation to indigenous craft traditions is displayed by D'Ambrosio (1985) by way of weaving, building, measuring, and designing, which are major modes of indigenous crafting practices. This orientation is taken up in the current research, where the textile and beadwork patterns are discussed as mathematical stories about how those patterns are created as an embodied, artisanal practice.

The articles by Zaslavsky (1994) and Ascher (2017) are additional sources that inform the work, challenging mathematical sophistication in African and Native American designs. Through their analyses, one can find how mathematical concepts, such as fractals, permutations, geometry, among others, are employed within the realms of ritual, narrative, and aesthetic space.

Knijnik (2002) provides a rigorous outlook by bringing out the mechanisms through which power relations and official forms of education oppress indigenous knowledge, thus arguing for pedagogical approaches that would demonstrate epistemological pluralism. The educational implications presented in this article are informed by her understanding of ethno mathematical justice to make sure that indigenous ways of knowing are not simplified or distorted in terms of their formulation through craft-based mathematics learning.

Rosa & Orey (2010) also enrich the analysis with their socio-cultural model of mathematics education, accenting the importance of community-based knowledge systems, which are nevertheless different from the Western paradigms inasmuch as they provide explicitly logical structures, which, in turn, fit to be called mathematics. Both of their works on the dialogic pedagogy and inclusive curriculum design are interrelated with the educational implications that are seen in the course of this study.

These theoretical considerations are projected into the Indian setting, where the traditions of weaving, like Patan Patola and Toda basket-making, serve as autonomous systems of knowledge of mathematics. This intermingling of Brazilian, African, and Indian outlooks can decentralize the paradigms in formal schooling and bring to the fore indigenous logic and visual reasoning in terms of fundamental components around mathematical learning.

The study also makes use of concepts from:

(a) Geometry and Symmetry Theory, to classify and to analyze patterns.
(b) Semiotics to make the symbolic meaning of these patterns.
(c) Cultural Anthropology with the view of positioning weaving in the context of societal tradition, gender roles, and storytelling.

Objective 2: To interpret the cultural significance of mathematical patterns showing how designs like squares, triangles, colours, and circles express community beliefs, idea of stability, and symbolic values.

Double Ikat Technique in Patan Patola

Fig. 4 Patan Patola art work (Source: https://images.app.goo.gl/tDWGoFcuk8gdbYYt8)

Cultural History

Gujarat, India, is globally recognized for its exquisite textile heritage, particularly the Patan Patola, a double ikat weaving tradition that dates back to the 12th century. Patan Patola sarees are famed for their vivid colours, intricate motifs, and cultural symbolism. The unique double ikat technique involves resist dyeing both the warp and weft threads before weaving, ensuring that the patterns appear identically on both sides of the fabric, a hallmark of extreme precision and artisan mastery (Dewi Pebryani, 2018). The designs often include floral motifs, animal forms, and abstract figures arranged within structured grids, reflecting a deep alignment with Jain and Hindu cosmologies (Pebryani et al., 2020). These textiles are not only luxury artefacts but also vessels of cultural identity, spirituality, and artisanal lineage, passed down through generations within the Salvi community.

Kanchipuram Silk

Fig. 5 Kanchipuram Silk Art (Source: https://rmkv.com/blogs/posts/the-blessed-harvest-kanchipuram-motifs-inspired-by-abundance)

Cultural History

Kanchipuram silk is a prestigious handwoven textile tradition from Tamil Nadu, India, renowned for its vibrant hues, intricate borders, and exceptional durability (Kawlra, 2005). Traditionally worn during rituals, festivals, and weddings, these sarees are deeply embedded in South Indian cultural identity. The hallmark of Kanchipuram sarees lies in their contrasting pallus and temple-inspired borders, often embellished with geometric and symbolic motifs that reference natural and sacred forms. Among these, triangular motifs dominate the border patterns, reflecting both aesthetic sensibility and spiritual symbolism linked to South Indian temple architecture (Keerthi & E, 2024).

