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FROM LOOM TO CLASSROOM: EXPLORING THE EDUCATIONAL POTENTIAL OF JOLAHA ART OF WEAVING'S EMBEDDED MATHEMATICAL CONCEPTS

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ABSTRACT

One of the current challenges in mathematics education is how to link school mathematics to student's culture and everyday activities to improve the quality of the student's mathematical learning. Drawing ideas from scholarship in ethno-mathematics, this study attempted to comprehend the mathematical concepts embedded in the weaving art of jolaha peoples. The study employed a qualitative research method to unravel the mathematical elements. Evidence of mathematical practices of the Jolaha community in the art of weaving indicated that irrespective of the mathematical experience, they all employed a certain level of informal mathematics in the discharge of their duties. The researcher explored the Jolaha weaving skills from a mathematical perspective and noted the mathematical ideas, concepts of traditional counting systems, traditional measurement units, concepts of translation, and rhombus that can be used to teach mathematics through ethno-mathematical strategies in the classroom, and concluded with discussion of mathematical elements that can be integrated with the mathematics curriculum to enhance mathematics teaching in the classroom.

Keywords: Ethnomathematics, Mathematics Education, Jolaha Art of Weaving, Mathematical Elements

1. INTRODUCTION

Mathematics has been integral to human development since ancient times, fostering critical thinking, abstraction, and communication. Despite its significance and mandatory status in education, mathematical outcomes remain unsatisfactory, with only 56% of children able to perform basic division (ASER report 2018). Recent educational frameworks in India, including NCF 2005 and NCF-FS 2022, emphasise the importance of grounding mathematical education in social and cultural practices.

Culture plays a crucial role in shaping mathematical concepts and their application. As Swetz (2009) notes, no aspect of mathematics is free from cultural influence. The development and use of mathematics across societies exemplify this cultural impact. Contemporary research in mathematics education now encompasses history, philosophy, ethnomathematics, and anthropology, recognising the need for culturally responsive teaching methods.

Ethnomathematics, as defined by D'Ambrosio (1990), is a research program guiding pedagogical practices in education. It acknowledges that mathematics originates from societal needs and cannot be isolated from people's behaviours and practices. D'Ambrosio (1992) suggests that out-of-school mathematical practices are part of a community's heritage knowledge, often learnt more casually than formal school mathematics. Hurwitz and Day (1991) in their paper *"Children and Their Art"* contain a current conceptualisation of art and math integration employing math tools in art lessons under the theme "Correlating Art with Other Subjects." The authors observe that mathematics may start to appear in some of a child's artwork as soon as they are able to use a measured line in an academic setting. This correlation is supported by projects like building model homes, creating puppet outfits, and creating puppet stages. In an effort to bridge the two disciplines, some educators have assigned their students to create geometric shapes using mechanical drawing tools like compasses, triangles, and T-squares during art class. (Pages 500–01). So to connect the pupils artwork and mathematical knowledge in classroom, there need to be some cultural events that children encounter daily. For this, I tried to focus on the mathematics inherent in the Jolaha community art of weaving, exploring the intersection of mathematics and weaving culture among the Jolaha group. Julaha means a ball of thread because they have traditionally been weavers who were noted for weaving intricate designs and bold colours (Jashua Project). By examining their mathematical knowledge and skills within their profession, we aim to contribute to the growing field of culturally responsive mathematics education, aligning with the objectives outlined in India's New Education Policy 2020 and recent curriculum frameworks.

2. OBJECTIVES OF THE STUDY

1) To understand the weaving art of the Jolaha community with special reference to mathematical knowledge.
2) To explore the informal mathematics that exists in the Jolaha community.

3. RESEARCH METHODOLOGY

This study employed qualitative research methods to explore the implicit mathematical knowledge within the Jolaha community of Ramnagar Tehsil, known for its long-standing weaving tradition. Purposive sampling was used to select 10 participants from the community, aligning with the study's objective of identifying mathematical elements in their practices.

