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Research Article

Threads of Knowledge: Mathematical Practices in Traditional *Hablon* Weaving

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Abstract: *Hablon*, a traditional handwoven textile from Iloilo, Philippines, has been a vital part of the province's identity and economy since the pre-colonial era. While there were studies on the mathematical structures in the finished fabrics, there had been little to no studies exploring how weavers utilize mathematics in the process of loom weaving. This ethnographic study explored the mathematical knowledge and skills of weavers in two weaving centers in Miagao, Iloilo, Philippines. The study aimed to document *hablon* weavers' mathematical practices and competencies that could enhance teaching approaches. Four key informants were selected using purposive sampling, and data collection and analysis followed Spradley's Developmental Research Sequence. Participant observation, ethnographic interviews, field notes, recorded videos, photographs, and artifacts were used as primary data collection methods, ensuring triangulation and facilitating analysis. The findings revealed that the weavers utilized mathematics in designing, calculating and estimating number of threads, demonstrating parallelism, and establishing symmetry. These activities showcased mathematical competence in various areas of mathematics. These findings support a culture-based mathematics curriculum and instructions for high school and university students in the Philippines. Moreover, *hablon* weaving offers an avenue for weavers to utilize mathematics informally at work. Therefore, contextualizing mathematics lessons through the integration of indigenous *hablon* weaving culture may bridge the gap between classroom instructions and real-life applications. Recommendations include incorporating local culture and community needs into classroom instruction, integrating co-curricular activities, and community involvement for real-world learning.

Keywords: ethnomathematics; contextualization; workplace mathematics, culturally-responsive curriculum

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1. Introduction

The Philippines' mathematics curriculum framework is supported by the underlying learning principles and theories such as experiential and situated learning, which involve the linking of mathematical concepts to real life experiences of the students and their career aspirations, leading to a mandate that would eventually make lessons culture-appropriate, interdisciplinary, experiential, and work-related (Department of Education, 2013).

Mathematics is indeed everywhere and plays a significant role in our daily lives. It is indispensable, and therefore, integrating it with culture can significantly benefit learners, mainly through the lens of ethnomathematics, defined as the various ways, styles, arts, and techniques different cultural groups employ to learn, explain, understand, and cope with their natural environment (D'Ambrosio, 2014).

By incorporating ethnomathematics into education, learners are exposed to practical applications that connect them with the realities beyond the confines of the classroom and school environment. Paragas (2011) suggests that practical work is an effective method for enhancing learners' mathematical learning, as it involves real-world conditions, including workplace ethnomathematics, everyday human activities, and other contexts that stimulate active responses from learners. Studies have shown that learners performed significantly better on mathematical problems presented in real-life contexts compared to school-type word problems and context-free computational problems in formal tests (Anderson-Pence, 2013).

One of the cultural activities that may be integrated into mathematics education is loom weaving. Textiles hold enormous significance in the lives of indigenous Filipinos. The skills and artistry in weaving and embroidery reflect the mastery and vast knowledge of different indigenous cultural communities in the country, enabling them to create weaves that sustain their lives while preserving and upholding their traditional weaving heritage (National Museum of the Philippines, 2021). Strengthening efforts to preserve and protect the world's cultural and natural heritage is specifically under Sustainable Development Goal 11.4 of the United Nations which envisions to create sustainable cities and communities (United Nations, 2023).

Miag-ao in Iloilo, Philippines is renowned for its prosperous weaving industry, particularly in Barangay Indag-an, often regarded as the weaving community of the municipality (Philippine Commission on Women, 2013). *Hablon* weaving, similar to other loom weaving techniques, employs the loom as a crucial tool to secure proper tension on the warp threads and enable the interlacing of the weft threads. It is a form of decorative weaving that utilizes the plain weave technique, where the weft passes over and under every other warp thread (De Las Peñas et al., 2018).

Some studies were conducted to investigate the mathematics present in Philippine indigenous textiles. For instance, De Las Peñas and Salvador-Amores (2016) conducted research on funeral textiles in Northern Luzon, while De Las Peñas, Garciano, and Verzosa (2014) examined the color symmetry found in hand-woven mats of the Jama Mapun. Additionally, Baylas IV, Rapanut and De Las Peñas (2012) explored the weaving symmetry of the Philippine Northern Kankana-ey, and Libo-on (2019) delved into the crystallographic and frieze group structures of *hablon*. Nevertheless, all of these studies exclusively focused on the mathematical structures observable in the finished fabrics, without delving into the process involved in creating these intricate patterns and motifs.

Hence, this particular study explored how weavers utilized mathematics in weaving *hablon* fabrics. Specifically, it sought answer to the following research objectives:

1. In what ways do weavers utilize mathematics in *hablon* weaving?
2. What are the weavers' mathematical learning competencies that align with the competencies set by the Department of Education and the Commission on Higher Education?

2. Materials and Methods

2.1. Research Design

This study rests on the epistemological principles of constructionism and the theoretical framework of symbolic interactionism, which propose that meanings emerge from individuals' interactions and are shaped by their personal interpretations stemming from their unique experiences (Gray, 2004).

Ethnography began in cultural anthropology in the studies conducted by anthropologists such as Malinowski and Mead (Creswell, 2007; 2012). Crotty (1998) classified ethnography as a fitting methodology under symbolic interactionism since it involves participating in and observing people's lives in their natural settings while making sense of their experiences. Creswell (2007; 2012) referred to ethnographic designs as qualitative research procedures for describing, analyzing, and interpreting a group's learned and shared patterns of values, behavior, beliefs, and language that develop over time. As Spradley (1980) said, the central aim of ethnography is to understand a different way of life from the native point of view.