Naga Beadwork

Fig. 6 Naga Beadwork Design (Source: https://www.wxgsales.site/?ggcid=4300790)

Cultural History

The Naga tribes of Northeast India possess a rich tradition of beadwork that holds deep cultural and symbolic significance. Adornments such as necklaces, headbands, and breastplates are crafted using meticulously arranged beads in complex patterns that vary across tribal groups (Odyuo, 2013). These patterns are not merely aesthetic; they serve as visual markers of identity, rank, marital status, and clan affiliation (Kanungo, 2006). Each tribe employs its own colour codes and motifs, making Naga beadwork a dynamic language of heritage and social communication. The act of bead arrangement itself is an intuitive design tradition passed down through generations, reflective of both artistic ingenuity and cultural continuity.

Fig. 7 Toda Basket Design (Source: https://www.countryseat.com/spiral-bread-basket-pattern-by-hawkins.html)

Cultural History

The Toda tribe, an indigenous community residing in the Nilgiri Hills of Tamil Nadu, is known for its rich cultural legacy and intricate handicrafts, particularly basket weaving. These Toda baskets (locally referred to as puttukuli) are traditionally woven using bamboo strips and cane, serving both utilitarian (e.g., grain storage, goods transport) and ritualistic purposes (Bahadur Subba et al., 2022; Gogoi et al., 2022). The craftsmanship involved reflects not only manual skill but also the Toda people's intimate relationship with their environment, spirituality, and communal identity. The symbolic significance of these baskets is preserved through intergenerational transmission, making them a living artefact of the tribe's cultural epistemology (Rick, 2021).

Objective 3: To study the mathematical patterns such as symmetry, tessellation, and geometric transformation embedded in traditional Indian weaving, beadwork, and basketry.

Mathematical Patterns and Cultural Symmetry in Traditional Weaving

Ethnopedagogical Approach to Patola in Education
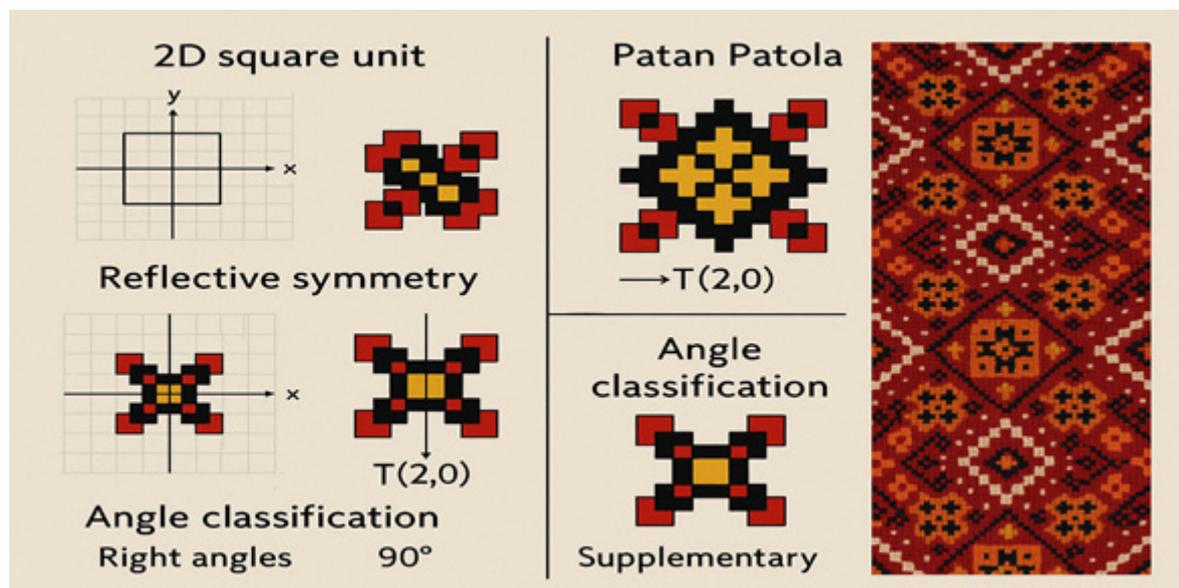
The square-based motifs in Patan Patola are not merely decorative elements but encode cultural cosmologies. Squares symbolize order, balance, and the sacred mandala structure seen in Jain and Hindu temples. The square tessellations of Patan Patola follow rigorous grid logic, which obeys the principle of Euclidean tessellation, allowing units to fill the plane without any untaken areas or the creation of unwanted overlaps. These square patterns may be said to possess translational symmetry, both in the x- and y-directions, and sometimes also rotational symmetry, about 90- and 180-degree angles around important points of intersection. The coincidences of neighbouring edges and the shape repetitions indicate indigenous knowledge of isometries, that is, geometric transformations such as reflections, rotations, and translations in which the original shape is preserved without distortion, but artists describe these methods using the terminology of balance or mirroring.