4. DATA COLLECTION METHODS INCLUDED

1) Participant observation
2) Informal communication
3) Structured interviews

The researcher closely observed participants in their workplace, documenting essential elements of the weaving process. This approach allowed for a deep understanding of the social and cultural context of the Jolaha community. Collected data was thematically categorised to highlight mathematical elements present in the Jolaha weaving art. This methodology enabled a comprehensive exploration of the intersection between traditional weaving practices and implicit mathematical knowledge within the community.

5. FINDING AND DISCUSSION

General mathematical process in the art of weaving: For the actual weaving to start on the loom, the jolaha had to prepare the materials required for weaving, i.e., the filled pirn *(gotta),* the shuttles *(sakhni)*, and a completely dressed-up loom *(khaddi).* Then, to start weaving by throwing a shuttle (sakhni) from right to left and from left to right through the shed, which was the most pleasant operation in hand weaving *(Dasti Kamm)*. It was also the simplest, as rhythm and speed come with practice. As an outsider, the researcher initially thought, after observing that the weaving was one-sided and shallow, that the weaving was simple and more of a physical exercise. However, after observing and understanding the whole essential pre-loom activities, the researcher thought completely changed because 70% of the weaving process had been completed before the actual weaving started. Weaving requires physical as well as mental skills. During observation, it was observed that the weavers start weaving by heading before staring at the patterns in order to pull together the group of threads of the warp. For heading, the weaver used scrap yarn, so that good weft yarn was not wasted, and it was always made with tabby treadles.

The jolaha used two types of motion for the weaving:

1) Primary motion: that involves shedding, picking, and beating motions.
2) Secondary motion: that involves taking up motion and left-off motion.
3) Shedding motion: The function of the shedding motion is to raise and lower the heddles (carry warp yarn through heddle eyes) through peddles to separate the warp yarns into two layers for the insertion of a pick.
4) Picking motion: The function of the picking motion is to fill the weft yarn from the left to right side and right side to the other side of the fabric through the shuttle.
5) Beating up: The function of the beater is to push the weft thread that has been inserted in the picking up motion through the shuttle up to the position of the last pick in the cloth woven.
6) Take-up motion: After weaving a suitable length, the weaver rolls the fabrics on the cloth rollers with the help of a take-up motion handle and continues the weaving.
7) Let off motion: It controls the amount of warp delivered and maintains the regional tension during weaving.

While weaving the material, the weaver followed the draft given to them to weave the required pattern in the cloth. For them, it was really important to read the draft carefully. Accordingly, they used to press the loom's treadles, which raised the heedless, and then they passed the weft through the shed to weave the required patterns.

Number Sequence in the Designs: The jolaha have created various designs on clothes that appear on customs and household items, mainly traditional fabrics. The uniqueness of motifs and patterns makes the handlooms of India a valuable heritage. Scientifically, these traditional motifs and designs are applied through mathematical and computational methods. Even in plain weave fabrics, coloured patterns are formed with different numbered sequences. Jolaha used number sequences during shedding motion that separate the yarns into layers for insertion of picks. The threads of the warp are alternately lifted and lowered while the weft is passed between the threads. The warp on a treadle loom is lifted mechanically by a series of foot pedals. For example, the pattern calls for you to treadle 1, 2. That means using your right foot once and then your left foot once and writing tie-ups like this.

×	*	×	*	×	*	×
*	×	*	×	*	×	*
*	×	*	×	*	×	*
×	*	×	*	×	*	×
*	×	*	×	*	×	*
×	*	×	*	×	*	×
×	*	×	*	×	*	×

Plain weave

Number sequence observed in plain weaving patterns:

- Odd number sequence: 1, 3, 5, 7, 9, 11, 13, 15, 17, 19, 21, 23...
- While weaving, the treadles and heedles were tied together so that when the weaver presses treadle 1, every odd-numbered warp is raised, and then the shuttle is passed through the shed to weave the pattern.
- Even number sequence: 2, 4, 6, 8, 10, 12, 14, 16, 18, 20, 22, 24...
- When the weaver pressed treadle 2, the even number of warp threads rose, and the shuttle was passed through the shed to weave the required pattern.
- Square of natural number: 1, 4, 9, 16, 25, 36, 25, 16, 9, 4........

