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Crystallographic and Frieze Groups Structures in Hablon

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Abstract

The existing hablon –a handloom textile of Hiligaynon and Karay-a speaker- is the manifestation of the Ilonggos' culture, tradition, as well as a livelihood which brought Iloilo to its highlight in the 19th century and further named to be the Textile Capital of the Philippines. This current study would like to classify the crystallographic group and the frieze group patterns present in the hablon designs. In addition, it attempted to determine the mathematical concepts embodied in the process of hablon. The ethnographic method was employed in this study, specifically, immersion, fieldworks, and interviews to understand the process in hablon. This study revealed that the seven frieze group patterns were present in hablon designs and ten for the crystallographic group. The mathematical concepts embodied in the process of hablon were harmonization of multiple processes for planning, practicing parallelism of threads for warping, logical sequencing of the direction for beaming, alternate injective and surjective sets for heedling, consecutively injective and surjective sets for reeding, establishing the limitation for tie-in, able to estimate for spooling and creating waving pattern of weft for weaving.

Keywords: Ethnomathematics, Ethnography, Hablon, Frieze, Crystallography, Weaving, Textile, Cloth, Philippines

Introduction

Indigenous mathematics knowledge is common to our environment. In our everyday life, we use it but we sometimes do not notice it. It is just like the start of a period of *amihan*-North East Monsoon in the Philippines- which reminds us that it is the last week of October or maybe it is already the month of November. Filipinos were once used to the term "*ganta*" in measuring when buying rice in the market or even in barter trade of products in provinces. Ganta is a Filipino indigenous mathematical knowledge of measurement as to weight which is equivalent to 2.25 kilograms in terms of the metric system. Embedding mathematics in man's daily life is inevitable, thus, further creating a culture within the group of people who observe and practice the phenomena.

To explore the link between culture and mathematics, D'Ambrosio (1985) first used the term ethnomathematics. Ethnomathematics then was defined as "the mathematics which is practiced among identifiable cultural groups such as national-tribe societies, labor groups, children of certain age brackets and professional classes". The purpose of it is to seek to understand mathematical knowing/doing throughout the history of humanity, in the contexts of different groups, communities, peoples, and nation (D'Ambrosio, 2001).

The ethnomathematics as aforementioned in the context of research is a great avenue to be done in the Philippines, for the country is an archipelagic type of land masses; as such the presence of diverse cultural heritage and practices is inevitable. The variation of the diverse culture in the country results in diverse customs and traditions. Exploring all the customs and traditions will take a long period of time. However, exploring and injecting mathematics to understand things will help man understand point-by-point the country's culture. Of course, by this, the culture that is still present is preserved and to the endangered ones to be documented.

Weaving is a mirror of cultural heritage. It gives an authentic printout of the generation in the past and at the present, since as early as pre-Spanish colonization, weaving has been established in the Philippines. The Philippines holds one of the oldest and remarkable *warps ikat,* a cloth weave from abaca in South East Asia. The Banton burial cloth is associated with the Ming period and found in a wooden coffin at Banton, Romblon and was dated in the 13th -14th century (Ocampo, 2011). Further, Bukley (2012) asserts that the Southeast Asian weaving customs are connected, and share a typical precursor among Neolithic culture in the Asian terrain. In addition, it underscores that the *warp ikat* themes and weaving started with the Bronze Age Dong-Son culture.

Several ethnic groups still exist in the Philippines and produce hand weaved textile, such as the Pinilian of Ilocos Region, Bontoc weave of the Mountain Province, Kalinga textile of the Province of Kalinga, Hablon of Kinaray-a and Hiligaynon, Saputangan tapestry weave of Yakan in Basilan, Mabal Tabih of Blaan in Saranggani and South Cotabato, Bagobo inabal of

Bagobo Manobo community in Davao del Sur, Dagmay of Mandaya community in Eastern Mindanao, Meranaw textile of Meranaw Community in Lanao del Norte and Lanao del Sur, Pis Syabit weave of Tausug in Sulu Archipelago, and T'nalak of Tboli community in South Cotabato (Sorilla IV, 2017).

Ngan (2017) believes that hidden patterns can be discovered in textile since geometric patterns are present in many things around us. Designs are the first thing that attracts the human eye besides the harmony of color and symmetries. Ahadian and Bastanfard (2012) use geometric groups in determining the patterns in the image, but later analysis of El ouaazizi, et al. (2015) specifies that frieze patterns are used to identify the common geometric pattern.

Some studies also used the crystallographic group to identify geometric patterns in weaving. De Las Peñas, et al. (2017) identified crystallographic group patterns that are present in the weaving techniques in Philippine indigenous fabric for *ikat* design of South Cotabato, in the decorative designs of *binakol*, Northern Philippines and in the design of Bunga Sama, in Zamboanga peninsula.

Crystallographic group and frieze group are the prominent groups used in determining the geometrical patterns. Dobre (2012) asserts that geometric symmetry is the basis to examine designs in different cultural contexts. The notion of symmetry is equivalent to the harmony and proportion of things. According to Clarke, et al. (2011) the plane crystallographic group, also known as wallpaper group, has 17 established patterns and the frieze group has seven established patterns. The established patterns are produced by reflection, translation, inversions, and rotations.

Baylas, et al. (2012) explored the weaving symmetry of Kakanna-ey a cultural group in the Cordillera region. There is the presence of horizontal and/or vertical reflections on their patterns. In Northern Luzon, weavers create a meaningful geometric design even without formal training. The pattern found is mostly refection symmetries and a horizontal and vertical axis that divides into upper and lower halves or right and left. Moreover, frieze patterns and plane crystallographic pattern were also evident (De Las Peñas and Salvador-Amores, 2016)

In Western Visayas, the hablon textile is a hand-woven textile of Karay-a and Hiligaynon community of Western Visayas. According to Cerbo and Lamera (2017) hablon industry in Western Visayas produces shawls, barongs, gowns, "*patadyongs*", ref towels, table runners, and handkerchiefs made-up of polyester thread, *jusi*, and cotton, and some industries also produce "*bestida*", blankets, and "*sablay*" aside from the common products. As regards the prices of these products, there are cheaper like those of the ref towels, table runners, and handkerchief, but *bestida*, *sablay*, barongs, and gowns are sold at a higher price. The biggest impact of hablon in the Western Visayas is in employment and also partly in tourism. Mostly women who were not able to finish their education due to poverty tend to engage in hablon weaving.

