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From Heritage to Classroom: Innovative Pedagogies for Teaching Mathematics through Indian Knowledge Systems

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Abstract

Mathematics classrooms frequently face the challenge of making abstract ideas meaningful for learners. Concepts such as symmetry, proportion, trigonometry, and spatial reasoning are often presented as isolated procedures, leaving students with little opportunity to connect mathematics to the world around them. Ironically, many of these ideas have been embedded in Indian art, architecture, traditional games, and cultural practices for centuries. Yet, these connections remain largely absent from everyday classroom experiences.

Situated within the broader discourse on innovative pedagogy, the present study explores the educational potential of Indian Knowledge Systems (IKS) in mathematics teaching. Drawing upon ethnomathematics, constructivist theory, and cognitive apprenticeship, the study examines how cultural artefacts—including mandalas, Gond paintings, Rani ki Vav, Konark Sun Temple, Ajanta–Ellora caves, Gol Gumbaz, Chaupar, and Gilli-Danda—can serve as meaningful contexts for learning geometry and related mathematical concepts.

A fifteen-day design-based intervention was conducted with Grade XI students, where learning unfolded through four stages: observation, investigation, creation, and reflection. Rather than functioning as passive recipients of information, students engaged with mathematics as investigators, designers, and interpreters of cultural knowledge.

The findings suggest that culturally responsive pedagogies deepen conceptual understanding while simultaneously fostering creativity, collaboration, critical thinking, and a sense of belonging. More importantly, the study highlights that innovation in education is not limited to the use of digital technologies; it also lies in designing learning experiences that connect disciplinary knowledge with learners' cultural identities and lived realities.

Keywords: Indian Knowledge Systems, innovative pedagogy, experiential learning, ethnomathematics, geometry education, cultural pedagogy.

1. Introduction

Educational innovation is often associated with technological advancements; however, meaningful pedagogical innovation extends beyond the adoption of new tools. It involves transforming learners' engagement with knowledge through **active, contextualised, and meaningful learning experiences**.

This need is particularly relevant to mathematics education, where classroom instruction may emphasise procedural fluency and symbolic manipulation despite mathematics being deeply embedded in architecture, art, culture, and everyday life. Consequently, learners may acquire procedural knowledge without developing a deeper appreciation of the mathematical ideas underlying real-world patterns and practices. **A key pedagogical challenge, therefore, is to create learning experiences in which students do not merely apply mathematics to familiar contexts, but recognise, investigate, and construct mathematical meaning from those contexts.**

India's intellectual and cultural heritage provides rich yet underutilised contexts for addressing this disconnect. The *Sulba Sutras*, temple architecture, traditional art forms, crafts, and indigenous games reflect mathematical reasoning developed through observation, experimentation, and practical application. These contexts demonstrate the historical interrelationship between mathematics, culture, aesthetics, and human activity.

In alignment with the **National Education Policy (2020)** and its emphasis on experiential, multidisciplinary, and culturally grounded learning, Indian Knowledge Systems (IKS) offer opportunities to recontextualise mathematical learning through exploration and inquiry. However, the presence of mathematics within cultural artefacts alone does not necessarily make them pedagogically meaningful. **The critical question is how such cultural and heritage contexts can be deliberately transformed into structured learning experiences that engage students in mathematical observation, investigation, creation, and reflection.**

Research Gap

Although research on **ethnomathematics, culturally responsive pedagogy, and Indian Knowledge Systems** has highlighted the cultural and historical dimensions of mathematical knowledge, there remains limited classroom-based research demonstrating **how Indian heritage can be systematically transformed into structured mathematical learning experiences**. Existing work often documents mathematical ideas embedded in traditional art, architecture, crafts, and games, but comparatively less attention has been given to the **pedagogical processes through which these contexts can be integrated into contemporary school mathematics**.