The sequence of squares of natural numbers was used in using the six colours in plain weave-like strip patterns.

Weaving is a practical art as well as mathematical. Many mathematical sequences can be used to create patterns using different colours, but which mathematical sequence would be pleasing to the eyes? This is what the weavers decide and play with the numbers in their designs. William (2000) stated that just as we want our music to have patterns, we want our fabrics used for clothing to have patterns. Fabric used for art may have fewer patterns, rather like realist art has to find patterns.

Counting in weaving practices: Mathematics began with the counting process used by representatives of a specific particular culture in ancient times. People in ancient times may have used the one-on-one correspondence process to count or record their family members, grains, or something else by different objects. The development of number ideas and a particular terminology for expressing them is an essential mathematical process. Many of the Jolaha people who were studied in this study were from rural areas. When the researcher asked various jolaha people about their counting systems; they all used their counting system passed on from generation to generation by their forefathers for a long time.

The Jolaha people mentioned many uses of numbers and counting. Counting is used to conduct trade activities and calculate the number of yarns required for a particular pattern. The researcher discovers the weaver's peculiar counting method during fieldwork and informal conversations with the weaver's group. For example, the Jolaha people count yarns in twos when putting the yarn into the eyelets of heedles. (This also depends on the thickness of the thread and the pattern to be woven into the fabric.) They count in fours (counting every four yarns as one) when placing the threads in the beater, and they count in hundreds when calculating the total number of yarns or colours of yarn required for warping yarn for different clothes. The most surprising thing to the researcher was that all weavers could count, regardless of whether they had formal schooling or not, because of the importance of counting in weaving. Counting is a significant and beneficial weaving activity. Counting is needed and used from the beginning to the end of the process of weaving work. Jolaha counts the amount of yarn required and the number of times they go around the pegs to obtain the desired size of the cloth. They count the number of patterns that make the strips and the number of strips that make the particular size of the fabric. Some elements of addition, multiplication, and divisions used by weavers in pashmina weaving are:

Determines the numbers of rolls (Gotta) needed to weave men's shawls or women's shawls. For example *(Ek loi gi bananegi kat kolo kat deu dassi gotta lagdiya, chithe ki deu Jodi gotta badhu chaidiya kiyaan ki ey kharab oey jandiya, ye sutar trutija).* To weave, a kambal weaver required $2 \times 10 = 20$ rolls of yarn and $2 \times 2 = 4$ rolls of yarn extra needed because of wastage of threads due to warp break or thread break in weaving. This statement indicates that to make a single kambal, weavers need $20+4 = 24$ rolls of yarn. Determines the number of colours needed to weave the demanded patterns, as well as whether there is a need for extra labour or a weaver to do things like warping and heedling. The researcher finds that weavers divide the background into parts that match the pattern he intends to design before incorporating (locating) the patterns into the fabric. Furthermore, this involves counting the number of yarns, measuring the length on the cloth before introducing the pattern, or even drafting the designs.

All the Jolaha peoples under study are Dogri-speaking people, and their counting numbers are shown below in the table:

Table 1: shows the counting numbers

	Number	English	Hindi	Dogri
	0	Zero	Shunya	Khali
	1	One	ek	Eke
	2	Two	Do	Due
	3	Three	tin	Trae
	4	Four	Char	Chare
	5	Five	panch	Penj
	6	Six	Chah	Sheh
	7	Seven	saat	Sette
	8	Eight	aaṭh	Ethe

	9	Nine	nau	Nau
	10	Ten	Das	Desse
	11	Eleven	gyarah	Jara
	12	Tweleve	Barah	Bara
	13	Thirteen	terah	Tera
	14	Fourteen	Caudah	Chuda
	15	Fifteen	pandrah	Pendra
	16	Sixteen	Solah	Sola
	17	Seventeen	satrah	Stara
	18	Eighteen	aṭharah	Thara
	19	Nineteen	unnis	Unni
	20	Twenty	Bis	Bih

From the above table, the researcher found the Jolaha peoples do not have their own native numerical; all are illiterate and are unable to write any number. They have been speaking in their native language, i.e., Dogri. The language Dogri is one of India's 22 official languages. The Dogri language was added to the Indian constitution's 8th schedule in 2003. Except for 1, 2, 3, 5, 7, 19, and 20, all numbers from 1 to 20 are expressed in Dogri as normal Hindi expressions. However, some schoolchildren and literate Jolaha people are familiar with the decimal system and can express and write any number.