Based on the aforementioned studies, this study sought to classify the frieze and crystallographic group present in hablon designs as well as explore the mathematical concepts in the process involved in hablon weaving.

Research Methodology

The ethnographic method was employed in this study. The ethnographic method focuses on the group of people or culture and it is conducted on-site or in a naturalistic setting where the participants live (Angrosino, 2007). This method involves immersion and field works in the area where hablon is present-Western Visayas Philippines. It also provided opportunities for documenting native terms used in the process of weaving and for the informants to express their attitude towards cultural development of hablon. Furthermore, the ethnographic method gave qualitative data by means captured images of hablon designs and classified into structures in terms of crystallographic and frieze groups. Moreover, the mathematical concepts embedded and process related to weaving hablon was determined through immersion and indirect interview.

The participants of this study were the hablon weavers in Western Visayas Philippines. The data gathered were classified, and organized for analyses and interpretations.

The present study classified the geometrical patterns present on hablon using the crystallographic group patterns and frieze group; it also determined mathematical concepts embodied in the process of weaving hablon. The paradigm for this study as presented in Figure 1, the hablon designs are collected on site thru image capturing. Then, the design pattern of the hablon is identified and further classified by the investigator into crystallographic and frieze group structure. After the classification by the investigator, printouts of the identified and classified geometric patterns are subjected to verification of experts in crystallography. Thus, this leads to the classification of geometric patterns in hablon textile.

Since mathematical concepts embodied in the process of weaving hablon are also explored, the investigator engaged in emersion. To validate the mathematical concepts embodied in the process of hablon, the investigator returned to the sites and conducted the indirect interview, after which the determined mathematical concepts embedded is subjected to the validation of the expert in the field of ethnomathematics.

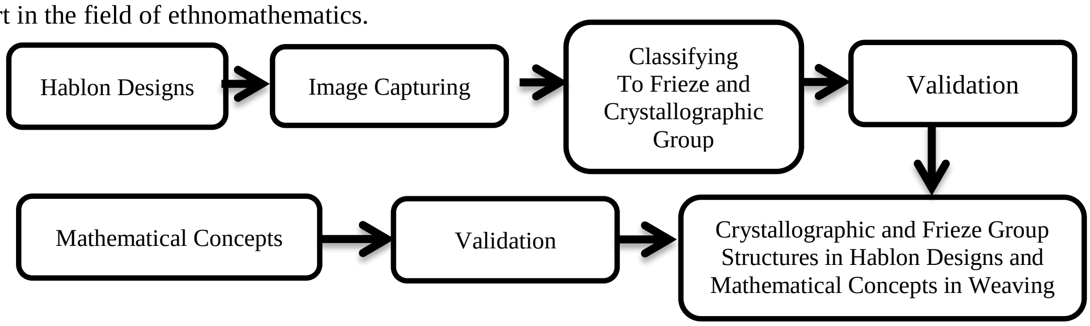

Figure 1. Research Framework

To classify the hablon into crystallographic and frieze group the algorithm made by Washburn and Crowe (1991) was used.

For the frieze group:

p1 - it is a trivial group or singly produced, by changing the least distance over which the design is isometric. In a simple term, it is a translation (T), only group.

p11g - it is a singly generated group, by a glide reflection, with translations being obtained by joining two glides reflections. In a simple term, it is a glide-reflections and translations group (TG).

p11m - it is a group produced by a translation and the reflection in the horizontal axis. The glide reflection arises as to the composition of a translation and horizontal reflection. In a simple term, there is a presence of translations, horizontal reflections, glide reflections (THG).

p1m1- it is equivalent to the non-trivial group in the one-dimensional case; it can be generated through a reflection in the vertical axis and translation. It is a vertical reflection of lines and translations (TV) in a simpler term.

p2 – it can be generated by a translation and a 180° rotation. Translations and 180° rotations are (TR) which is the simpler term for this group.

p2mg – it is with vertical reflection lines, glide reflections, translations, and 180° rotations or (TRVG). This group is produced by a glide reflection and also a rotation or a vertical reflection; hence, the translation here arises from the glide reflections.

p2mm - it is commonly observable with horizontal and vertical reflection lines, translations and 180° rotations (TRHVG). For this group, it needs three generators, with one producing set comprising of a translation, the reflection in the horizontal axis and another reflection across a vertical axis.

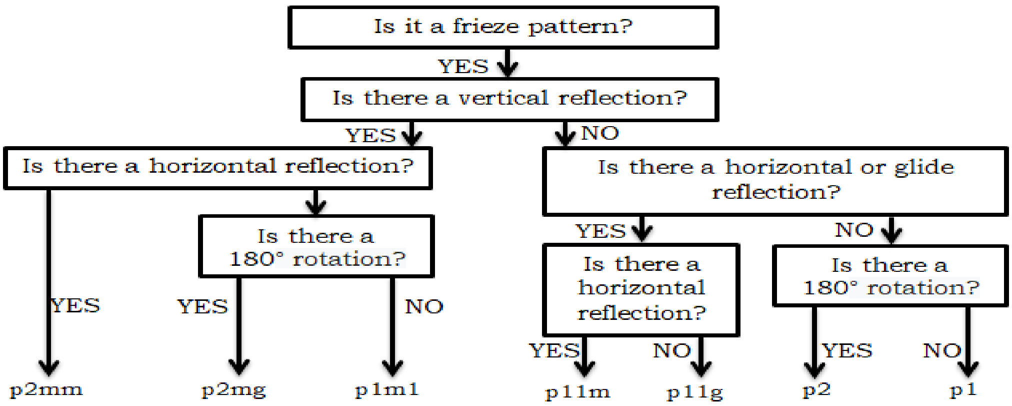

Figure 2 a: Paradigm Showing the Process in the Development and Testing the Frieze Group Pattern (Washburn and Crowe, 1991)

