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CULTURALLY RESPONSIVE MATHEMATICS PEDAGOGY: INSIGHTS FROM NCF-2023 AND ETHNOMATHEMATICS

Mampi Howlader*[1)], Puja Sarkar[2)]
1. The University of Burdwan, India
2. The University of Burdwan, India

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* Corresponding author.
Mampi Howlader
E-mail address:
mampihowlader99@gmail.com

ABSTRACT
Throughout the school curriculum, mathematics is an indispensable subject that is used in both everyday life and the study of other disciplines. Nonetheless, there is a widespread belief that most students despise mathematics. Numerous studies have shown that rather than the topic itself, the issue may be in the methods teachers use to teach. Only 43% of grade 8 students can answer grade 5 math problems, and only 28% of fifth-grade students can do division operations, according to the 2018 Annual Status of Education Report (ASER). To counter this problem, NCF-2023 suggests reassessing the pedagogical approach to foster students' interest in mathematics and integrate it into their daily lives. The purpose of our study is to teach various concepts of school mathematics through traditional activities. This study is descriptive in nature. We delimit our study to the foundational stage, the preparatory stage, and the middle stage. Furthermore, we only focus our study on Indian students and NCERT textbooks. We show how to teach the concept of the highest common factor (HCF), fractions, integers, and various shapes through the traditional activities of beading, pottery, weaving, and fishing.

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I. INTRODUCTION

MANY educators are aware that in the modern, increasingly complicated and dynamic environment, individuals need to possess certain information and skills in order to address difficulties. Teachers are aware that when students take an active role in their own education, they become more motivated. This is particularly true, according to Freire [1], when students are urged to address the problems that most affect them personally and in their communities. It is evident now that the process of teaching and learning mathematics involves intricate interactions between cognitive, affective, emotional, social, cultural, and linguistic elements [2].The relationship between theory and practice is one of the primary concerns in mathematics education. Making the proper decision and figuring out how to handle both aspects may be rather challenging at times [3].
Most people only consider "school math" when they think of mathematics, despite the fact that math-based technology dominates our culture. Most students grow to despise math very early in their education or come to feel that they are incapable of "doing" mathematics, as it is defined by the traditional academic approach. Math education should promote a deeper knowledge of how mathematics is employed in our increasingly technologically driven society, rather than fostering dread and contempt [4]. Because of the many connections between these elements, teaching mathematics is a challenging task made considerably more difficult in multicultural classrooms. As a consequence, teachers have had to reconsider the purpose and design of their curriculum as well as alter their pedagogical approaches in recent years [5]. Mathematics education should promote a deeper knowledge of how mathematics is employed in our increasingly technologically driven society, rather than fostering dread and contempt. The scope of math in the classroom has to be increased in order to better represent the mathematics that students encounter in their everyday lives. Including elements of ethnomathematics, or culturally-based mathematics, is one approach to do this and encourage kids to become more interested in mathematics [6].

It is widely recognized that Brazilian Mathematician Ubiratan D'Ambrosio is "the intellectual father of Ethnomathematics." In his paper, "Overall Goals and Objectives in Mathematics Education," he explains how organizing a panel on "Why Teach Mathematics" at the Third International Congress on Mathematics Education (ICME 3) in Karlsruhe, Germany, in 1976, was a pivotal moment in his development of the concept of Ethnomathematics [7]. He coined the term “ethnomathematics” in 1977 in his speech delivered at the American Association for the

Advancement of Science. In 1984, at ICME 5 in Adelaide, Australia, he delivered the theory and examples that led to the famous conceptualization of Ethnomathematics as Ethno [culture] + mathema [explaining, understanding] + tics [techné, arts, techniques] [8]. He argued that

> "*Ethnomathematics is the mathematics which is practised among identifiable cultural groups such as national-tribe societies, labor groups, children of certain age brackets, and professional classes.*" [9].