There is also a need to move beyond simply *identifying mathematics in heritage* towards creating **inquiry-oriented experiences** in which learners actively observe patterns, investigate mathematical relationships, construct representations, collaborate, and reflect on their learning.

The present study addresses this gap by designing and examining a **structured IKS-based mathematics intervention** for Grade XI students. Indian art forms, heritage monuments, and indigenous games were used as contexts for mathematical inquiry, positioning learners as **observers, investigators, creators, and reflective learners**. The study further proposes the **Heritage-to-Mathematical-Inquiry Cycle—Observe → Investigate → Create → Reflect**—as a pedagogical framework for connecting cultural heritage with contemporary mathematics learning.

Thus, the study responds to a broader pedagogical need: **to move from mathematics being taught about cultural contexts to mathematics being learned through them.**

2. Theoretical Framework

Ethnomathematics and Indian Knowledge Systems

Ethnomathematics challenges the conventional view of mathematics as a culturally neutral and universally constructed body of knowledge by emphasising its **social, cultural, and historical situatedness** (D'Ambrosio, 2001). Mathematical thinking develops through human practices such as architecture, art, craftsmanship, trade, and games, reflecting the ways in which communities interpret and organise their environments.

Indian Knowledge Systems provide diverse contexts in which such mathematical reasoning can be explored. **Symmetry, proportion, measurement, and spatial relationships** are evident in mandala art, temple architecture, traditional crafts, and indigenous games. The *Sulba Sutras* further demonstrate the use of systematic geometric reasoning in the construction of ritual spaces.

An ethnomathematical perspective therefore positions mathematics not merely as an abstract symbolic system but as a **culturally situated form of knowledge**.

Constructivism and Cognitive Apprenticeship

Constructivist theory conceptualises learning as an **active process of knowledge construction** through interaction, inquiry, and reflection rather than passive transmission (von Glasersfeld, 1995). Consistent with this perspective, the present study situated mathematical concepts within culturally familiar contexts, enabling students to explore geometry through artistic patterns, architectural structures, and indigenous games.

The **cognitive apprenticeship framework** (Collins et al., 1989) further informed the intervention by emphasising observation, guided participation, and experiential learning. Students engaged as *apprentice mathematicians*, examining and reconstructing the mathematical principles underlying the work of artisans, architects, and designers. Thus, learning extended beyond mathematical content to encompass the cultural practices and processes through which mathematical knowledge is expressed and developed.

Cultural Pedagogy

Education extends beyond cognitive achievement to shape learners' **identities, values, and connection with the world**. Cultural pedagogy makes learning more meaningful by linking it with students' lived experiences and heritage. Indian educational traditions often integrated logic with aesthetics, and intellectual learning with observation, creativity, patience, and reflection. Integrating IKS into mathematics can therefore strengthen conceptual understanding while nurturing **curiosity, perseverance, mindfulness, and cultural appreciation**, supporting learners' intellectual as well as social and cultural development.

3. Objectives

The study aimed to:

1. explore how Indian cultural and heritage contexts can be integrated into Grade XI mathematics;
2. design experiential mathematical activities using Indian art, architecture, and indigenous games;
3. examine students' responses to IKS-based mathematical inquiry; and
4. develop a pedagogical framework for connecting heritage with contemporary mathematics learning.

4. Research Design and Methodology

The study adopted a **qualitative, design-based research approach** to explore how Indian cultural and heritage contexts can enrich mathematics teaching and learning. A **15-day intervention with Grade XI students** was structured around four interconnected stages: **Observe, Investigate, Create, and Reflect**.

Observe: Students examined monuments, artworks, architectural forms, and indigenous games to identify patterns, symmetry, and mathematical relationships.

Investigate: Learners explored geometric properties, measurements, transformations, ratios, tessellations, and recursion through guided inquiry.

Create: Students developed mandalas, game boards, architectural models, and geometric representations inspired by Indian heritage.

Reflect: Students recorded their learning in journals and engaged in discussions to connect mathematical ideas with cultural contexts and personal experiences.