For the crystallographic group:

p1- the simplest symmetry group consisting only of translations, and neither reflections, glide-reflections, nor rotations for this group are present. Finally, at an angle to each other, two translation axes may be inclined.

pm - contains reflections, the axes of the mirror image are parallel to one axis of translation and also perpendicular to the other axis of translation.

pg - contains the direction of the glide reflections, and glide reflection is parallel to one axis of translation and also perpendicular to the other axis of translation. Furthermore, there are neither rotations nor reflections for this group.

cm - contains reflections and glide reflections with parallel axes. In addition, the translations may be inclined at an angle to each other and there are no rotations in this group, but the axes of the reflections bisect the angle formed by the translations.

p2 - it is like p1 but it differs by an additional 180° rotations of that in p1, specifically, the rotations on the second order. Then, in all symmetry groups, there are translations, but there are neither glide reflections nor even reflections. Finally, the two translations axes could also be inclined at an angle to every alternative.

pgg - contains glide-reflections and 180° rotations but without reflections. In addition, there is a perpendicular axis for the glide reflections, and the rotation centers do not lie on the axis.

pmg - contains reflections and glide reflections which are perpendicular to the reflection axes and has rotations of order 2 on the glide axes, halfway between the reflection axes.

pmm - contains perpendicular axes of reflection, with 180° rotations where the axes intersect.

cmm- comprises of perpendicular reflection axes, similarity group pmm, but it has also additional rotations of order 2 and the centers of the additional rotations do not lie on the reflection axes.

p3 - the simplest group that contains a 120°-rotation or rotation of order 3 and the group has no glide reflections or even reflections.

p31m- contains reflections --whose axes are inclined at 60° to one another- and rotations of order 3 and some of the centers of rotation lie on the reflection axes, but some do not. Moreover, there are some glide-reflections present.

p3m1 - similar to the p31m, for it contains reflections and order-3 rotations. Also, the axes of the reflections are again inclined at 60° to one another, but for this group, all of the centers of rotation do lie on the reflection axes and there are some glide-reflections.

p4 - a group that has a 90° rotation, a rotation of order 4 and it also has rotations of order 2. In addition, the centers of the order-2 rotations are midway between the centers of the order-4 rotations, but there are no reflections for this group.

p4g - just like the p4 group, this group contains reflections and rotations of orders 2 and 4. For this group, there are two perpendicular reflections passing through each order 2 rotation. However, the order 4 rotation centers do not lie on any reflection axis and there are four directions of a glide reflection.

p4m - it has both order 2 and order 4 rotations, but it has four axes of reflection. The axes of reflection are inclined to each other by 45° so that four axes of reflection pass through each order 4 rotation center. Every rotation center lies on some reflection axes. There are also two glide reflections passing through each order 2 rotations, with axes at 45° to the reflection axes.

p6 - containing 60° rotations, a rotation of order 6 and also contains rotations of orders 2 and 3, but no reflections or glide-reflections.

p6m- a complex group that has rotations of order 2, 3, and 6, as well as reflections and the axes of reflection, meet at all the centers of rotation. Moreover, at the centers of the order 6 rotations, six reflection axes meet and are inclined at 30° to one another. Also, there are some glide-reflections.

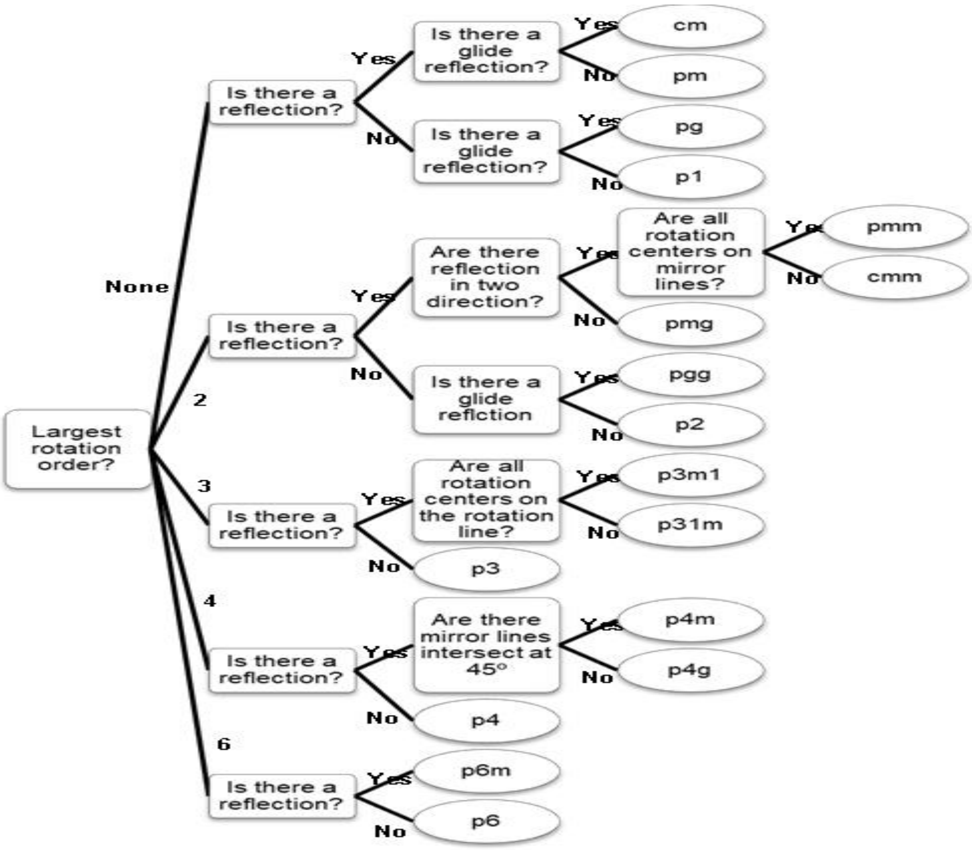

Figure 2b: Paradigm Showing the Process in the Development and Testing the Crystallographic Group Pattern (Washburn & Crowe, 1991)