2.2. Informants

The research took place at two weaving centers in Miagao in Iloilo, Philippines. Initially, a list of potential informants was compiled, consisting of individuals who were approached and agreed to participate. Ultimately, four key informants were purposively selected following a specific set of criteria: (1) the weaver had to express willingness to participate in the study through the consent form; (2) the weaver had to be employed at either of the two selected weaving centers; and (3) the weaver needed to have a minimum of five years of continuous weaving experience. In this study, pseudonyms are used instead of the actual weavers' names. Table 1 present the profile of informants.

Table 1. Profile of informants

Informant	Length of Experience	Educational Attainment	Willingness to Participate
Aurora Knottingham	47 years	College Graduate	Yes
Stella Loomis	14 years	High School Graduate	Yes
Abaca Warpington	50 years	College Graduate	Yes
Piña Weaverton	39 years	Vocational Course	Yes

2.3. Data Collection

Data collection, which lasted about eight weeks, involved the utilization of Spradley's (1980) Development Research Sequence (DRS), a structured approach that outlines a sequence of tasks to be completed during an ethnographic research, which involved doing participant observations, making an ethnographic record, making descriptive observations, making focused observations and asking structural questions.

In doing the participant observation, a consent form, patterned from Cerbo (2012) was presented and signed by the informants. This was followed by making an ethnographic record that include descriptions of the weavers' workplace activities, use of mathematics, emotions, behavior, and other details that helped to complete the story. These were recorded using an observation guide and contact summary sheet. Additionally, field notes, pictures, audio recordings, and videos were taken to capture additional observations and details for future reference to augment the data collected in the contact summary sheet, refining the observation guide, and eliciting further information from the weavers during interviews.

Making descriptive observations and asking descriptive questions then followed. Descriptive questions such as "*Pwede mo maistorya kanakon ang imo gina-obra halin sa pagsulod mo giya asta mag-uli kaw sa inyo balay* [Could you tell me what activities you usually perform from the time you arrive at the weaving center until you go back home?]" was used to elicit expanded and detailed responses. These descriptive questions allowed for a deeper understanding of their daily work routines, tasks, and experiences.

Subsequently, the researcher made focused observations, which were used to verify the semantic relationship, cover term, and included term. Asking questions such as, "*Paano mo maman-an nga amo ran dapat kabilog ang samay kag patadag nga isab-ong? Puwede mo ran ayhan mapa-athag kanakun* [How do you know that such is the number of samay and patadag to be prepared for warping? Could you enlighten me about it?"] revealed some knowledge of the weavers in mathematics.

Finally, asking structural questions were employed to explore the variations and nuances within the domain of weaving. During informal interviews with the weavers, the following questions were asked, "*Ano ang kinanlain maghabol kaw kang checkered kag ran nga may mga design? Sa kananda nga duwa, diin mas budlay ihabol ?*[What are the differences between weaving checkered fabric and those with motifs? Between the two, which one is more difficult to weave?]"

2.4. Data Analysis

The analysis of the gathered data involved the utilization of Spradley's (1980) analysis methods, encompassing domain analysis, taxonomic analysis, componential analysis, and theme analysis, which enabled a systematic examination and interpretation of the collected data, identification of patterns, categories, and themes within the information obtained from the informants.

Initially, ethnographic data were analyzed using domain analysis. After the interviews were transcribed manually and efforts were made to categorize them based on each informant and the specific day they were conducted, the transcripts were coded and assigned relevant codes to segments of the data that captured key themes or concepts. To ensure easy access and organization, all electronic data, including photographs, voice recordings, and videos, were stored and arranged on a computer. A Domain Analysis Worksheet, based on the chosen means-end relationship, was also prepared. This process was repeated with other semantic relationships until a tentative list of 17 identified domains was compiled.

Then taxonomic analysis was carried out. Using Spradley's box diagram format, the 17 domains were condensed into four overarching domains that represented cultural knowledge of the informants.

Componential analysis using a paradigm worksheet as a tool to guide the exploration and documentation of the attributes within each domain was carried out. This worksheet served as a checklist and reminder, helping identify any missing attributes and guiding the researcher in interactions with the informants to gather the necessary information.

Lastly, cultural themes were formed using thematic analysis.The researcher identified two larger domains that emerged from the analysis: Ways Weavers Utilize Mathematics and Mathematical Learning Competencies in *Hablon* Weaving. These domains encapsulated the overarching themes that were evident in the data and highlighted the significant role of mathematics in the weaving practices of the *hablon* weavers.

3. Results

The examination of different stages in *hablon* weaving has revealed promising results regarding the incorporation of various mathematical concepts. This exploration highlights the mathematical competencies demonstrated by the weavers and sheds light on the significant role mathematics plays in the weaving process.

Table 2 presents the various ways *hablon* weavers utilize mathematics in weaving vis-a-vis the mathematics learning competencies set for high school learners according to the Department of Education and learning outcomes expected to be mastered by university students in the Philippines as guided by the Commission on Higher Education.

Table 2. How *hablon* weavers utiize mathematics and their mathematics learning competencies.

Ways *Hablon* Weavers Utilize Mathematics	**Mathematics Learning Competencies**
Designing • Writing a note • Sketching motifs • Sequencing threads	Identifying the patterns in nature and regularities in the world Articulating the importance of mathematics in one's life Identifying and constructing the line of symmetry
Calculating and Estimating Number of Threads • Converting units of ethno-measurement in weaving • Performing basic arithmetic operations and estimation	Converting measurements from one unit to another Calculating the sum, difference, product, and quotient of rational numbers Estimating the measure of quantities Solving problems involving two variables, particularly Linear Diophantine Equations
Demonstrating Parallelism and Perpendicularity • Manipulating threads individually • Applying tension on threads	Determining the conditions under which lines and segments are parallel and perpendicular
Establishing Symmetry • Weaving squares and rectangles • Translating motifs on fabric	Applying geometric concepts especially isometries in describing and creating designs

3.1. Designing

By incorporating elements from nature, weavers infuse their textiles with a sense of harmony, beauty, and a deep connection to the captivating patterns that surround us (figure 1). Designing *hablon* fabrics unravels the following mathematical competencies: identifying the patterns in nature and regularities in the world, articulating the importance of mathematics in one's life, and identifying and constructing the line of symmetry.