Only a year after ICME 5, in Adelaide, Australia, the International Study Group on Ethnomathematics (ISGEm) was founded during the 1985 National Council of Teachers of Mathematics of the USA Annual Meeting [10]. This event provided a significant organizational framework for ethnomathematics as a research program in the history and philosophy of mathematics with pedagogical implications. In 1998, the First International Conference on Ethnomathematics took place in Granada, Spain, convened by Maria Luisa Oliveras [10], [11]. The goal of NASGEm is to enhance our comprehension of the cultural variety of mathematical practices and to use this information in education and development initiatives [12].

The researcher [13] studied different groups of Papuans and New Guineans. Their research primarily focused on the various tools and techniques used in counting goods, people, cattle etc. Social interactions provide ideas, facts, concepts, principles, and abilities related to mathematical problems, as noted by [14] and [15]. Rose and Orey [16] argued for the significance of culturally relevant education concepts from an ethnomathematics stance. They emphasised that the goal of the ethnomathematics and culturally relevant pedagogy-based approaches to mathematics curriculum is to increase students' engagement with and understanding of the subject matter. Gerdes [17] investigated the use of artefacts in the classroom in Mozambique. Palhares [18] researched the caulkers and how they built boats as part of his study of the fishing communities. Ron Eglash et al. [19] is a well-known ethnomathematics researcher whose work is partly based on West African content. He has created the computer programme Culturally Situated Design Tool, which lets students create and change patterns from traditional cultures on their own. While Porter and Haggerty [20] view mathematics as a technology of distance because it increases the gap between informal and formal mathematical knowledge, Bishop [21] shows how mathematics is utilised as a weapon for cultural imperialism.

Hidayati and Prahmana [22] made a systematic review of the literature of ethnomathematics research in Indonesia over a period of 5 years from 2015 to 2020. Sutarto et al. [23] developed an ethnomathematics-based e-Module using a 4D development model to improve students' metacognitive abilities. Silva et al. [24] did an ethnomathematical study that demonstrates the sociocultural interactions felt in a Brazilian Quilombola community. The research of Iskandar et al. [25] intended to evaluate the efficiency of student worksheets with West Java batik patterns that are based on ethnomathematics in helping students solve their mathematical difficulties. The works of Pandey [26], [27] and Sarkar and Howlader [28], [29] describes the traditional activities of the Kumhar community through the lens of ethnomathematics and its applicability in the teaching and learning process of mathematics. Motseki et al. [30] explopre how to teach elementary geometrical concepts using Ndebele artefacts through the ethnomathematical point of view. Näslund-Hadley et al. [31] provide experimental evidence on the effect of ethnomathematical teaching on preschool studentsTheir research indicates that the indigenous achievement gap can be reduced using a well-designed ethnomathematics program. Sunzuma & Umbara [32] made a systematic review on the effect of "digital cultural-based media integration into mathematics education" with the published articles from the year 2013 to 2023. For more recent work in ethnomathematics, see [33], [34], [35], [36].

Along with fundamental math abilities, mathematics stimulates the development of critical thinking, innovative problem solving, and clear and accurate communication skills in pupils. Understanding topics in science and social science classes, as well as art, physical education, and vocational education, depends heavily on mathematical knowledge. The significance of mathematics education in India is clearly shown by the NEP-2020.

> "*It is recognized that Mathematics and mathematical thinking will be very important for India's future and India's leadership role in the numerous upcoming fields and professions that will involve artificial intelligence, machine learning, data science, etc." (NEP-2020, Para 4.25)*

There are many obstacles facing our existing educational system when it comes to teaching mathematics. One of the main obstacles is that students find mathematics dry and useless, as most of the assessment techniques and questions focus on facts, procedures, and memorisation of formulas. According to NCF-2023, we need to reconsider our teaching strategy so that students like mathematics and perceive it as a part of their lives, with an emphasis on critical thinking and creative problem solving. By using ethnomathematics, students can get better at maths in the

best way possible. This is because students are given tasks that are relevant to their everyday lives or that are close to their feelings while they are learning [37], [38].