Results and Discussion

Classified Frieze Group Structure in Hablon

The identified, classified and validated frieze groups present on hablon were p1, p11g, p2, p1m1, p11m, p2mg, and p2mm.

Figure 3.a Image of hablon cloth for p1.

Figure 3.b Image of hablon cloth for p11g.

Figure 3.c Image of hablon cloth for p2.

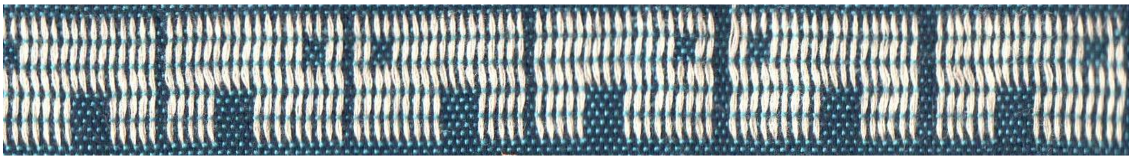

Figure 3.d Image of hablon cloth for p1m1.

Group Figure 3.e Image of hablon cloth for p11m.

Figure 3.f Image of hablon cloth for p2mg.

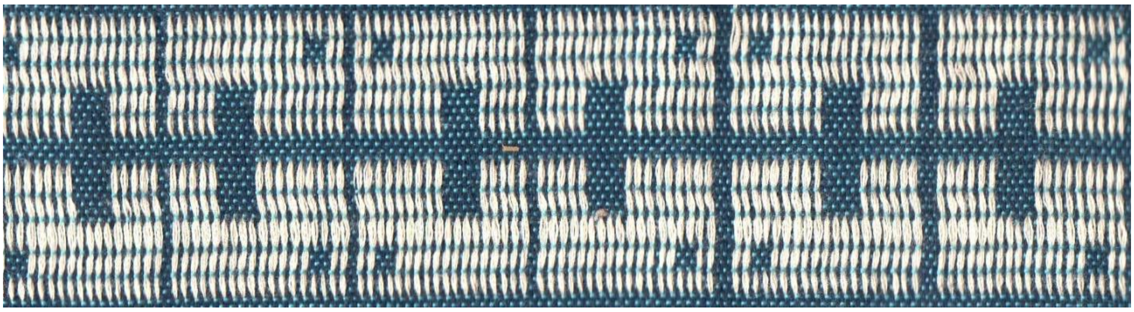

Figure 3.g Image of hablon cloth for p2mm.

Classified Crystallographic Group in Hablon

The crystallographic groups present on hablon were cm, pg, p1, pmm, cmm, pmg, pgg, p2, p4m, and p6m.