Counting System in the Jolaha people's art of weaving: An 68-year-old senior jolaha answered the following questions:

How many clothing orders do you have in a month? *(kinne ge kamm ayi janda ek minne ch shal banae tai).* He answered, I had a *DEU DASSI SATT* order to make shawls last month. But this month, I have only *Ek DESSE NAU* orders. The researcher expressed it mathematically: He had *DEU DASSI SATT* last month, i.e., 2 × 10 + 7. But this month's order was *Ek DASSE NAU,*

i.e., 1 × 10 + 9.

The concept of subtraction is here:

2 × 10 + 7 *(DEU DASSI SATT)*

- 1 × 10 + 9 *(EKKE DASSE NAU)*

= 1 × 10 – 2 *(DEU KATT EKKE DASSI)*

= 8 *(DEU KATT DASSI) = ETHE*

A 38-year-old Jolaha member, education up to primary school, answers the following question in an informal conversation at their workplace.

Researcher: How many shawls for weave orders did you get in a month?

(Ek minne ch kinne shal banana da kamm anda.) Answer: (Ey mosma upper ge , sayale te Ek Dina da Ek Saab layilo Minne Bich TRAE DASSI shale da Kamm ayi Janda, te garmiya chi ye koi tarona katiye Ekk dasse deu ge reyi Janda.) He answered, its depends upon the season. In summers he had work of about *EKK DASSI DUE* shawls per month, but in winter he got work three times more than in summer, which means *TRAIE DASSI SHEH* shawls per month.

The researcher expressed it mathematically like Jolaha had *EKKE DASSI DEU* per month in summers, i.e., 1 × 10 + 2. But in winters, he got order three times: *EKK DASSI DEU* that means *TRAIE DASSI SHEH* per month, i.e. 3 × 10+ 6

Here, the concept of multiplication is determined

1 × 10 + 2 (EKK DASSI DEU)

3 (1 × 10 + 2) *[TROUNA (EKK DASSI DEU)]*

= 3 × 10+ 6 *(TRAIE DASSI SHEH)*

= 30+6 *(TRAIE DASSI SHEH)*

= 36 *(TRAIE DASSE SHEH)*

The above is the researcher analysis of the mathematical art that exists in weaving; it is found that all of the community uses the base 10 *DASSE* number system. The community does not have its own symbols for numbers. They can orally determine the numbers but are unable to write them. However, some literate weavers who have formal education can read and write the decimal number system

Traditional measurement units used by the Jolaha community: In the primary school mathematics curriculum, measuring is defined as determining the magnitude of a quantity, such as a length, width, weight, and height, concerning a specific unit, such as meters or kilograms. Time, distance, length, height, area, and volume can all be compared using measurements. Measurement may also be defined as the process of determining the relationship between a physical quantity (length, width, and time) and a unit of measurement.

After staying with the Jolaha community for a while, the researcher discovered that they used a special method for measuring length and width fabrics. They used a measurement method that progressed from smaller to larger units of measurement.