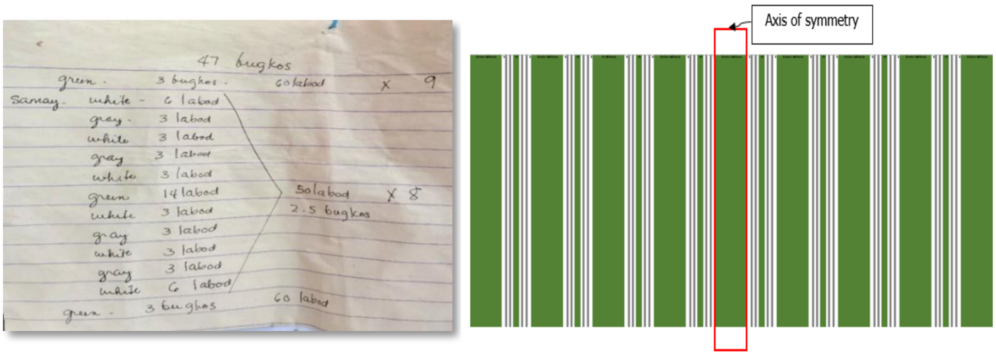
Figure 1. Examples of *hablon* fabrics.

Moreover, Weavers understand the fundamental role of mathematics in their craft and its relevance to their workplace. They recognize that mathematical concepts and skills are essential in tasks such as measuring, counting, designing, and ensuring the proper alignment of threads. Mathematics provides them with the tools and understanding needed to create precise and well-crafted woven fabrics. Piña Weaverton mentioned, "*Importante man ang math sa paghabol. Ginagamit umpisa sa sab-ong kag sa design. Tapos suklon mo man kung pila ka inches ang mahabol mo sa isa ka halin* [Math is important in weaving. It is used starting with the warping stage and in the design making. At the end of the day, you also need to measure the how much you have woven in inches."]

Hablon fabric is often associated with its checkered designs in its shawls and the *patadyong*, a traditional wrap around skirt. Designing the fabric is both a collaboration between the clients and the weavers. If the clients have no design in mind, the weaver presents sample fabric and with the client, they decide on the color combination and the variations in the checkered pattern. The succeeding sub-section explores the vital components of designing a *hablon* fabric

- Writing a note

When the design is finalized the weaver figures out the number and sequence of warp threads needed to generate the design. This combination is written down by the weaver and serves as her guide in the succeeding stages of *hablon* weaving.



47 bugkos
green - 3 bugkos - 60 labod x 9
Samay- white - 6 labod
gray - 3 labod
white 3 labod
gray 3 labod
white 3 labod
green 14 labod 50 labod x 8
white 3 labod 2.5 bugkos
gray 3 labod
white 3 labod
gray 3 labod
white 6 labod
green - 3 bughos 60 labod

Figure 2. Weaver's note on the sequence of threads (left) and the resulting pattern of warp threads (right).

Figure 2 shows a sample note made by the weaver and the resulting pattern when the warp threads are set up on the loom. The note also includes other information which will be discussed in the succeeding subsections.

- Sketching motifs

The pick-up technique, a weaving technique that involves picking up a stick behind the heddles for a specific configuration of warp threads, is commonly employed for fabrics like barongs, office uniforms, and shawls, where intricate motifs are desired. Prior to the weaving process, it is essential for the weaver to sketch the motif on a graphing paper. This sketch serves as a visual guide, allowing the weaver to plan and organize the placement of the warp threads and the pick-up pattern.

Sketching motifs also involves identifying its elements. By mapping out the motif on the graphing paper, the weaver can determine the specific pattern of thread manipulation required during weaving. This preliminary step ensures accuracy and precision in executing the desired design, enabling the weaver to create intricate and well-defined motifs on the fabric.

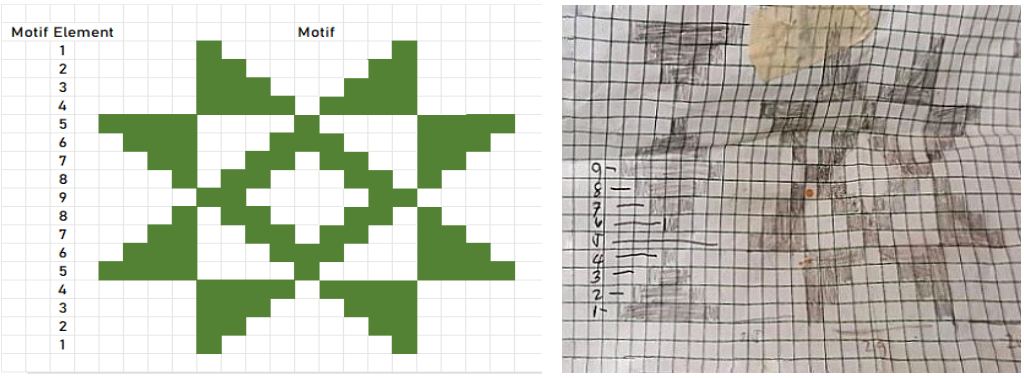


Figure 3. Sample motif created using MS Excel based on the weaver's sketch (left) and actual weaving motif and its elements as labelled (right).

Each motif element within a row is identified and numbered arbitrarily to distinguish the unique patterns. There are a total of nine distinct patterns within each row, and each pattern is assigned a corresponding number. The numbering scheme allows the weaver to identify which pattern to follow for each motif element within the row, facilitating accurate reproduction of the desired motifs and ensuring the consistent and intentional arrangement of patterns throughout the fabric.