In geometry, each unit can be approximated as a two-dimensional square of identical dimensions (e.g., 1 x 1 inch). In this area, lines at 450 angles, 900 angles, and perpendicular bisectors serve as secondary/

sub-motifs and create nested symmetry. It can be modelled digitally by plotting the configuration on coordinate planes or grid paper, on which symmetry axes and vectors of translation (T (x, y)) can be plotted and calculated.

Such analysis helps educators connect craft with formal mathematics:

  (a) Reflective symmetry → Mirror line = y-axis (vertical)

  (b) Translational symmetry → Vector = T (2,0) (horizontal shift)

  (c) Angle classification → Right angles (90°), supplementary angles (180°), or congruent isosceles patterns.

By using Patola as a teaching tool, mathematics becomes more contextualized and culturally inclusive, especially for students with heritage connections to textile traditions. This not only improves engagement but also fosters epistemological pluralism – the idea that multiple valid ways exist to understand and represent mathematics (Rosa & Orey, 2011). Incorporating such rich, hands-on content aligns with UNESCO's goals for education rooted in local knowledge systems, enabling learners to appreciate mathematical reasoning in their own cultural surroundings.

Ethnopedagogical Approach to Kanchipuram Silk in Education
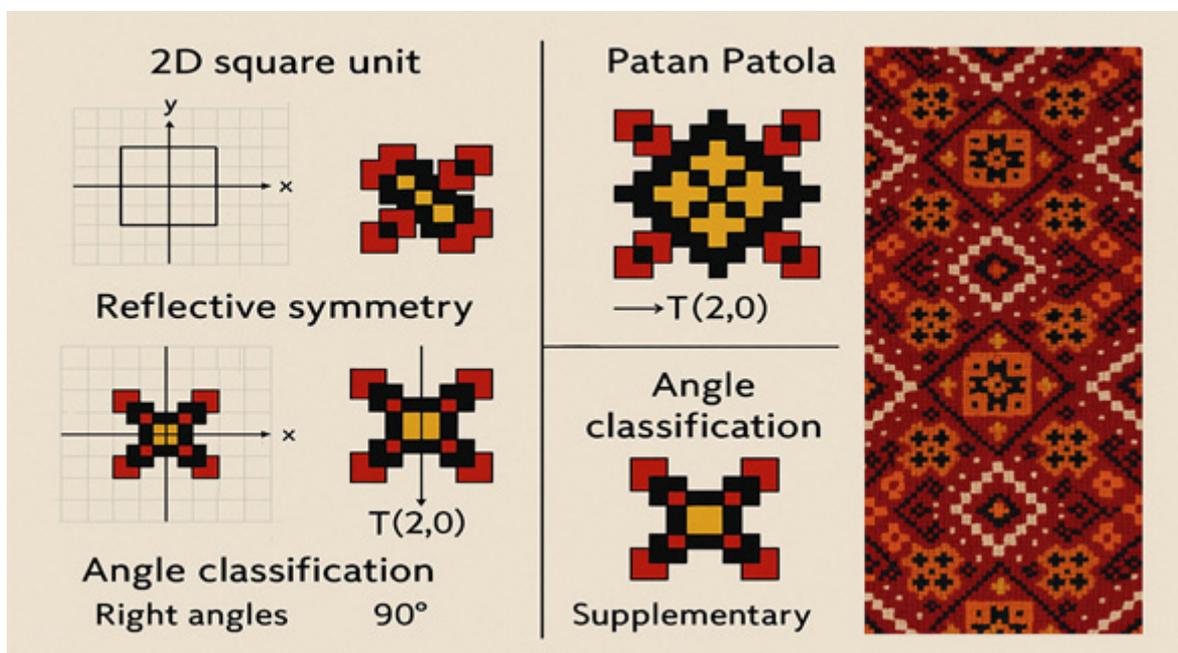
The triangular motifs in Kanchipuram sarees often represent 'gopuram' temple towers, signifying ascent and divine energy. These triangles are symmetrically aligned in alternating or mirror patterns along the borders and pallu, showcasing bilateral symmetry. In terms of tessellation, these repeated triangular units mirror concepts of polygonal tiling, and artisans carefully calculate proportional spacing to ensure continuous flow across the weave, demonstrating spatial awareness and abstract reasoning embedded in cultural motifs. Triangles are structurally stable and commonly used in both architecture and textiles for their rigidity. In the Kanchipuram borders, this reinforces not only design continuity but also mirrors the gopuram's architectural integrity.