Data Sources and Analysis

Student journals, mathematical drawings and artefacts, measurement records and calculations, classroom observations, photographs, group discussions, and presentations were used as sources of evidence. The data were analysed through **thematic analysis** following Braun and Clarke (2006), with attention to recurring patterns related to **conceptual understanding, creativity, learner engagement, and cultural connections**.

5. IKS-Integrated Mathematical Experiences

5.1 Mandala Art: Geometry through Pattern and Symmetry

Mandala construction emerged as a powerful entry point into geometry, blending analytical and aesthetic learning. By drawing concentric circles and equal sectors, students explored **symmetry, coordinate geometry, proportional reasoning, and transformations**. The central *Bindu* served as a geometric reference point from which the patterns developed.

Students investigated radial symmetry, rotations, reflections, repeated motifs, proportional spacing, and recursive expansion. The activity encouraged learners to make mathematical decisions while simultaneously attending to visual balance and artistic composition.

One learner reflected:

"For the first time, I felt that geometry was not only about solving questions. It was hidden inside patterns that people have been creating for centuries."

The repetitive pattern-making process was also described by students as calming and meditative, suggesting that mathematics could support reflective engagement alongside analytical thinking.

5.2 Gond Art: Mathematics in Indigenous Patterns

Gond art provided another context for exploring mathematical structure through creative expression. Students examined **branching patterns, repeated motifs, curves, symmetry, scaling, and transformations**.

The branching structures in Gond artwork provided opportunities to discuss recursive patterns and geometric progression, while repeated motifs encouraged exploration of tessellation, area, and perimeter.

Curved forms could be interpreted through coordinate representations, while dots and lines encouraged students to investigate spacing and pattern formation.

One learner observed:
“The patterns looked artistic at first, but later I realized that they follow mathematical rules.”
The experience demonstrated how **creative expression can foster mathematical reasoning**, highlighting the value of indigenous knowledge contexts in developing conceptual understanding.

5.3 Heritage Monuments as “Living Laboratories”

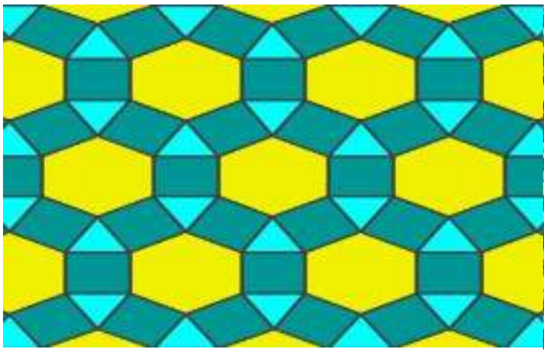
Conventional mathematics classrooms often present geometry as formulas detached from everyday experience. The intervention addressed this gap by transforming heritage monuments into **“living laboratories”** where students could observe, question, and reconstruct mathematical ideas.

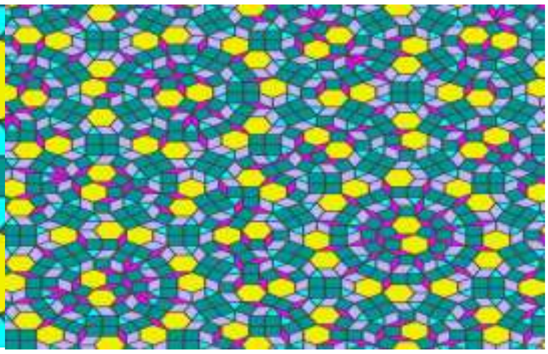
Students explored **Rani ki Vav, Konark Sun Temple, Ajanta–Ellora caves, and Gol Gumbaz** through specific mathematical activities. They **identified symmetrical patterns and geometric shapes in Rani ki Vav, estimated heights and angles using trigonometric methods at Konark, analysed spatial arrangements and geometric forms in the Ajanta–Ellora caves, and investigated dimensions and acoustic properties of Gol Gumbaz**. Students also prepared sketches, made measurements, performed calculations, and presented their findings collaboratively.