Within the loom, the weaving process involves the interaction of individual weft threads and groups of three warp threads, which collectively determine the thickness of the motif on the fabric. This convention of using three warp threads per column is arbitrary but widely adopted by weavers. Graphing paper with shaded blocks is often used to represent the warp threads that the motif threads will pass over during weaving. Each row on the graphing paper corresponds to a single weft thread that is woven across the loom, while the columns represent the arrangement of the warp threads. By following the shaded blocks on the graphing paper, weavers can accurately position the motif threads to create the desired pattern, ensuring that they pass over the designated warp threads to generate the motif on the fabric.

- Sequencing threads

Once the design is fixed and the number of warp threads is determined, the weaver meticulously sets up the threads and rolls around the warping tool based on the sequence of colors and the number of threads to be used per color. After all warp threads have been set, the assigned weaver sequentially transfers the threads onto the loom through the stages of beaming, heddling, and reeding, cautiously following the sequence of threads that had been set up.

3.2 Calculating and Estimating Number of Threads

The distinctive checkered patterns, characterized by a diverse array of colors and sizes, stand out as one of the defining features of *hablon* textiles. However, finding the actual number of threads necessary for the desired sequence is no easy task and weavers go through some calculations in order to accurately weave the pattern as the variations in checkered designs are not only determined by the sequence of colors used but also the sizes of resulting squares and rectangles formed on the checkered fabric. Calculating and estimating number of threads encompasses covers four learning competencies: converting measurements from one unit to another, calculating the sum, difference, product, and quotient of rational numbers, estimating the measure of quantities, and solving problems involving two variables, particularly Diophantine Equations.

- Converting units of ethno-measurement

Warp threads are grouped in terms of bugkos or labod, which are ethno-measurements pertaining to number of threads. The weavers convert between a unit of length (or width), usually in inches, into a number of threads and vice versa as shown in table 3.

Table 3. Units of ethnomeasurement and conversion used by *hablon* weavers.

Unit	Conversion
1 *bugkos*	20 labod
1 *labod*	1 pair of threads
30 inch fabric	47 *bugkos*
20 inch fabric	32 *bugkos*
1 inch fabric	30 *labod* or 1.5 *bugkos*

- Performing basic arithmetic operations and estimation

Many of the checkered *hablon* fabrics consist of the *patadag* or the often plain large single color part and the *samay*, which often consists of thinner vertical multi-colored threads that often form smaller squares and rectangles on the fabric. The weaver decides on the number of threads needed for each color width, vis-à-vis the widths of the desired fabric based on the size of the loom; 30 inches is the standard width, while 20 inches is generally used for the *patadyong* and shawls.

Weavers generally utilize the four basic operations and some degree of educated estimation especially in counting the number of threads needed to generate a desired pattern. As Aurora Knottingham patiently discussed, "Te kay 2 inches ang patadag, 3 ka *bugkos* ran. Sa isa ka *bugkos* 20 ka labod, te 60 tanan ka labod. Multiply mo to sa 9 kagina, 540 tanan ka labod para sa patadag. Sa 30 inches kay 47 ka *bugkos*, may dyan nga 940 ka labod. Minus mo duman to ang 540. 400 dalang para sa *samay* mo. Pagkatapos divide mo duman sa 8. 50 ka labod sa kada *samay*. Tungaon mo duman ran kay lain-lain kolor sa *samay*. Parehos ka dya bi white, gray, white, gray, white, green tapos balik duman sa white. Unahon mo anay ang mga gagmay. Tag tatlo o anum man lang na ka labod ang mga nipis. Sulat mo para maman-an mo kung pira dun nagamit mo. Te parehos ka dya ka gin obra ko, 6 + 3 + 3 + 3 +3 = 18. Times 2 mo kay timbang sanda sa *samay*. Bale 36 ran. Ang bilin nga 14 amo ran ang green sa tunga. Sulit-suliton mo ran lang pagpasunod sa sab-ong asta 47 ka *bugkos* dun tanan [Since the patadag is 2 inches, it is equivalent to 3 *bugkos*, and since 1 *bugkos* equals 20 labod, you'll need 60 *labod* for one *patadag*. Multiply it to 9, so we get 540 *labod*. In 30 inches there are 47 *bugkos*, so that makes 940 *labod*. Then subtract it with 540 *labod* to get 400 *labod*, which is the total pairs of threads for your *samay*. Since there are 8 *samay* in the fabric, divide 400 by 8 to get 50 *labod* each *samay*. However, since the *samay* consists of the sequence of colors white, gray, white, gray, white, green before the sequence returns, you have to divide the 50 again into these colors. Start with the thinnest columns first; they usually just consist of 3 or 6 labod. You should also the colors and the count of threads on a piece of paper so you can track how many threads have been counted. Just like this one, 6 + 3 + 3 + 3 +3 = 18. Multiply it by 2 since the following pattern is simply a reflection of the previous sequence in the *samay*. Thus, you will get 36 *labod*, and the remaining 14 *labod* from the 50 *labod* is the green one at the center of the samay. Repeat the process until all 47 *bugkos* of threads are warped.]"