Kabuye Batiibwe's [39] study indicates that the predominant fields of ethnomathematics research are traditional games and weaving, comprising 45.9% and 40.9% of the total, respectively. Less prominent study domains include cultural dance, architecture, cuisine, ceramics, and similar subjects. The majority of this study was carried out in Indonesia, with some completed in the Philippines [39]. There is a noticeable lack of comprehensive, classroom-based pedagogical frameworks grounded in Indian cultural practices. Although a few studies (e.g., [26], [28]) have examined the ethnomathematical aspects of specific communities like the Kumhars, such studies are limited in scope and do not provide broader curriculum-linked strategies. There is hardly any research on the ethnomathematical aspect of the newly adopted NCF-2023 and its integration in the school curriculum. This study aims to fill this gap by demonstrating how to align the basic mathematical concepts with traditional Indian cultural practices like beading, weaving, and pottery. Hence, we want to investigate how ethnomathematics can be integrated into the mathematics curriculum in India. This study is based on the principles of culturally responsive pedagogy and constructivist learning theory. Like culturally responsive pedagogy, our approach reveals that students' culture is inextricably linked with formal mathematical teaching. According to constructivist learning theory [40], knowledge is derived from learners' prior experiences; hence, learning is an adaptive and experiential process rather than a mere translation of information. Our study utilizes the experience gained from cultural art forms like pottery and weaving to learn mathematical concepts. It helps students understand better by connecting lessons to things they already know and find meaningful. Unlike many earlier studies that talk about CRP or learning theories in general or foreign ways, this study gives clear examples that match the school curriculum and are based in the Indian context.

The objective of our study is to integrate traditional Indian cultural activities such as beading, pottery, weaving, and fishing into the school mathematics curriculum in alignment with NCF-2023.
Our main aim is to address the following research question:

- How can traditional Indian cultural activities such as beading, pottery, weaving, and fishing be effectively used to teach foundational mathematical concepts in alignment with NCF-2023?

II. METHODOLOGY

This review article employs a descriptive research design that aims to explore various mathematical concepts of pottery, bead making, fishing, and weaving. The traditional activities, such as pottery, weaving, beading, and fishing, were selected because of their cultural prevalence and underlying mathematical concepts. These activities are commonly practiced in various parts of India. Priority was given to activities that align with the foundational and middle school curriculum outlined by NCERT. The data was collected for this descriptive research from NCERT mathematics textbooks (for classes I–VI), the curriculum guidelines (NEP-2020 and NCF-2023), and literature related to ethnomathematics and cultural practices in India. The cultural accuracy and teaching potential of the selected activities were also checked through informal discussions with math teachers. However, no formal interviews or classroom observations were done during the research.

We follow a descriptive-analytical methodology rooted in the dialectical model of ethnomodeling [41] to translate the cultural practices into mathematical learning activities, see figure 1:

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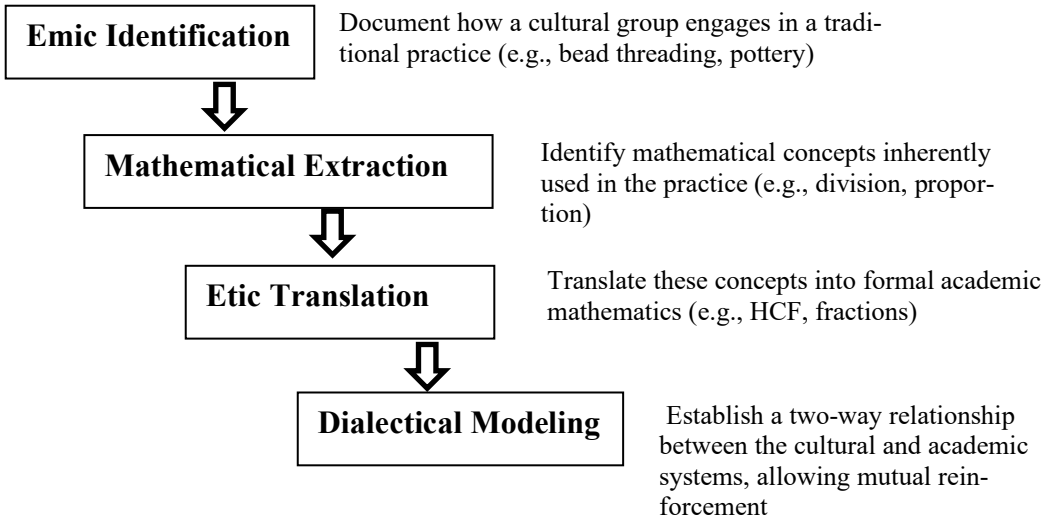