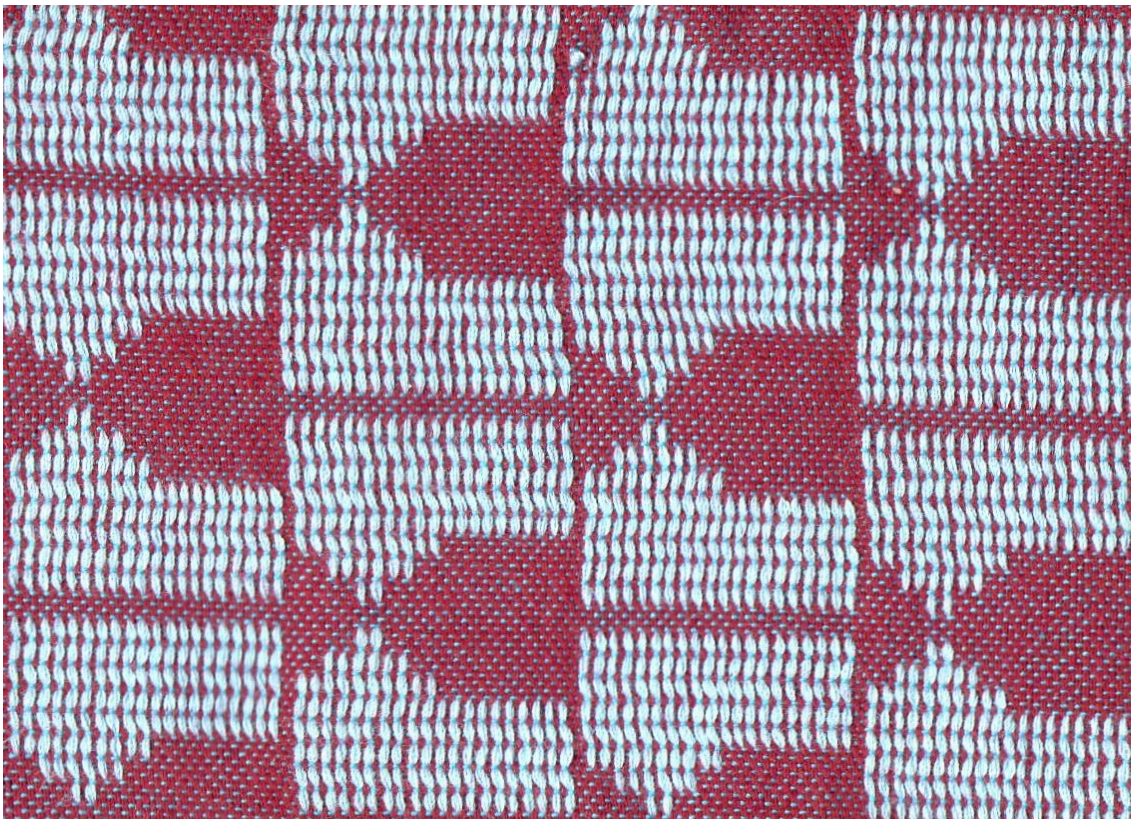

Figure 4.a Image of hablon depicting cm of the crystallographic group

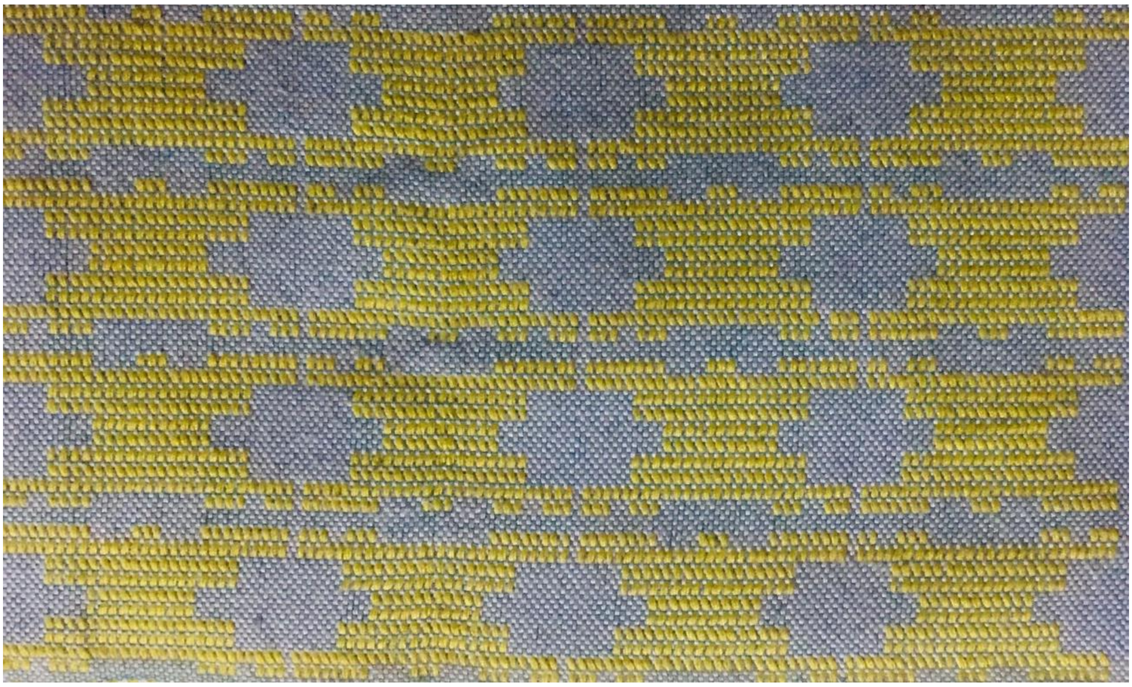

Figure 4.b Image of hablon depicting pg of the crystallographic group

Figure 4.c Image of hablon depicting p1 of the crystallographic group

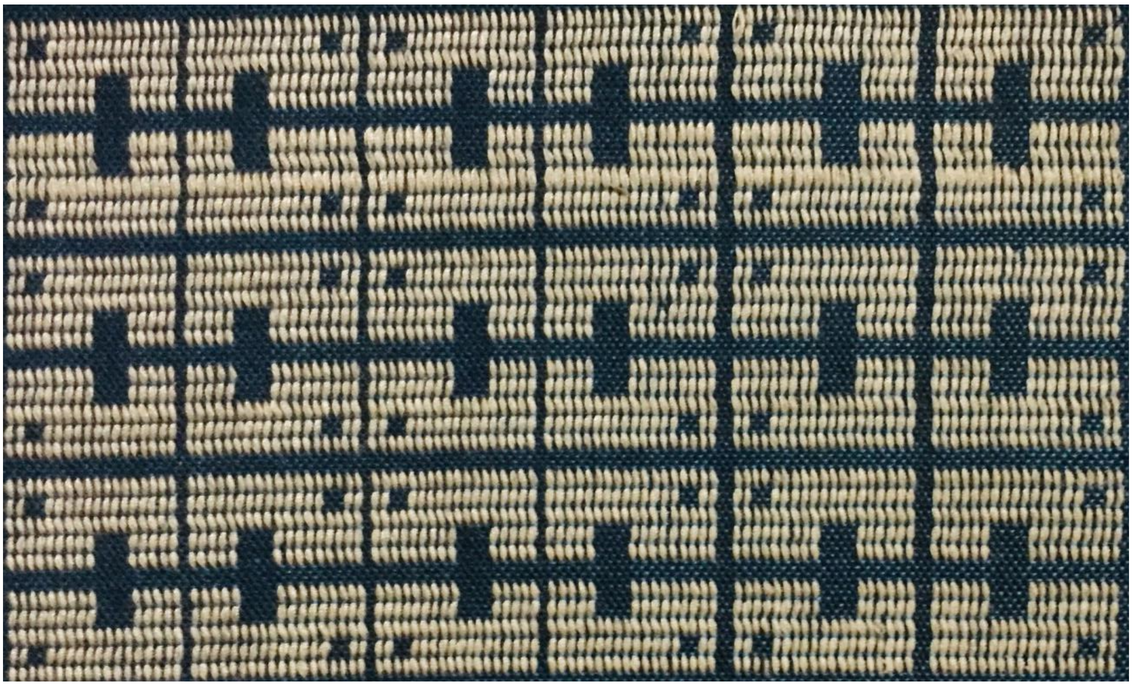

Figure 4.d Image of hablon depicting pmm of the crystallographic group

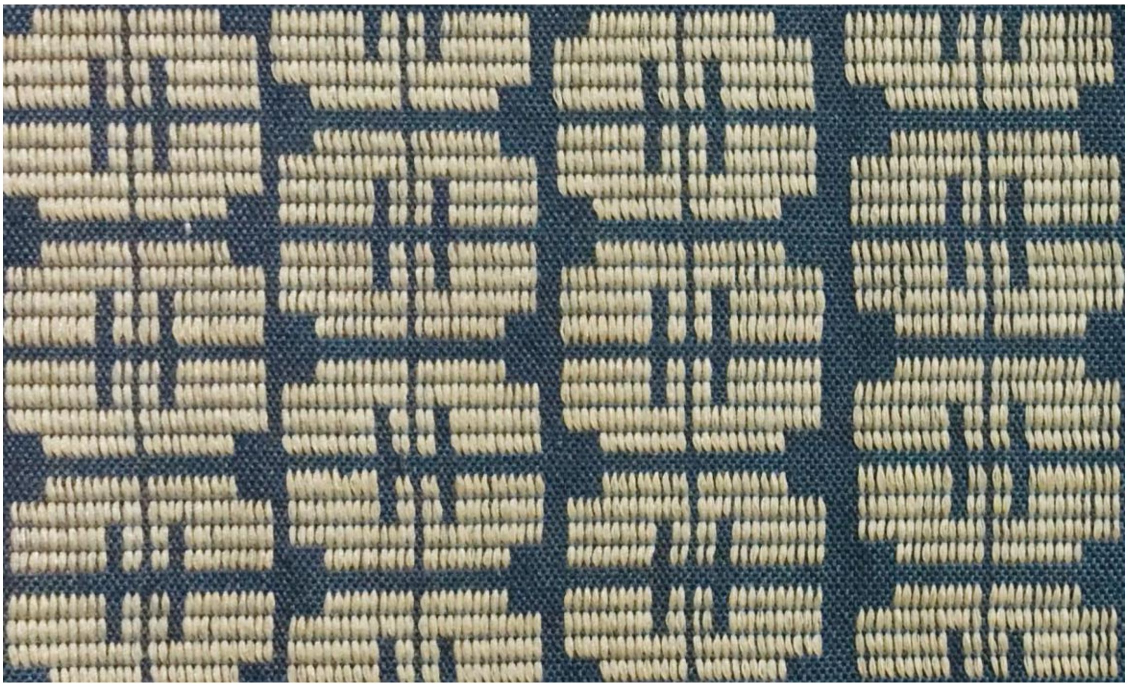

Figure 4.e Image of hablon depicting cmm of the crystallographic group

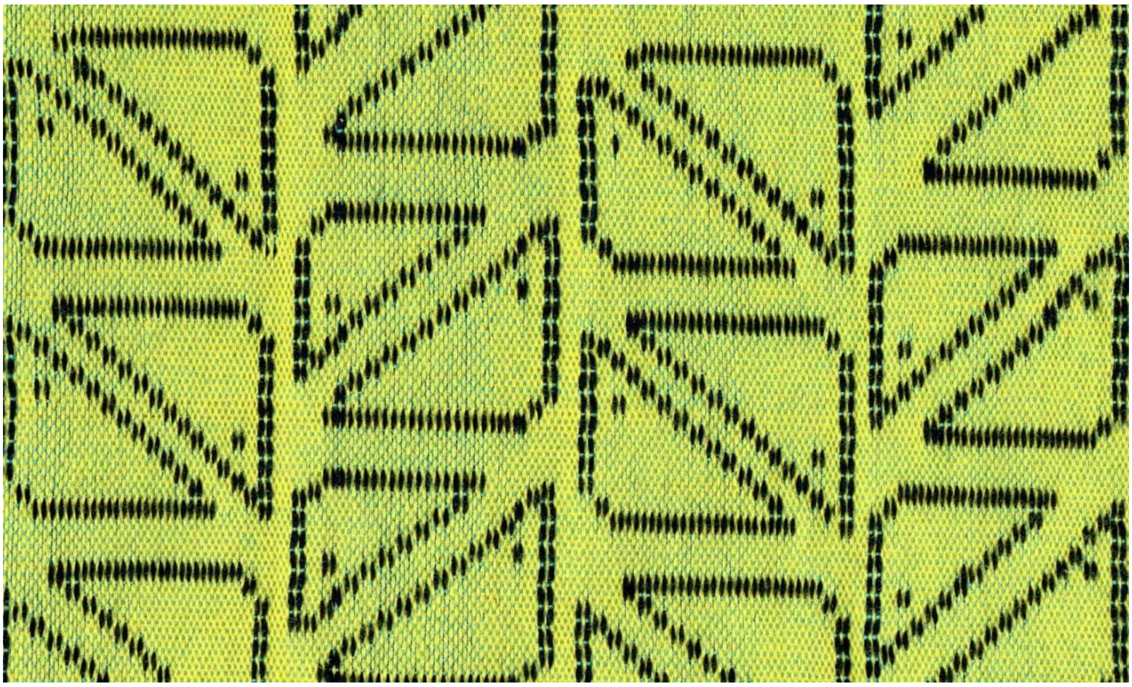

Figure 4.g Image of hablon depicting pgg of the crystallographic group