The triangle that Kanchipuram silk employs is often an isosceles triangle

(equal angles at the base) or is based on a scalene variant (unequal angles at the base), based on the region. The mighty visual flow and rigidity with the angle properties, which may comprise 300, 600,900 in many instances, are chosen to confirm the strong upward design and structural stability as the temples themselves changed their logic to the construction and point out the structural stability by means of the use of the triangles.

Mathematical concepts derived:

(a) Triangle interior angle sum = 180°

(b) Bilateral symmetry → line of reflection through triangle's height.

(c) Glide symmetry = R + T (x, y), where R is reflection, T is translation.

Within a South Indian context of textile design, several motifs have a mathematical interest, as they are not only aesthetic elements, but also carriers of the encoded language of divine order, cosmic movement, and social ideals.

Mathematical Structures and Patterns in Beadwork

### *Ethnopedagogical Approach to Teaching through Beadwork*
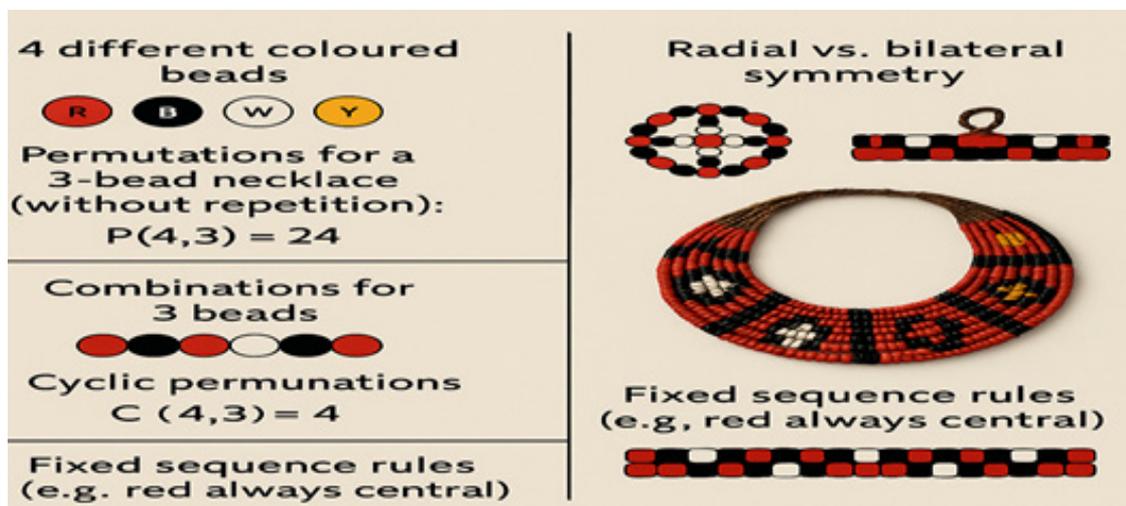
Naga beadwork shows the application of principles of combination to ornament design by using coloured beads in orderly combination. Cyclical patterns are also typical of traditional motifs, with such examples as the red, black, white, black, red, repeated pattern giving radial symmetry when wrapped around circular chokers and bilateral symmetry when wrapped along flat strips.