6. LENGTH MEASUREMENT UNITS

The jolaha people often used measures in their everyday lives for various purposes, which were not identical to standard measurements but had already been imbibed culturally. The source of these measurements, however, were unknown. They used these measurement units to measure the length and width of shawls, kambalsor Lois. During informal conversation and participant observation, the researcher finds these measurement units that they used in their work. *(EK KAMBAL JEDA BANANA) ONY UDHEE KOI AATH GE GAZZ CHODA TE DEU GAZZ LAMMA BUNI LENE).*

Researcher finds that the average length of kambal the Jolaha produce was about 8 gazz and 2 gazz. *(ASI CHIDE MARDANA TOTE YA SHAWL BANANA ONEY OO KOI TRAEE GAZ LAMMA TE CHEDA KOI DAID GAZZ TE 1 GITH BUNNA ONDA, JANANA SHAWLS CHEDA EY O KOI TAI GAZZ LAMMA TE SABHA GAZZ CHODA BUNNE ONEY).* The length of shawls for men was three 3Gazz lengths wise, and the width of shawls was 1 Gaz + ½ Gaz + 1 Gith, and the women's shawls measure 2 Gaz + ½ Gaz length and width is 1 Gaz + 1 Gith. During the conversation with the jolaha, the researcher also found that in making patterns and designs on fabric, they measure the perimeter of cloth using the smallest unit of measurement, which is the pottu, or finger width.

(SHALA UPAR JA FER LOIYA , PATTU UPAR KADAE KARDE TAIM AAS ISI CHAPE DE SABA KANNE MINEE LENNE, EY KADAYE GI DIKHIYE PTA CHALDA , JINJA JE JARIYA BANAI OYE SEDDA SEDDA UPAR TE EK CHAPPE DI CHODAI DE SAABA KANNE AAS SUTAR DA TANA BANAI LENE PALE GE). To make the design on shawls or Lois, it depends upon the size of the designs. Generally, we make designs over the borders of fabrics that are about one Chappa width. Some time weavers also use their fingers to measure the size of design on cloths when the size of design is very small. However, modernisation and the application of formal education in which school graduates or school dropouts have become weavers have led to using the metric units, where the meter is the main measurement unit.

The table, along with the accompanying images, depicts the measurement system used by weaver community culture.

Table 2: shows Informal system of measurement

Pottu (smallest measurement unit)	Finger width (index finger)	3/4 inches or 1.905 cm
Chappa	Palm (four fingers)	4.5 inches or 11.43 cm
Gith	Hand span (distance from the tip of thumb to tip of little finger)	8 inches/millimetres or 20.32 cm
Adha Gazz	half Arm length / cubit	16 inches or 40.4 cm
Pouna Gazz	Cubit + hand span	24 inches or 63.36 cm
Gazz (largest measurement unit)	Half Arm spam	34.09 inch 90 cm

Tradition Weight Measurement Units used by the Jolaha Community: Weight is a term used in schools to describe how big anything is. To measure mass (or weight), we use balance scales or weighing scales. Mass is measured in grammes (g) and kilogrammes (kg). We weigh lighter objects in grammes and heavier things in kilograms. One kilogramme equals 1000 grammes, or 1000 grammes equals one. The kilogram is the standard unit of mass measurement.

During fieldwork, the researcher finds the traditional weight measurement techniques or units used by jolaha in their weaving work. Weight measurement is involved in weaving while purchasing the wool from the Gaddies and Bakkarwals, whose core activity is sheep and goat rearing. The artisan did weight measurement using stones of different weights, described below with lower weight measurement units to the higher weight measurement unit.

Traditional measurement units	Standard international units
Panj pai	450gm
Ser pakka	900gm
Ekk batti	2kg
Mann kacha (8 battiya)	16 kg
Mann pakka (20 battiya)	40 kg
Tree mann (30 battiya)	60kg

Table shows Traditional weight measurement units

Geomatrical art: The researcher explains the geometric transformation on the woven motif and how this motif can be created by translating many cloths by an axis in the Cartesian coordinate system. The technique of forming the new objects by translating along the horizontal lines, such as by repeating prior objects. The orientation and shape are also identical to the prior version.

Fig. 1 shows Chashme Bulbul weave on Pashmina shawl.