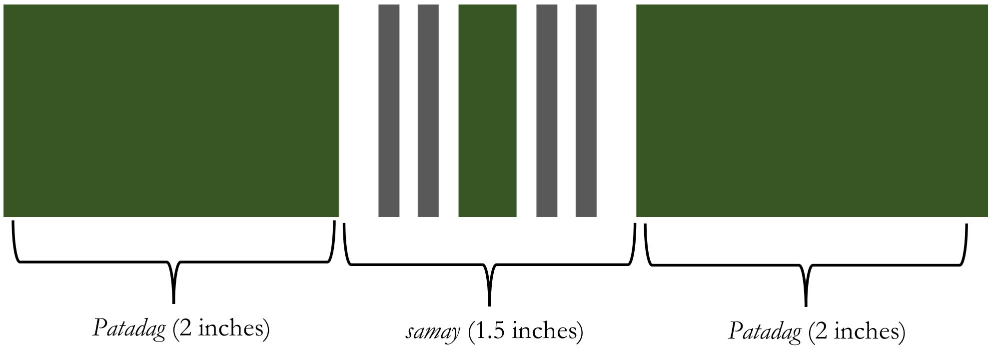


Figure 4. Set-up of warp threads on the loom based on the weaver's note.

Weavers may not be familiar with the formal concept of Linear Diophantine Equations, equations whose solutions are exclusively integers, yet certain activities in their workplace suggest that they subconsciously and indirectly engage in problem-solving similar to solving such equations through basic arithmetic operations. Upon presentation of the pattern or design from the customer, the weaver's first major dilemma is to figure out how many times the pattern has to be reiterated or translated on a 30-inch fabric, without actually cutting any portion of the pattern. This implies that the weaver needs positive integral values as solutions to this dilemma. In Figure 4, the basic pattern on the fabric consists of the 2-inch patadag and the 1.5-inch *samay*, which translates to the Linear Diophantine Equation,

$$2x + 1.5y = 30$$

where x represents the number of patadag and y represents the number of *samay*.

As per the solution of the weaver, the uncanny exploitation of calculation using basic arithmetic operations, and the trial-and-error method are apparent as Abaca Warpington tried to enlighten me,"Bale sa amo gya nga design, sa una gid patadag na nga 2 inches, dasun 1.5 inches ang *samay*. Total na 3.5 inches. Te $3.5\ in \times 9 = 31.5\ in$ ran. Lapaw sa 30 pay rapit man gawa. Diyan kaw maka-ideya kung paano ang pagtunga kay 30 in ang kalapadon. Gintestingan ko $2\ in \times 9 = 18\ in$ sa patadag kag $1.5\ in \times 8 = 12 in$ sa *samay* para 30 in [For example, in this checkered design, there is a 2-inch patadag at the very left followed by the 1.5-inch *samay*, which adds up to 3.5 in. I tried multiplying 3.5 in by 9 to get 31.5 in. It is not 30 in but is really close. From that arbitrary substitution, you can infer how to divide 30 inches into parts. I also tried multiplying 2 in by 9 and obtained 18 in for the *patadag* and multiplied 1.5 in by 8 to get 12 inches. They both add up to 30 inches.].

$$2x + 1.5y = 30$$
$$2(2x + 1.5y = 30)$$
$$4x + 3y = 60, \qquad \text{where } x, y \in Z^{+}$$

$$x = \frac{60 - 3y}{4} \quad y = \frac{60 - 4y}{3}$$

$$\text{if } x = \frac{60 - 3y}{4} = 15 - \frac{3y}{4}, \text{then } 0 < y < 20 \text{ and } y = 4k, \text{where } y \in Z^{+}$$

Thus, the weaver was able to accurately determine that 9 of the 2-inch patadag and 8 of the 1.5-inch *samay* must be used for a 30-inch fabric. It is, however, worth pointing out that there may be more than one pair of solutions to the linear equation. In the case of the above equation, $(9\ patadag, 8\ samay)$ is the weaver's solution to the equation, while the actual solution set to the equation is $\{(3,16),(6,12),(9,8),(12,4)\}$, which can be obtained using high school algebraic techniques.

For k=1,2,3,4, y=4,8,12,16 and x=12,9,6,3 respectively. Thus, there could be different combination of patterns of the same samay and patadag that the weaver may generate on the fabric. However, the weavers take into consideration the aesthetics of the finished fabric and deemed the alternating 9 patadag and 8 samay as the most visually pleasing.

3.3. Demonstrating Parallelism and Perpendicularity

To prevent entanglement and ensure equal spacing of threads during weaving, weavers insert the threads individually into their respective holes in the heddle and reed. Tension is also applied to maintain a consistent and even alignment of the weft threads as they are inserted into the warp threads.

- Manipulating threads individually

For the warp threads, parallelism must be in the mind of the weavers at different stages of weaving. First, the weaver patiently and sequentially rolls the warp threads around bamboo pegs of the warping tool. "*Ginapasunod kada kolor kag ginabadbad para indi mag-gumon* [The warp threads are organized per color and are untangled.]" Then warp threads are rolled along the loom's beam. In beaming in order for the threads to be parallel, weavers carefully organize the threads on the beam, making sure they do not overlap each other. Additionally, each thread is meticulously inserted through openings of a heddle before going through even tinier holes of the metal reed. "*Magpasulod ka gani sa binting, isa-isa gid dapat. Amo man magpasulod sa salod, isa-isa man ra. Isa ka hilo sa kada buho* [You have to insert each thread individually into each hole of the heddle. The same is done when inserting each thread into each opening of the reed,]" said Stella Loomis

- Applying tension on threads

The beaming stage of weaving involves rolling the sequenced warp threads around the beam of the loom (figure 5). At this stage, tension is applied to ensure warp threads are straight and taut. Aurora Knottingham expressed, "*Kay kung halog imo paglikis, galatoy ang hilo. Budlay maghabol kaw* [If you do not apply enough tension on the warp threads, they will be loose and weaving will be difficult.]"At the start of the actual weaving, weft threads are being pushed by the reed towards the wooden cane at the base of the loom. In order to make sure weft threads are not loose, an adequate amount of force must be applied.