In view of fundamental combinatorics, when four differently coloured beads (R, B, W, Y) are at the disposal, the total number of the permutations of the necklace composed of three beads with no repetitions is 24= P (4,3). In the case of a combination, no matter the order, then it is C (4, 3) = 4.The types of arrangements follow standard sequencing rules (usually due to tribal or symbolic meaning), showing the co-evolution of combinatorial reasoning and aesthetic tradition in Naga craftwork. Teachers may use such designs to explain the concepts of radial and bilateral symmetry and cyclic permutations, the pattern rules of mathematics, and cultural symbolism (such as the systematic use of red in the centre of a pattern).

The Geometric Principles and Concepts in Basketry
Ethnopedagogical Approach to Teaching with Toda Basket
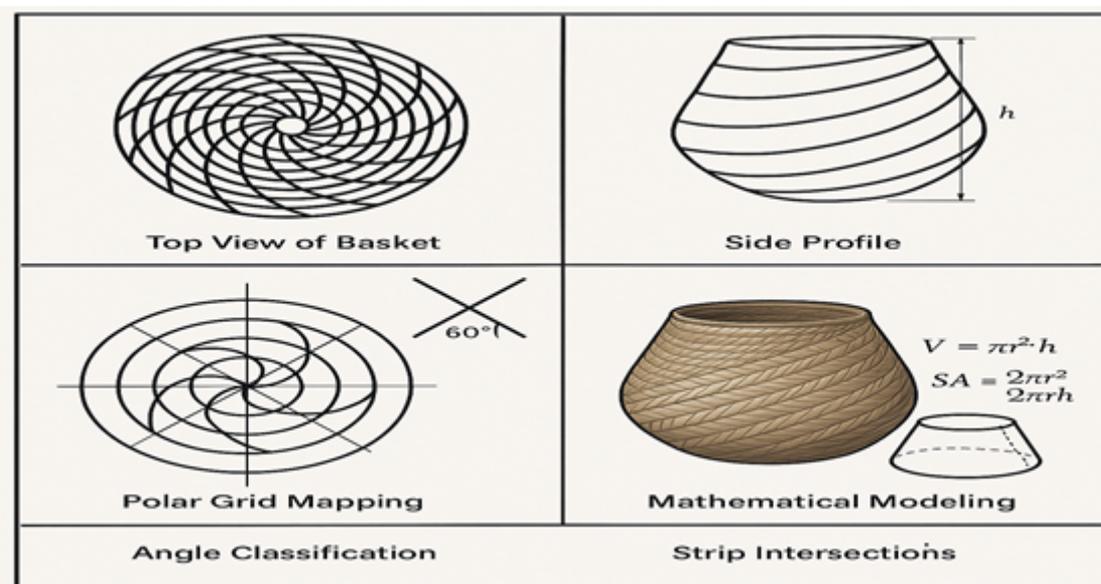
The spiral and round shape of the Toda basket demonstrate an advanced understanding of radial geometry, rotation symmetries, and concentric growth plans, which are produced with no formal mathematical training at all. Unlike planar tessellations, Toda basketry functions on a cylindrical spatial system, where raw materials are stacked and interwoven in a three-dimensional spatial package to yield symmetric, balanced vessels. The radial nature of cane or bamboo strips creates a very logical pattern of repetition or order of sectors and rotatable sequencing, which is normally every sixty or ninety degrees or so, subject to design. The harmonious adjustment of curvature, strip distance, and angle rhythm witness an intuitive grasp of geometric constraints similar to Euclidean constructions, of which craftsmen often speak (understandably) of a sense of cycle, wholeness, or flow.