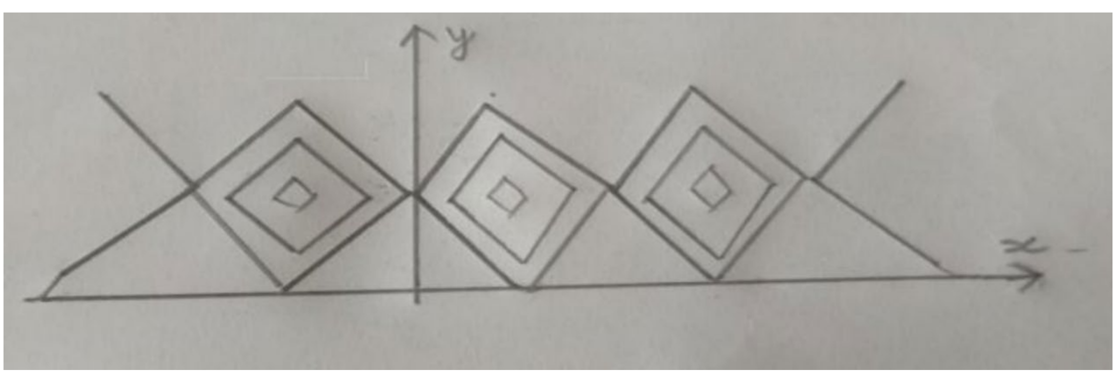

Fig. 2: Shows concepts of translation in Chasme Bulbull weave,

In the above figure 2, the researcher describes the pattern and quantity of threads on the cahsme-bulbul motif. Analysis by the researcher, the piece of motif, and yarn counting in every design can be seen. The Chasme bulbul (eyes of bulbul) motif on Pashmina cloth was rhombus in shape. This motif in a rhombus shape was geometrically designed by picking yarn up and down in a certain sequence and configuration, 4-1-3-2-1-4-2-3. This shows the weavers skills in designing chasme-bulbul weave/diamond weave, prevalent in the environment that transfers as a motif on pashmina shawls (rhombic). Weavers skillfully used geometrical symmetry to make a chasme bulbul weave on the pashmina.

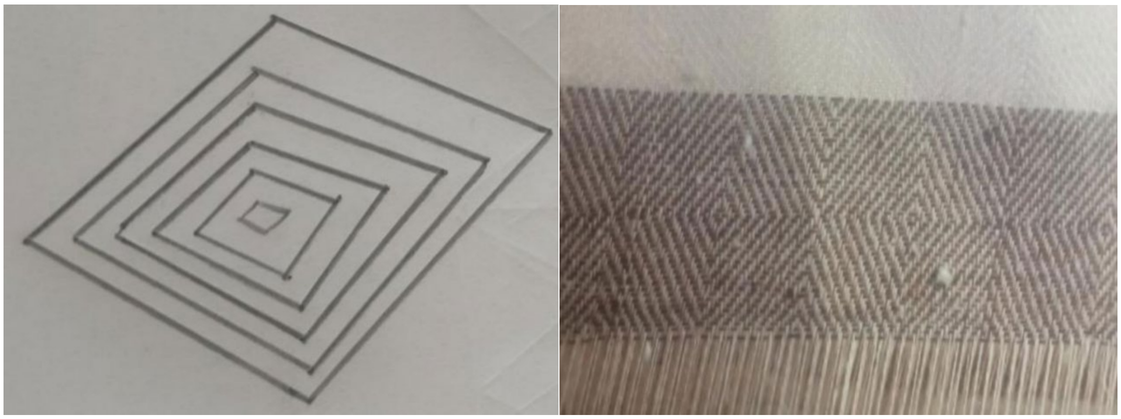

Fig. 3 shows the chasme-bulbulul weave/nested weave/diamond weave/rhombus-shaped weave.

Geometrical Pattern:

Chasme-Bulbul is the dominant weave on pashmina cloth. Different arrangements of this diamond weave make different patterns.

The formula for the rhombus is R = 4S, where S is the length of the side of the rhombus.

$R_1 = R$, where R is the perimeter of the largest rhombus.

$R_2 = R - 4a$, where a is the difference between any two consecutive rhombus.

$R_3 = R - 4\ (2a)$.