Figure 1: Dialectical model of ethnomodeling

This model ensures that cultural relevance, curricular alignment, and conceptual clarity are maintained throughout the instructional process.

III. Results and Discussion

A. Results:

Since our country gained its independence, math has been an important part of the curriculum, sometimes because it teaches students how to think, reason, analyse, and speak in a logical way. It also encourages them to be curious and builds their scientific temper. In the various commission reports established to improve education within the country, one has seen the emphasis on mathematics as a foundation discipline for children from all sections of the society (especially marginalized sections and girls), making it compulsory for every child to study it till the end of grade 10.

Given how teachers are trained to teach mathematics and how briefly the goals and aims of mathematics are explained in the curriculum, it is not that surprising that most students in the country have not learned much mathematics [42]. The National Curriculum Framework (NCF-2023) was created in response to these issues. It fought against the common ways that mathematics has been taught and learned, as well as the feelings of failure and fear that it has caused in children for many years. According to NCF-2023, the basic aim of mathematics education can be described in the following diagram:

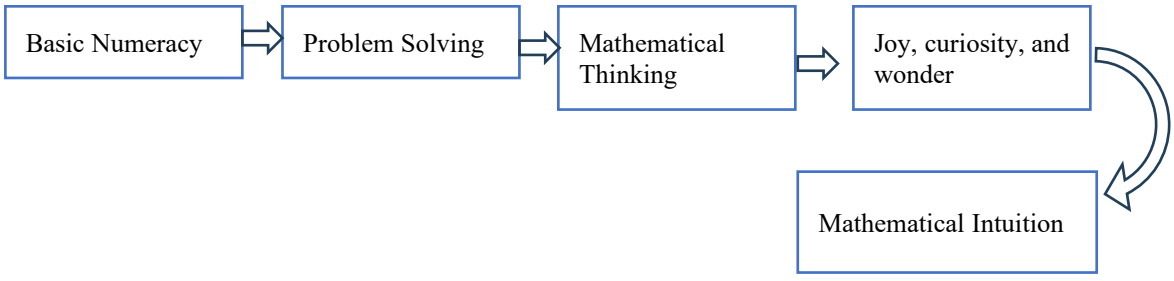

Figure 2: Aims of Mathematics education according to NCF-2023

In traditional ways of teaching mathematics, students go straight into manipulating vague symbols. It's not very helpful for making maths easy for students to understand [43], [44], [45], [46]. The objective of developing an ethnomathematical programme for Indian classrooms is to assist students to become aware of how people mathematise or think mathematically in their culture, to use this awareness to learn about formal mathematics, and to increase their ability to mathematise in any context in the future [4].

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i. Teaching fractions through pottery

Students learn the concept of fractions in classes IV, V and VI. The NCERT mathematics book of these classes describes various techniques such as playing games, dividing a bread, colouring a flag, etc, to teach fractions. The figure shows that students are taught the concept of 1/3 through flag colouring.
In this section, we show how to teach fractions through pottery, see Figure 2. The steps are as follows:

- First, make a disc from a lump of clay
- Then divide the disc into eight equal parts using a knife, see the figure
- Then, use different colours, such as red, to paint two of the eight parts and make the remaining six parts green.
- These two red parts are the $2/8^{th}$ portion of the whole disc.
- How many parts remain? Only six green parts. These four green parts are the $6/8^{th}$ portion of the whole disc.