Geometrically, the viewing profile of the basket may be modelled by a two-dimensional circle on its top and a truncated cone or cylinder on its side. The alternating strips create angular sectors, which intersect to define repetitive angular sectors (e.g., six-fold or eight-fold repetitive angular parts), thus defining visually nested circular motifs internally. The polar coordinates (r, θ) or the circular grids can be projected to show the radial layers and spiral increments, where angle sectors, the rotation centres, and continuity can be delineated and mathematically explained. This kind of study helps in making a meaningful use of Toda basketry in teaching mathematics:

Top View of a Basket

1. A circular diagram showing radial symmetry with lines at 60° or 90° intervals (Order-6 or Order-4 symmetry).
2. Overlaid spiral patterns or sector-based strip layout.

Side Profile Diagram

Depicting the basket as a truncated cone or cylinder, with labels for radius (r), height (h), and curved surface

Polar Grid Mapping

A polar coordinate plot showing how the spiral or radial strips align with (r, θ) positions.

Angle Classification Diagram

Close-up of strip intersections with labelled internal angles (60°, 90°, and supplementary pairs).

Mathematical Modelling

Simple geometric shapes overlaid on a 3D render of the basket, showing volume and surface area formulas like:

- $V=\pi r^2 h$
- $SA=2\pi r^2+2\pi rh$

Taken together, these spatial constructions support a conception of geometric thought and prove that Toda weavers are quite natural students of 3-dimensional geometry and mathematical optimization. Their production, therefore, provides practical evidence on symmetry, structure, and measurement, and makes a good example of a cultural resource towards ethnographic mathematics-based teaching.

Major Findings from the Traditional Indian Art Form

Table 1: Summary of Mathematical and Ethno pedagogical Insights

Art Form	Mathematical Concepts	Ethno mathematical Approach (in Brief)	Example for Classroom Use
Patan Patola (Gujarat)	Tessellation, symmetry, grid geometry, translation, square-based repetition	Demonstrates precise spatial reasoning through double ikat weaving; ideal for teaching patterning and transformations.	Students design a tessellated pattern using square grids that mirror Patola motifs.
Kanchipuram Silk (Tamil Nadu)	Triangles, tessellation, symmetry (reflection, rotation), polygonal structures	Borders reflect sacred architecture and rhythmic geometric placement, useful in exploring types of triangles and symmetry.	Learners identify and classify triangle types used in saree borders and replicate border patterns.
Naga Beadwork (Northeast India)	Permutations, combinations, radial and bilateral symmetry, pattern repetition	Bead arrangement introduces combinatorics and pattern logic, a culturally responsive method to teach sequence and order.	Students use coloured beads to calculate and create different patterns using permutations.
Toda Basketry (Tamil Nadu)	Cylinder geometry, volume, surface area, circular symmetry, 3D visualization	Basket form supports teaching spatial dimensions and solid geometry; it connects abstract geometry to utilitarian design.	Learners model a Toda-style basket using paper cylinders and calculate surface area/ volume.

Table 2: Symmetry in Traditional Indian Fabric Arts

Art Form	Type of Symmetry	Mathematical Interpretation	Cultural Function
Patan Patola (Gujarat)	Reflectional (bilateral), Translational, Rotational	Symmetry across vertical and horizontal axes; grid tessellation with square motifs	Reflects order, harmony, and spiritual balance; used in double-sided patterns

Kanchipuram Silk (Tamil Nadu)	Reflectional, Rotational, Glide symmetry	Triangle motifs form mirrors and repeated patterns along fabric borders	Symbolic of temple architecture (Gopuram); denotes divine ascent and auspiciousness
Naga Beadwork (Northeast India)	Radial and Bilateral Symmetry	Patterns radiate from a central point or are mirrored along axes	Denotes tribal identity, status, and continuity; promotes visual equilibrium
Toda Basketry (Tamil Nadu)	Circular and Rotational Symmetry	Symmetry around the cylindrical axis; spiral formations in 3D	Practical for stability; signifies cyclicity and continuity in traditional use