$R_n = R - 4\ (N-1)$ units, where n is a natural number.

The formula for the area of a rhombus is $P = ½\ (A_1) \times (A_2)$ where A_1 and A_2 are diagonals.

$P_1 = ½\ (A_1) \times (A_2)$

$P_2 = ½\ (A1-A) \times (A1-A)$

$P_3 = ½\ (A1-2A) \times (A2- 2A)$

$P_n = ½ \times [A_1 - (n-1)\ A] \times [A_2 - (n-1)\ A]$ Sq units, where P_n is the required area of a rhombus.

The Researcher analyses from the above Figure 15 that the weavers knew/concept of symmetry and reflection. *(Ase gi pedal saaba kariye Marne ponde, Je pedal di chal sehi nahi oyi te design Sahi ni banda, fir log usi design gi pasand ni karde te Katta peyi janda),* we have to follow the sequence in peddling to put the yarn up and down. It also shows that the weavers had a concept of vertical and horizontal symmetry and translation, rotation, and reflection in making the motif on the Pashmina. The above figure of nested weave shows that the weavers could determine location, strong mental imagination, mental calculation, and remembering power in counting threads.

7. AN ACCOUNT OF MATHEMATICAL PRACTICES IN ART OF WEAVING

The Jolaha weaving art incorporates several mathematical practices shaped by cultural context and work environment. Three primary mathematical activities are identified: Counting: Essential in various stages of weaving, from determining yarn quantities to pattern creation. It's fundamental regardless of the weaver's educational background. Measuring: Crucial from the start of the weaving process. Weavers use traditional methods, often employing hands and arms to estimate distances and sizes. Designing: A core activity integrating counting and measuring. Creating unique patterns requires sophisticated mathematical thinking, with varying degrees of complexity.

Additional mathematical practices include:

- Business mathematics for profit optimization
- Problem-solving and logic
- Estimation for time management and pricing

These practices are interconnected and essential for successful weaving. The Jolaha decision-making process heavily relies on numerical considerations, such as available yarn quantities influencing pattern choices.

The Jolaha mathematical thinking is driven by two main objectives:

1) Creating unique designs on cloth
2) Maximising profit while minimizing yarn usage

This blend of traditional knowledge and practical mathematics demonstrates the rich, implicit mathematical understanding within the Jolaha community, highlighting the intersection of cultural practices and mathematical concepts.

8. EDUCATIONAL IMPLICATIONS

This study reveals the rich mathematical concepts embedded in the Jolaha people's art in weaving tradition, highlighting significant educational implications. The research demonstrates how traditional weaving techniques can serve as powerful teaching tools for various mathematical concepts.

Key educational implications include:

1) Geometry instruction: weaving patterns, such as the chasme-bulbul weave, offer tangible examples of geometric shapes like rhombuses and triangles, making abstract concepts more concrete for students.
2) Counting and arithmetic: The weaving process naturally incorporates counting and basic arithmetic, providing a real-world context for these fundamental skills.
3) Modular arithmetic: The colour-changing patterns in weaving demonstrate practical applications of modular arithmetic, offering an intuitive introduction to this concept.
4) Engagement and relevance: As Earnest (1986) noted, incorporating fun and culturally relevant examples can enhance mathematical learning and improve student attitudes towards the subject.

The study emphasises the importance of integrating ethnomathematics into teacher training programs and mathematical education curricula. This approach would enable teachers to:

- leverage students' prior knowledge and cultural experiences in the classroom.
- Present mathematical concepts in context, demonstrating their real-world significance.
- Create more engaging and culturally responsive learning environments.

By recognising and utilising the informal mathematical knowledge present in communities like the Jolaha weavers, educators can bridge the gap between traditional practices and formal mathematical education. This integration not only enriches the learning experience but also helps preserve valuable cultural knowledge. In conclusion, this research underscores the potential of ethnomathematics to enhance mathematical education, calling for its inclusion in teacher training syllabi and broader educational curricula.

CONFLICT OF INTERESTS

None.

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None.

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