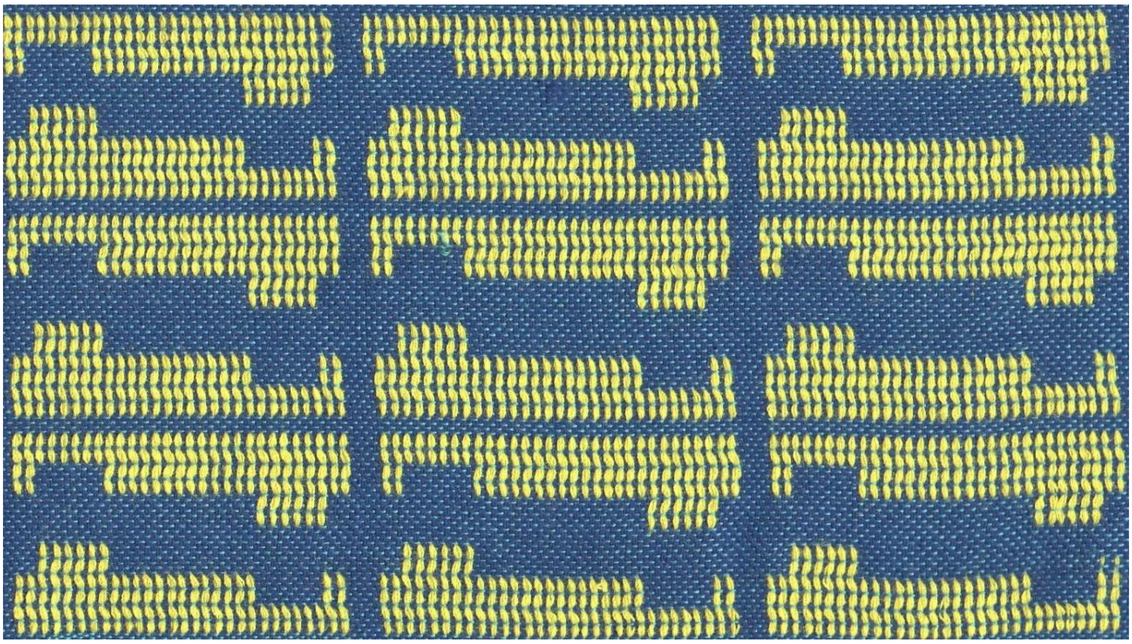

Figure 4.h Image of hablon depicting p2 of the crystallographic group

Figure 4.i Image of hablon depicting p4m of the crystallographic group

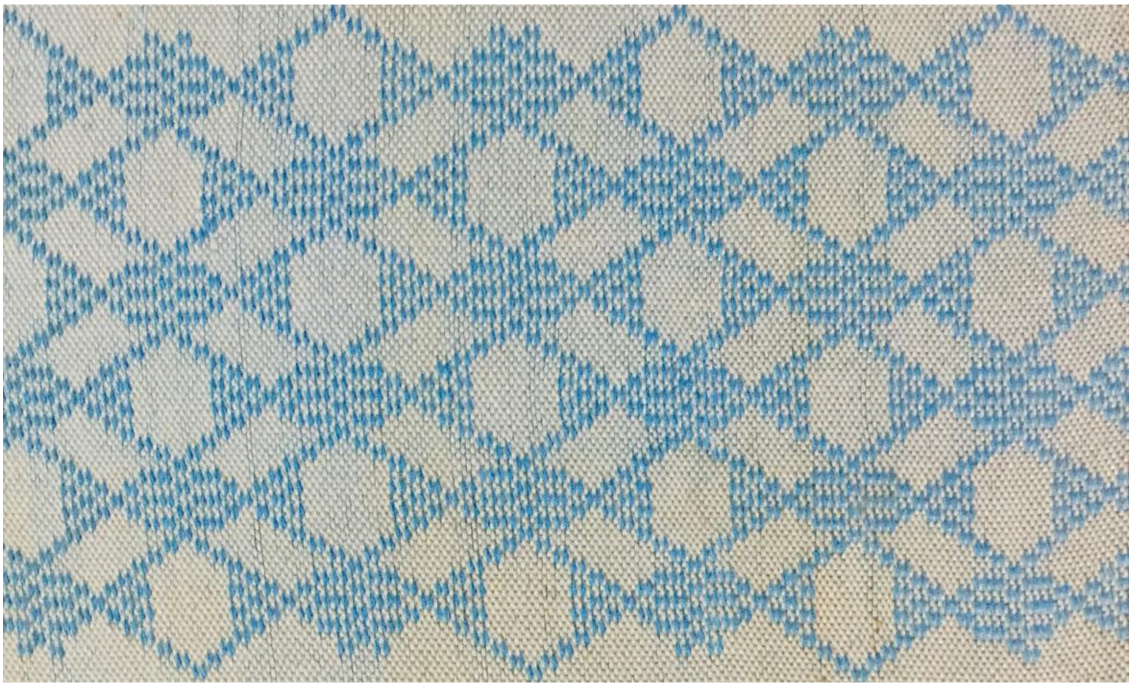

Figure 4.j Image of hablon depicting p6m of the crystallographic group

Mathematical Concepts Embedded in Weaving Hablon

The mathematical concepts embedded in the process of hablon were:

Planning

Planning in terms of weaving is the way the weavers decide and arrange in advance the necessary materials and supplies needed for weaving in accordance to the demands of the customers and sometimes for personal consumption. This illustrated that weavers were able to deal with the assimilation of the latter weaving harmonization of multiple processes of the color of thread and to allocate necessary time. A concept in a mathematical investigation is given emphasis. As for the weavers, the concept refers to "*…thinking of the materials and the next sequence of the process.*" Also, *"…it is important that time is considered for sometimes there were orders that needed the product in just a short period of time…if you could not anticipate the time frame in the weaving process, customers look for the weavers in the other town that can handle."*

Warping (Sab-ong)