The intervention integrated **place-based, inquiry-based, and problem-based learning**, enabling learners to connect **symmetry, trigonometry, mensuration, spatial visualisation, and proportional reasoning** with tangible cultural and architectural contexts.

Rani ki Vav

At Rani ki Vav, students identified two- and three-dimensional geometric forms, examined symmetry and repeating motifs, compared dimensions, and explored measurement and proportional relationships. They investigated how geometric reasoning contributed to structural design and water conservation.





The discussion extended beyond geometric concepts to broader considerations of **sustainability, engineering, and functional design**. One participant observed:

“Geometry was not only decoration—it solved real problems.”

This reflection highlighted students’ emerging understanding of mathematics as both an **aesthetic and functional form of knowledge**.

Konark Sun Temple

The Konark Wheel provided a context for exploring **circle geometry, sectors, radii, arcs, chords, angular divisions, symmetry, proportion, and trigonometric measurement**. Students used shadow lengths and angular relationships to investigate connections between mathematics and traditional solar observation.

The activity helped learners recognise the relationship between **mathematics and astronomy**, as the wheel's divisions provided a context for understanding traditional time measurement through observation and calculation.

One student reflected:

"The wheel looked like a sculpture, but when we studied it carefully, it became a clock, a circle, and a mathematical model all at once."

Ajanta–Ellora Caves

The exploration of the **Ajanta–Ellora caves** enabled students to understand geometry as a tool for interpreting three-dimensional space. They identified **cylinders, hemispheres, cuboids, and composite solids** in pillars, domes, and chambers, and applied mensuration concepts to **estimate dimensions, calculate areas and volumes, and visualise spatial relationships** rather than merely memorising formulas.

Students also considered symmetry, proportional relationships, spatial planning, and three-dimensional modelling. This allowed them to connect textbook geometry with the practical reasoning involved in architectural design.

Gol Gumbaz

Gol Gumbaz provided a context for exploring **solid geometry, mensuration, symmetry, trigonometry, coordinate representation, and acoustics**. Students investigated the dome as a geometric form and considered how its dimensions and structure influenced sound reflection.

The activity challenged the belief that mathematics exists only in textbooks, helping learners recognise its presence in everyday phenomena.

One student reflected:

"I had never imagined that sound could depend on geometry."

5.4 Indigenous Games: Mathematics through Play

Traditional games provided opportunities to connect mathematics with movement, strategy, probability, and data.

Chaupar

Chaupar enabled students to investigate **probability, combinatorics, sequences, symmetry, statistics, and strategic decision-making**. Learners examined outcomes generated by cowrie shells, recorded frequencies, compared possible moves, and considered the role of chance and strategy.

Learners explored questions about **frequency, randomness, prediction, and strategy**, transforming probability from an abstract concept into an experience-based inquiry.

One student reflected:

"We were not solving probability problems from a textbook; we were discovering probability by playing."

Gilli-Danda

Exploring **Gilli-Danda** connected bodily movement with mathematical reasoning. Students measured launch angles and distances and represented trajectories on coordinate planes, naturally engaging with **trigonometric ratios, parabolic motion, vectors, and statistics**. The activity made otherwise abstract mathematical concepts tangible through experimentation and observation.

6. The Heritage-to-Mathematical-Inquiry Cycle

A central outcome of the intervention was the development of the **Heritage-to-Mathematical-Inquiry Cycle**:

OBSERVE → INVESTIGATE → CREATE → REFLECT

The cycle begins with observation of a cultural artefact, monument, artwork, or game. Students then investigate the mathematical relationships they notice, create representations or models based on their findings, and finally reflect on both the mathematical and cultural significance of their learning.

The cycle transforms heritage from a passive source of information into an **active context for mathematical inquiry**. It can be adapted across topics and grade levels and does not require sophisticated technological infrastructure.