ii. Teaching negative & positive numbers through weaving

Indian student start their journey of counting through natural numbers from class I. But from class VI, students become familiar with negative numbers. The NCERT mathematics book of class VI teaches negative numbers through diagrams, water level, and a dice game. In this section, we demonstrate the concept of negative and positive numbers through the Charkha (Spinning wheel), see Figure 3. Suppose we want to sum -2 and 3. The steps are:

- Let us assume that counterclockwise rotation is positive and clockwise rotation is negative.
- Initially, when there is no thread, take it as a zero position.
- The counterclockwise rotation three times is 3, and the clockwise rotation two times is -2.
- If we first rotate counterclockwise three times, followed by two times clockwise rotation, we will be left with only one thread band in the clockwise direction. It can be demonstrated that the sum of 3 and -2 is 1.

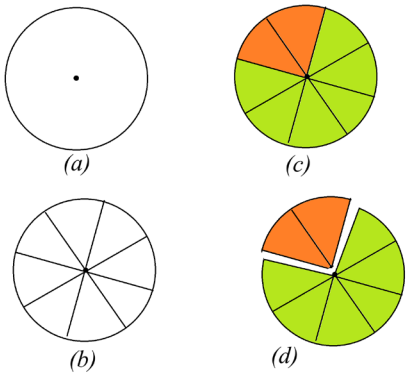

Figure 3: Teaching fraction through pottery

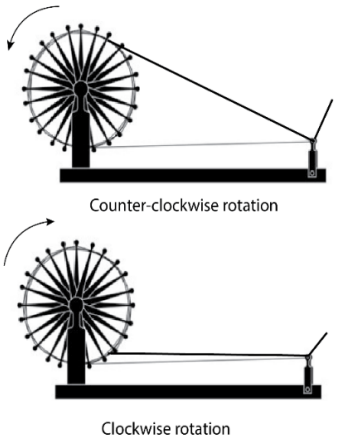

Figure 4: Teaching number system through weaving

iii. Teaching HCF through beads

The concepts of the highest common factor (HCF) and the least common multiple (LCM) are important ideas in mathematics. According to NCERT, Indian student learns these concepts in class VI. In the NCERT class VI book, the concepts of HCF and LCM are taught using calculation. There is hardly any practical demonstration of how HCF and LCM work. In this section, we demonstrate how to teach HCF using beads, see Figure 4. The steps to find the HCF of 6 and 4 are as follows:

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- First take two strings string-1 and string-2 having 6 and 4 beads respectively.
- Now divide string-1 into equal parts as much as possible. There are at most 3 ways to divide it:

a. Two parts having 3 beads in each part
b. Three parts having 2 breads in each part
c. Six parts have 1 bread in each part.

- Now try to divide the string-2 like (a), (b), and (c). We can see that it is only possible to divide string-2 like (b) and (c).
- Hence, string-1 and string-2 have common divisors 2 and 1. The largest one is 2, which is the HCF of 6 and 4.