Educational Implications

This study clearly demonstrates the transformative potential of incorporating traditional Indian crafts like Patan Patola weaving, Kanchipuram silk designs, Naga bead work, and Toda basketry into mathematics instruction. These cultural activities integrate mathematical ideas that can be applied in the classroom, such as symmetry, tessellation, permutation, and spatial reasoning. These practices are particularly significant because, when effectively connected to mathematics curricula, they form ethno pedagogical tools that simultaneously support the development of conceptual knowledge and promote respect for indigenous knowledge systems (Burkhardt, 2008; Firdaus & Nasution, 2023). According to D'Ambrosio (2006), mathematics can be characterized as a culturally situated practice with its historical, natural, and symbolic contingencies, which is consistent with the ethno mathematics approach. By incorporating them into the curriculum, these cultural forms provide learners with experiences that are both culturally and intellectually relevant while establishing indigenous forms of knowledge.

Additionally, this plan stimulates linguistic and cultural diversity in mathematics instruction. A symbolic language with a specific set of cultural coding and mathematical illustrations is found in every cultural artefact. Examples include the symmetrical reasoning of Patola designs, the temple directed connotations of Kanchipuram symbols, and the mathematical arrangements of Naga colour patterns. Acknowledging these various domains of knowledge allows students from many backgrounds to enter what may be perceived as a foreign and abstract field.

The masterful harnessing of the diversity of epistemologies also helps educators establish an inclusive classroom learning space wherein home cultures and native languages of the students are not marginalized; instead, used as resources that can intensify the student learning processes. This kind of pedagogical position not only improves mathematical discourse but also leads to identity affirmation, which induces learners to appreciate both their cultural background and their academic development (Rosa & Orey, 2011).

Furthermore, the paradigm encourages interdisciplinary engagement by rethinking mathematics as a medium that somehow links anthropology, history, art, and language, among other disciplines. To create cross-curricular literacy, a lesson about the radial symmetry of Naga beadwork, for instance, might be transformed into a language lesson about the colour names used in tribal languages or about the semiotics that the weaving patterns reflect.

Overall, incorporating conventional mathematical knowledge into the curriculum results in a pedagogical system that is pluralistic, inclusive, and culturally

sustainable. In addition to helping students grasp abstract concepts through context that is specific to them, it enables them to see mathematical complexity as a component of their own cultural identities.

Conclusion

Traditional Indian arts that most people know about, such as weaving, beading, and basketry, are not solely a result of visual phenomena alone, as they represent the traditional laws of mathematical thinking embedded in their culture, spirituality, and community. A careful analysis of the Patan Patola, Kanchipuram silk, Naga beadwork, and Toda basketwork has brought to light how mathematical ideas, such as viewing balance in terms of symmetry, tessellation, combinatorics, and space-positioning related sense, inform the cultural sensibility of these communities. This paper uses the theoretical input of D'Ambrosio (1985),

Knijnik (2002), Rosa and Orey (2011), and their comparative studies between Africa and Brazil to place ethno mathematics in the context of a decolonial pedagogical approach. Instead of considering such crafts as cultural oddities or symbolic representations of mathematics, the study considers them as plausible forms of mathematical practices that challenge the power of the themes of Western abstraction.

When incorporated into classroom learning, these arts lend authenticity and inclusivity to mathematics even as they respect and acknowledge indigenous knowledge systems. In this way, the classroom becomes a site of epistemological democracy in which students are able to explore mathematics from cultural, social, and imaginative angles. The next step should involve a study of the artisans themselves, through interviews in the field as well as a continuing comparison with other crafts and oral literature. Ethno mathematics is not only a discipline or an idea, as this paper purports, but it is a paradigm in the reshaping of education in a pluralistic, respectful, and empowering way.

This redefines ethno mathematics not as a preparation to school-based formal mathematics that should be absorbed before progressing to formal mathematics, but as an actual cultural epistemology. Through providing alternative formations of representing, conceiving, and applying mathematics, these traditional practices reveal a refined geometrical understanding of patterns of formation and abstraction that appear beyond the formalized contexts of education.

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