7. Thematic Analysis and Findings

Analysis of classroom artefacts, journals, discussions, and observations revealed three interconnected themes.

Learning by Doing

Students experienced mathematics through drawing mandalas, analysing patterns, measuring monuments, constructing models, and playing indigenous games. These activities made mathematical ideas more tangible and encouraged learning through action, observation, and reflection.

One student observed:

"I used to think mathematics existed only in books. Now I realize it exists in art, buildings, and everyday life."

Learning by Connecting

IKS-based activities helped students connect mathematics with culture, heritage, and everyday experiences. Learners began to recognise mathematical ideas embedded in art, architecture, traditions, and games, with several expressing surprise and appreciation for this mathematical heritage.

As one student remarked:

"I had visited these monuments before, but I never looked at them as mathematical creations."

Learning Through Creativity and Collaboration

Activities encouraged students to communicate, work collaboratively, experiment with patterns and representations, and construct mathematical meaning together. Learners described the classroom as interactive and different from conventional mathematics lessons.

Overall, the findings indicate that IKS-integrated mathematics learning supported learning at **cognitive, affective, and social levels**. Cultural contexts helped students engage with mathematical concepts through tangible experiences, while collaborative activities promoted communication and collective problem-solving.

Importantly, the intervention also shifted classroom roles: students participated as **investigators and knowledge creators**, while teachers functioned as facilitators.

8. Pedagogical Implications for Twenty-First-Century Education

The study highlights the potential of heritage-based pedagogy to connect abstract mathematics with real-world experiences while strengthening cultural awareness and learner engagement. IKS integration also supports interdisciplinary learning across **mathematics, history, art, architecture, environmental studies, and culture**.

Such an approach is consistent with the **National Education Policy (2020)**, particularly its emphasis on experiential, holistic, multidisciplinary, and learner-centred education.

The study also demonstrates that pedagogical innovation need not depend entirely on technology. A monument can become a mathematical model, a painting a pattern to investigate, and a traditional game a probability experiment. Mathematics classrooms can consequently move beyond formula transmission towards **curiosity, creativity, inquiry, collaboration, and cultural understanding**.

9. Limitations

The study involved a limited group of Grade XI students over a period of fifteen days; therefore, the findings cannot be generalised to other contexts. The intervention focused primarily on geometry and related mathematical concepts. Future research could examine IKS integration across **algebra, calculus, statistics, and applied mathematics**, using longitudinal, comparative, and quantitative designs to explore conceptual understanding, achievement, motivation, and learner engagement.

10. Conclusion

This study demonstrates the pedagogical potential of using Indian heritage as a starting point for mathematical inquiry. Mandala art introduced symmetry and spatial reasoning; Gond art encouraged exploration of patterns and recursion; heritage monuments provided contexts for geometric and spatial investigation; and indigenous games connected mathematics with probability, statistics, trigonometry, and movement.

The significance of IKS integration lies not simply in *finding mathematics in heritage*, but in using familiar cultural contexts to encourage learners to **notice, question, investigate, construct, represent, and reflect**. The classroom consequently shifted from explanation towards inquiry, with students engaging with mathematics as something to be explored rather than merely received.

The proposed **Heritage-to-Mathematical-Inquiry Cycle—Observe → Investigate → Create → Reflect**—offers a practical pedagogical framework for integrating Indian cultural knowledge with contemporary mathematics education.

The movement **from heritage to classroom** represents a dialogue between inherited knowledge and contemporary learning. The pedagogical proposition emerging from the study can therefore be expressed as:

Heritage + Curiosity + Inquiry + Creation + Reflection = Meaningful Mathematical Experience

Ultimately, innovative pedagogy should not only help students **learn differently but also see differently**. When learners recognise mathematics within the cultural world around them, the textbook and lived experience become connected, making mathematics simultaneously **rigorous, creative, historical, and human**.

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