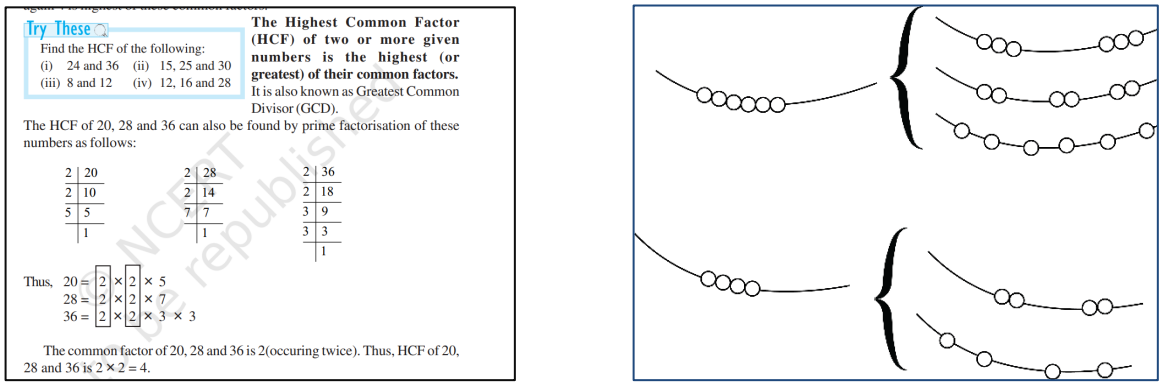

Figure 5: Teaching HCF through beads

iv. Identifying different shapes through fishing

Identifying various shapes is an integral part of mathematics education for students in the foundational stage. The NCERT books of classes I and II explain various shapes by demonstration. In this section, we try to teach various kinds of shapes through fishing equipment.

- The rectangular shape can be thought of as the shape of a Ghuni, figure (5a)
- Circular and cylindrical shapes can be taught through Lorb, figure (5b)
- Cone shape can be taught through Julki, figure (5c)

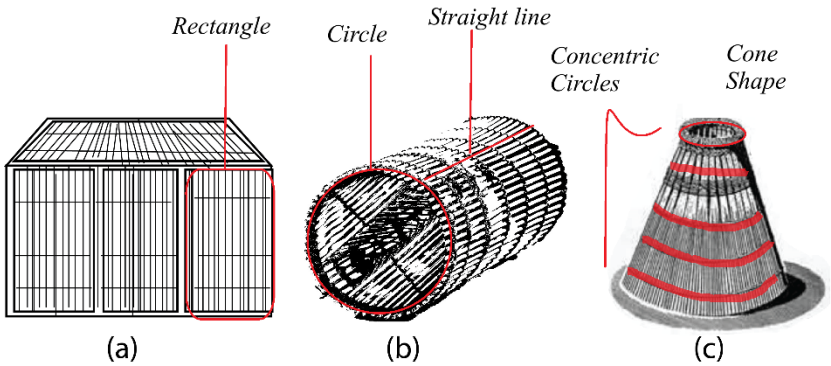

Figure 6: Teaching shapes through fishery

B. Discussion:

Although India has a rich and thousands-year-long heritage in mathematics, the country lags significantly behind in the world of mathematics education. According to the 2017 National Achievement Survey (NAS-2017), students in classes 3, 4, and 5 scored 64%, 53%, and 42% on the mathematics exam, respectively, which was carried out by the MHRD to evaluate learning outcomes among children throughout India in several disciplines. This demonstrates a downward trend in mathematical curiosity. According to NCF-2023, "too often, mathematics is shown as a finished result that is purely demonstrative and formal, which makes students anxious and bored." NCF-2023 also clearly recommends that "meaningful practice, through worksheets, puzzles, games, mental and oral Mathematics, group work, and homework involving paper and pencil, should be an integral part of the Mathematics classroom. Practice problems should be designed so that students revisit concepts and techniques and see different situations where a certain technique can be used."
Adam et al. [47], show that including culturally relevant mathematical ideas and practices within the formal academic curriculum might enable students to draw on their prior mathematical knowledge to comprehend and apply concepts more effectively. Studies show that students retain information better when they can see its practical utility[46]. Practical examples give context to the math they learn, improving long-term memory retention of concepts . The field of ethnomathematics has seen a proliferation of theoretical and applied studies during the last three decades. Around the same period, a plethora of scholarly works discussing the nexus between cultural norms and mathematical practices and pedagogy were published [6]. When making an ethnomathematical programme, there are various methods that can be taken. The choice of which style to use relies on the goal. Practical mathematics was used as a teaching aid in this study to help students comprehend what mathematical knowledge is all about and incorporate it into their own understanding. Although our research does not cover how to use these results in the classroom, previous research shows that using culturally relevant practices makes students more engaged in mathematics learning [16], [37]. When teachers demonstrate the mathematical concepts through traditional practices, students are more excited and understand the math concepts better when they learned them through pottery and beading. These results are in line with the ideas of constructivist and experiential learning, which say that students learn best when new ideas are connected to things they already know and can touch.