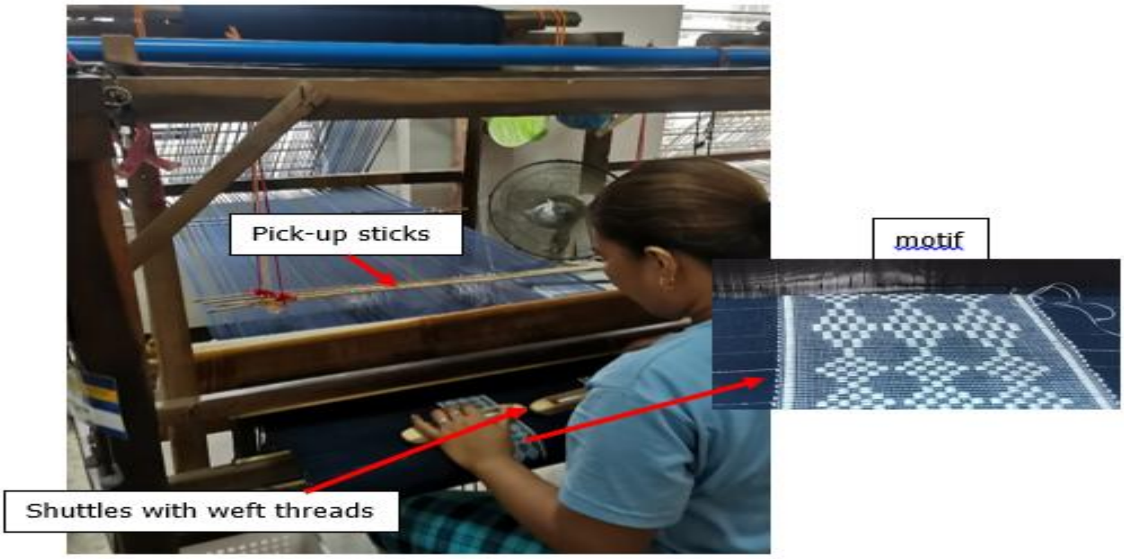


Figure 5. Traditional loom used in *hablon* weaving.

3.4. Establishing Symmetry

By incorporating symmetry into fabric designs, weavers create visually striking and aesthetically pleasing compositions that have a timeless allure (figure 6). In establishing symmetry, the weavers are able to manifest a learning competency set by the Commission on Higher Education - applying geometric concepts especially isometries in describing and creating design. Isometries are geometric transformations that preserve the distances between points, resulting in invariant configurations. In weaving, these isometries are manifested through the meticulous arrangement of threads, with their specific sequences and quantities determined during the planning stage.

In checkered designs, the number of repetitions or transformations of the *samay* and *patadag* patterns within the fabric is initially calculated. The threads corresponding to these identified sequences and repetition counts undergo the warping process before being transferred to the loom. By carefully implementing these transformations, weavers achieve the desired geometric patterns and symmetries in their woven fabrics. On the other hand, when creating motifs using the pick-up technique, isometries are manifested through the careful setting up of warp threads according to the weaver's sketch. The weaver translates the desired motif onto the warp threads by selectively raising and lowering specific warp threads to form the desired pattern. By following the sketch and manipulating the warp threads in a predetermined manner, the weaver brings to life the isometries and geometric transformations inherent in the motif.

Figure 6. Some *hablon* motifs that exhibit geometric transformations.

- Weaving squares and rectangles

The geometric shapes such as squares and rectangles on the fabric are a consequence of both the warping stage and the actual weaving of the fabric. Once the warp threads are secured tightly on the loom, weft threads are run across the loom. In a checkered pattern, in order to come up with a square pattern, the weaver must consider the sequence of colors and the number of threads prepared by the weaver. The sequence of weft threads used by the weaver also follows the sequence of warp threads prepared beforehand.

It is time consuming to count warp threads especially for larger square designs, so weavers opt for estimation instead. Visual inspection and measurement are also employed to come up with the desired dimension of the design. To achieve perpendicular corners in the woven fabric, warp threads are set up on the loom with sufficient tension. Weft threads, on the other hand, are woven across the loom perpendicular to the warp threads. The weaver then applies enough force while pulling the reed onto the wooden cane located at the base of the loom to secure the fabric.

- Translating motifs on fabric

The symmetries commonly observed in *hablon* weaving are often characterized by translational symmetry. This means that the motif or figure is shifted or moved across a two-dimensional plane, while maintaining its original shape and size.

Once the motif sketch is completed and its elements are labeled, the weaver proceeds to set up the warp threads on the loom. This process involves individually configuring each element of the motif. The graphing paper with shaded blocks is used as a reference, where each block represents three warp threads on the loom. By convention, weavers assign three warp threads per block on the paper. Figure 7 concerns shaded blocks representing a motif and its elements.

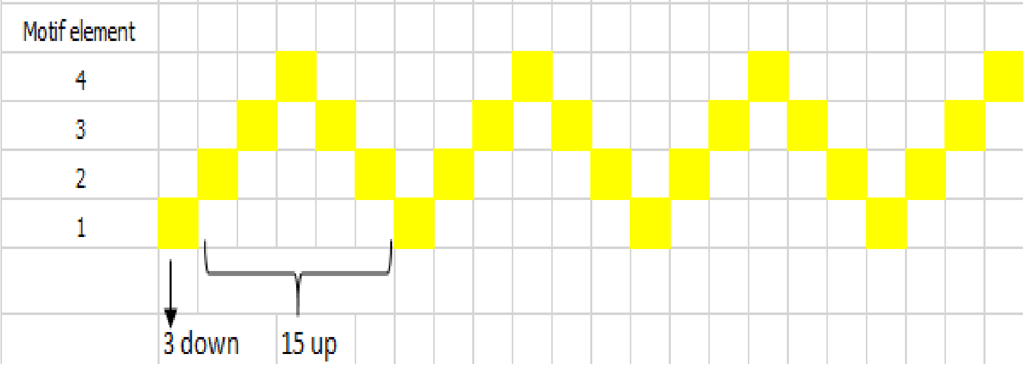


Figure 7. Shaded blocks representing a motif and its elements.