Pagsab-ong is a meticulous and patiently done process by clipping the warp thread in the pegs of *sab-ongan*-warping tools. It illustrated how weavers sequentially clipped the warp thread to give continuity in the latter weaving process. Furthermore, this showed that the weaver practiced parallelism of threads to avoid it to tangle. A concept in plane geometry is given emphasis. The parallelism refers to the threads which are not intersecting and untangling while in the warping process; for the weavers, this leads to *"…so that it will be easy for a sequential reeding." and "…so that to avoid tangling of thread."*

Beaming (Likis)

"*Likis*" or beaming gave traces where the warps thread would pass through. It drove a logical sequencing of the direction to where the warp threads must be clipped, rolled and penetrated. As to the weavers said, *"…it should be sequential and parallel to tighten the thread."* A concept in a mathematical investigation is given emphasis. The logical sequencing of the direction refers to the succession of the direction in which part of the *tiral* where the thread must be passed through. The logical sequence of the direction of warped threads is moton-to-breast beam-to-heddles-to-reed-to moton. The weaver affirms that "*If you trace the sequence of the warp in beaming it will start in moton-to-breast beam-to-heddles-to-reed-to-moton.*"

Heddling (Sulod sa Binting)

Sulod sa binting is a tricky process among all. It required much patience for the weavers because each of the sinab-ong thread must be inserted into the eye of every mesh. This process demonstrated that weavers were practicing a "*bal-ot bal-ot nga tig-isa-isa*" or alternate injective and surjective sets to avoid misdirection of the heddler that might lead to the disjoining of warp thread. A concept in algebra specifically on function is given emphasis. The *bal-ot bal-ot nga tig-isa-isa* or alternate injective and surjective set refers to the mathematical concept in which the alternate insertion of the warp threads to the eye of the mesh of the heddler is one-to-one and onto or one-to-one correspondence. As the weavers said *""… it is necessary to be alternate injective and surjective when heddling to avoid tangling towards the mesh of heddler and for the thread not to snap."* Also, it is necessary to avoid the snapping of thread as the other weavers said: *"...it is necessary to be alternate injective and surjective when heddling to avoid tangling towards the mesh of heddler and for the thread not to snap."*

Reeding (Sulod sa Solud)

"*Sulod sa salud*" is the is just like the process of sulod sa binting. It also required much patience for the weavers because each of the *sinab-ong* thread must also be inserted into the dent of the metal reed. This process illustrated that weavers did practice a "pasunod nga tig-isa-isa" or consecutively injective and surjective sets to avoid misdirection of the reed that might lead to the disjoining of warp thread. A concept in algebra specifically on function is given emphasis. As the weaver said this is *"...to provide a track for the shuttle during weaving."* In the same way around weavers also are carefully practicing the concept to avoid snapping during the final process of weaving as the other weaver said *"... to avoid snapping of thread when the reed is pushed."* The *pasunod nga tig-isa-isa* or consecutively injective and surjective sets refers to the mathematical concept of consecutive insertion of the warp threads to the dents of the reed is one-to-one and onto or one-to-one correspondence. For the weavers said *"... to avoid snapping of thread when the reed is pushed."* and *"...to provide a track for the shuttle during weaving."*

Tie-in (Higot sa Baston)

Higot sa baston is the process where the end of the *sinab-ong* thread is tied and served as the starting point of weaving. In this process, the weavers established the "*pundo*" or limitation of the thread and tightly tied into *baston*. A concept in pre-calculus is given emphasis. The "*pundo*" or limitation refers to the threads that were tightly tied into baston for the restriction and is being substantiated by tying since the weft in the final process is limited only to run on this point of the warp thread. Also, it is purposely maintaining the tension on warp thread as the weaver said "*To stiffen the thread."* and *"...indication of the starting point of weaving."*

Spooling (Pangalinyas)

Pangalinyas is a process where threads are twirled in a cylindrical rod by the aid of galingan. In this process, the weavers were able to "*sukol*" or estimate unto how thick the whirled thread that filled the *lasandera*-weft shuttle. In due consideration, it would be better if the thickness of the twirled thread was less than the space provided between the twirling rod and the bottom of lasandera. The concept in the fundamentals of mathematics was given emphasis. As the weavers said *"...sukol? Estimate or to measure."* It is commonly used in *"...in the thickness of the spooling (thread)."* and the weavers undergo estimation in the process of spooling by *"Just by looking to the thickness that will fit on the shuttle."*

Weaving (Habol)

Habol is the final processes where the lasandera runs across the width through the opening created by the stepping on the treadles. The running of the lasandera through the warp created "*iwol-iwol*" or waving pattern of weft just like the inverse graphical trigonometric representation. A concept in trigonometry is given emphasis. *The iwol-iwol* or waving pattern of weft is a resemblance of the inverse graphical trigonometric representation. As the weaver said to weave the weaver is *"...making of waving thread."* The purpose of making a waving thread is to lock or create a continuous weft as the weaver said *"...to make the weft continuous." and "...to avoid pulled weft."*

Conclusions

There appears that the entire frieze group patterns are evident in the hablon cloth. There are only ten out of seventeen crystallographic groups were present in the hablon cloth, that is, only the group of cm, pg, p1, pmm, cmm, pmg, pgg, p2, p4m, and p6m. The mathematical concepts embedded in the weaving process are hablon were harmonization of multiple processes for planning, practicing parallelism of threads for warping (sab-ong), logical sequencing of the direction for beaming (likis), "bal-ot bal-ot nga tig-isa-isa" or alternate injective and surjective sets for heedling (sulod sa binting), "pasunod nga tig-isa-isa" or consecutively injective and surjective sets for reeding (sulod sa salud) establishing the limitation for tie-in (higot sa baston), able to "sukol" or estimate for spooling (pangalinyas), and creating "iwol-iwol" or waving pattern of weft for weaving (habol)

Based on the results and conclusions as described above, it can be submitted suggestions for future research as

1. Exploring hablon using Fourier analysis.
2. Explore other textile using crystallographic and frieze group.

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