Each of the traditional activities presented in this study, pottery, beading, weaving, and fishing, has been carefully selected and designed, maintaining the National Curriculum Framework 2023 (NCF-2023) and the NCERT mathematics textbooks for the foundational, preparatory, and middle stages. For example, pottery discs are split up and colored to show how parts fit together, like halves, quarters, and eighths. This helps students see and talk about fractions using real things, which is what they need to do in classes IV–VI. Artifacts that are part of a culture help students connect abstract ideas to real-life situations, which supports the constructivist idea that learning is most effective in familiar settings. Students can learn about divisibility and common factors through pattern repetition and physical grouping in beading exercises. The study by Sutarto et al. [48] indicates that students possess misconceptions regarding HFC and LCM, stemming from instruction that focuses solely on calculating the lowest common multiple and the greatest common factor, rather than clarifying their true meanings or practical applications. This ethnomathematical method does that and also encourages students to think critically as they look for patterns and analyze bead groupings across strings. In spinning wheel (Charkha) weaving, spins in both directions look like positive and negative numbers. Using number lines and real-world examples like temperature and depth, the NCERT Class VI textbook teaches students about integers. The weaving comparison makes numbers easier to understand and helps with opposites and directionality, which is what NCF-2023 wants to achieve with intuitive understanding and spatial thinking. The fishing tools Ghuni, Lorb, and Julki have geometric shapes like rectangles, cylinders, and cones, which can be useful in identifying various 2D and 3D shapes as described in NCERT textbooks. These teaching tools make learning more enjoyable and interesting for students.
NCF-2023 also stresses the importance of joyful learning by making connections with other subjects. Teaching using traditional activities includes all of these features. The suggested method encourages students to engage in mathematics. Furthermore, the results are also beneficial for those uncertain about how to begin the integration of the ethnomathematics curriculum into the educational process.

To put this study in a larger global context, it is useful to consider how other countries implement ethnomathematics. For instance, Gerdes [17] used traditional African artefacts in teaching geometrical concepts. Similarly, Silva et al. [24] investigated the sociocultural practices of Quilombola communities to show how local traditions could help students learn and own mathematics better. The systematic review of ethnomathematics research in Indonesia by Hidayati and Prahmana [22] showed how local games, architecture, and crafts can be utilized in teaching mathematics. In South Africa, Motseki et al. (2025) also showed how Ndebele art can be used to teach basic geometry,

which helps students learn while also boosting their cultural pride. Despite the fact that they are excellent examples, many of them are nonetheless unique to their particular circumstances. It is important to note that the present research is distinct from prior overseas initiatives since it establishes a clear connection between Indian cultural practices and the official curricular aims of the NCERT. As a result, it is a brand-new framework that can be utilized at the national level and is scalable.

C. Challenges

While the integration of ethnomathematics with the NCF-2023 framework provides valuable pedagogical insights, the study also faces several challenges. First, the challenge is in integrating traditional knowledge with mainstream mathematics curricula, since ethnomathematics seeks to include indigenous mathematical knowledge and practices into the educational framework. This means that the current curriculum needs to be carefully looked at and changed so that it includes local mathematical ideas, methods, and concepts while also meeting the requirements of structured education. Research indicates that in India, individuals are consistently migrating from rural to urban regions [49], resulting in classrooms populated by students from diverse linguistic, cultural, and culinary backgrounds. Consequently, teaching mathematical concepts through specific traditional activities poses significant challenges, as some students may be entirely unfamiliar with particular traditions. Second, even though this study gives examples like pottery, weaving, fishing, and beading, we are unable to really measure how engaged or academically improved the students are because there wasn't any real-world testing in the classroom. Third, teachers' knowledge and awareness are one of the big challenges as most of them have hardly any experience in teaching mathematics through traditional activities. Also, it is still hard to make sure that these culturally embedded activities fit with formal curriculum standards and assessment practices. These problems show that more pilot studies, teacher training programs, and efforts to align the curriculum are needed to fully realize the potential of ethnomathematics in Indian classrooms.

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