During the weaving process, the shaded blocks on the graphing paper indicate the warp threads that the motif threads will pass over. To represent this on the loom, the weaver counts "three down" for each shaded block where the motif is present, indicating that the motif threads will pass over three consecutive warp threads. Conversely, for each block without the motif, the weaver counts "three up," signifying that the motif threads will not interact with those particular warp threads.

For each motif element identified, there is a specific warp thread configuration tied around a particular bamboo stick, which is also labelled accordingly. Consequently, in order to weave a specific motif element, the weaver only needs to pick up the stick at the heddles associated with the said motif.

Furthermore, weavers possess an understanding of the axis of symmetry. This knowledge allows them to plan and execute their motifs with precision, ensuring that the resulting fabric exhibits the desired symmetrical properties.

For example, to weave element 1 of the motif on the fabric, the weaver begins by picking up bamboo stick 1, which lifts all the "up" warp threads tied to the stick. This action creates a visible gap between the "up" and "down" threads. To maintain this gap, a wooden plank known as *pakang* is inserted between the threads. Once the gap is established, the weaver propels the weft thread across the loom, passing it through the gap created by the raised "up" threads. This weaving technique allows the weft thread to interlace with the warp threads, incorporating element 1 of the motif into the fabric.

4. Discussion

Bishop (1988) emphasized that all cultural mathematics-related activities can be categorized as either counting, locating, measuring, designing, playing, and explaining regardless of the diverse ways in which societies develop and apply mathematics. Furthermore, Bishop (2002) considers mathematics to be a cultural creation that emerges from various cultural activities, particularly through the process of acculturation. Therefore, the learning of mathematics takes place within the context of cultural interaction. As the study revealed, the field of weaving demonstrates the presence of mathematics within its workplace culture. Bishop's six pan-cultural activities are also evident, with counting being the most frequently employed activity, as weavers engage in counting tasks at various stages of the weaving process. Through active participation in workplace activities alongside other weavers, weavers acquire mathematical concepts and skills in a distinct manner compared to formal learning environments like schools.

Furthermore, the findings of this study strengthens the claims of De Las Peñas and Salvador-Amores (2016) that weavers possess the clarity and exactness of mind since it takes mathematical calculation to weave cloth on a loom and mathematical ingenuity to create complex geometric patterns. By performing basic arithmetic operations and estimation on the number of threads to be used, they exhibit critical thinking and problem solving skills, indirectly solving Linear Diophantine Equations. This study also asserts that each design demonstrates the weaver's ability to fuse horizontal and vertical elements of the warp and the weft to arrive at a pattern illustrating various concepts of mathematical symmetry. As for the mathematical concepts embodied by *hablon* weavers, results of this study support the findings of Libo-on (2019), where he revealed mathematical concepts of sequencing, parallelism, and creating symmetry through the patterns in *hablon* weaving and that of Dominikus, Udil, Nubatonis, and Blegur (2023) where counting, estimation, measuring, and designing are also evident. Also, the findings of the study also aligned with the mathematics involved in weaving *tembe nggoli* of Mbojo tribes in Indonesia, where translation, rectangles, and parallalograms were documented (Nurbaeti et al., 2019). While Libo-on (2019) revealed that seven frieze groups and ten of the seventeen crystallographic groups are present in *hablon* fabrics, this study shed light to how these types of symmetry were created from the planning up to the actual weaving stage, providing insights into the mathematical principles and artistic considerations influencing the intricacies of *hablon* weaving.

This study also presented more detailed units of ethno-measurement used by *hablon* weavers. However, some conversions from inches to *bugkos* are not mathematically as accurate. By inspection, if 30in = 47 *bugkos*, then 1 inch = 31.33 labod in a standard *loom* or fabric. Also, by using the 20-inch fabric = 32 *bugkos* conversion for the *patayong* and shawls, then, 1 inch = 32 labod, which equates to a 10-labod difference in weaving a 30-inch fabric, neither of which is the same as 1 inch = 30 *labod*. While there were inaccuracies with the ethno-measurement conversions used, the weavers generally do not perceive minor deviations from the target size of the fabric as a significant problem in weaving. This may be due to the inherent flexibility of the fabric itself and the varying pressure applied by the weaver during the weaving process. They understand that achieving absolute precision in fabric sizing is challenging, given the nature of hand weaving and the involvement of human factors. This perspective showcases the weavers' adaptability and acceptance of the inherent variability that can arise during the weaving process. Instead, they seem to focus more on the overall quality, aesthetics, and cultural significance of the fabric rather than being overly concerned with exact measurements.

While the study adhered to the methodology of an ethnography, the study recognizes the limitations on the number of informants. Increasing the number of informants from other weaving centers may give additional and meaningful insights to the mathematical practices of *hablon* weavers. Moreover, the findings of the study may not be extended to the mathematical concepts that can be found in other crafts and cultural activities and even in other weaving communities whose own unique culture may have some influence in the weavers' mathematical activities and cultural practices. Deeper investigation on how each of the ten crystallographic groups are generated may also be explored further.

5. Conclusions

The findings of the study revealed fascinating results of the weavers' complex mathematical mind and activities at work. Despite not being well versed in mathematics, the weavers were able to manifest the following mathematical skills: designing; calculating and estimating number of threads; demonstrating parallelism and perpendicularity; and establishing symmetry in various fabric designs. These skills were also found to be aligned with mathematical competencies set by the Department of Education and the Commission on Higher Education for Filipino students.

Mathematics is extremely useful in any workplace, and the *hablon* weavers were able to prove the extent to which they manifest certain mathematical competence aligned with the expected learning outcomes. Thus, it is crucial that lessons be designed to reflect the local culture such as weaving and cater to the needs of the community, while co-curricular activities and community involvement be incorporated to provide real-world contexts for learning. Lesson exemplars and performance tasks may be developed, incorporating *hablon* weaving based on the learning competencies embodied by the weavers. By integrating mathematical concepts directly into the context of weaving, the task can provide a meaningful and relevant learning experience for the learners. Additionally, educators may encourage collaboration in working on projects and tasks, allowing learners to apply mathematical concepts collectively to promote communication, cooperation, and problem-solving skills, while fostering a sense of community and shared responsibility. The inclusion of indigenous craft does not only bridge everyday life mathematics and academic mathematics, but also promotes a cultural heritage, aiding its preservation and sustainability.

Furthermore, continual improvement is essential for any craftsperson, including weavers. Governments should continue with their initiatives to offer training programs that provide valuable opportunities for weavers to enhance their skills, learn new techniques, and expand their knowledge base. By taking advantage of these training programs, weavers can further develop their mathematical abilities and refine their weaving techniques. Finally, workplace mathematics across various communities of practice can also be examined, along with an investigation into the effectiveness of ethnomathematics-based instruction.

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References

Anderson-Pence, K. (2013). Ethnomathematics: The Role of Culture in the Teaching and Learning of Mathematics. *Utah Mathematics Teacher, 6*, 52–61.

Baylas IV, N. A., Rapanut, T. A., & De las Peñas, M. L. A. N. (2012). Weaving symmetry of the Philippine Northern Kankana-ey. In R. Bosch, D. McKenna, and R. Sarhangi (Eds.), *Proceedings of Bridges 2012: Mathematics, Music, Art, Architecture, Culture* (pp. 267–274). Tessellations Publishing. http://archive.bridgesmathart.org/2012/bridges2012-267.html

Bishop, A. J. (1988). *Mathematical enculturation: A cultural perspective on mathematics education.* Dordrecht: Kluwer Academic Publishers.

Bishop, A. J. (2002). Mathematical acculturation, cultural conflicts, and transition. In G. de Abreu, A. Bishop and N. Presmeg (Eds.), *Transitions between contexts of mathematical practices* (pp. 193-212). Dordrecht, Holland: Kluwer.

Cerbo, C. A. (2012). A glimpse of Pisay history through oral history an instructional methodology in teaching Social Science I. Unpublished manuscript, West Visayas State University, La Paz, Iloilo City.

Creswell, J. (2007). *Qualitative inquiry and research design: Choosing among five approaches* (2nd ed.). USA: Sage.

Creswell, J. (2012). *Educational research: Planning, conducting, and evaluating quantitative and qualitative research* (4th ed.). Boston: Pearson.

Crotty, M. (1998). *The foundations of social research: Meaning and perspective in the research process.* Australia: Allen & Unwin.

D'Ambrosio, U. (2014). Ethnomathematics. In S. Lerman (Ed.), *Encyclopedia of mathematics education* (pp. 221-225). New York: Springer.

De Las Peñas, M. L. A. N., Garciano, A., Verzosa, D. M., & Taganap, E. (2018). Crystallographic patterns in Philippine indigenous textiles. *Journal of Applied Crystallography, 51*(2), 456–469. https://doi.org/10.1107/s1600576718002182

De Las Peñas, M. L. A., & Salvador-Amores, A. (2016). Mathematical and anthropological analysis of northern luzon funeral textile. *Philippine Journal of Science, 145*(1), 89–103.

De Las Peñas, M. L. A., Garciano, A., & Verzosa, D. (2014). Weaving mat(h)s. *The mathematical intelliger, 36*, 36-46.

Department of Education. (2013). K to 12 curriculum guide: Mathematics. Pasig City.

Dominikus, W. S., Udil, P. A., Nubatonis, O. E., & Blegur, I. K. S. (2023). Exploration of the weaving activities in Timor Island for mathematics learning. *Ethnomathematics Journal, 4*(1), 1–18.

Gray, D. (2004). *Doing Research in the Real World.* Sage Publication.

Libo-on, J. (2019). Crystallographic and Frieze Groups Structures in Hablon. *International Journal of Advance Study and Research Work, 2*(5), 25–36. https://doi.org/10.5281/zenodo.3236439

National Museum of the Philippines (2021). Ethnology. https://www.nationalmuseum.gov.ph/our-collections/ethnology/textiles-and-weaving/

Nurbaeti, S., Mikrayanti, S., & Edison. (2019). Ethnomathematics on Woven Fabric (Tembe Nggoli) of Mbojo tribe society. *Journal of Physics: Conference Series, 1280*(2), 022049. https://doi.org/10.1088/1742-6596/1280/2/022049

Paragas, A. (2011). Enhancing mathematics learning through practical work. www.psubc.edu.ph/eprp/files/enhancing%20mathematics%20learning%20through%20practical%20work.pdf

Philippine Commission on Women. (2013). Weaving Progress for the Miag-ao Hablon Industry Weaving Progress for the Miagao Hablon Industry Gender-Responsive Value Chain Analysis of Hablon Weaves in Miagao, Iloilo. https://library.pcw.gov.ph/wp-content/uploads/2020/12/PCW-GREAT-Women-Project-Weaving-Progress-for-the-Miag-ao-Hablon-Industry-Gender-Responsive-Value-Chain-Analysis-of-Hablon-Weaves-in-Miag-ao-Iloilo-March-2013.pdf

Spradley, J. P. (1980). Participant Observation. *Anthropological Quarterly, 53*(4), 260-261. https://doi.org/10.2307/3318111

United Nations. (2023). Sustainable Development Goals. United Nations Sustainable Development; United Nations. https://www.un.org/sustainabledevelopment/sustainable-development-goals/