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APPLICATION OF MATHEMATICAL PATTERNS IN THE DESIGN OF APAYAO LOOM WOVEN CLOTH: BASIS FOR AN INSTRUCTIONAL MATERIAL EXEMPLAR IN ETHNOMATHEMATICS

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Abstract

This study explores the application of mathematical patterns in the design of Apayao loomwoven cloth, with a focus on developing an instructional material exemplar in ethnomathematics. The study highlights the integration of mathematics and traditional weaving techniques to create aesthetically pleasing and culturally significant textiles. Through an ethnographic approach, the research examines the mathematical principles and patterns inherent in Apayao weaving, such as asymmetry, repetition, and geometric forms. The findings contribute to the understanding of how mathematical concepts can be applied in local crafts, providing insights for educational materials that promote ethnomathematical learning. By recognizing the mathematical foundations of Apayao loom weaving, this research aims to preserve and promote the cultural heritage of the Apayao community while fostering mathematical literacy and appreciation for diverse mathematical practices. Photographs and videos were taken to visually capture the different stages of the weaving process, including the use of mathematical patterns in the design. These visual materials helped in illustrating and documenting the unique weaving techniques and patterns employed by the Apayao weavers. The instructional material exemplar developed based on the gathered data validated by experts in the field of Apayao weaving, ethnomathematics, and education. Their feedback and suggestions incorporated to enhance the quality and effectiveness of the instructional material in Mathematics in the Modern World worktext. The instructional material has 4.16 as overall rating which has a verbal description of Valid. Overall, the application of mathematical patterns in the weaving of Apayao cloth exemplifies the connection between mathematics and culture. By embracing ethnomathematics and incorporating local knowledge, we can provide each student with a more thorough and culturally sensitive mathematics education.

Introduction

The complex patterns featured in traditional textiles frequently have more meanings beyond just aesthetic appeal. They frequently represent a community's historical narratives, cultural traditions, and even underlying mathematical ideas. This is especially true for the locally produced Apayao loom-woven cloth, which is a textile made in the Philippines by the Apayao local community. By expertly incorporating mathematical patterns into their creations, the Apayao weavers create an intriguing fusion of art and mathematics.

A foundation for analyzing the mathematical patterns seen in traditional textiles is provided by ethnomathematics, a discipline of study that investigates the cultural elements of mathematics. Ethnomathematics forms the basis for significant contributions in rethinking the nature of mathematics. This pedagogical practice is essential in developing the curricular praxis of ethnomathematics by investigating local knowledge (M Rosa 2016). Exposure to mathematical pattern tasks is often deemed important for developing a learner's algebraic thinking skills. Yet, there is a dearth of evidence on the cognitive underpinnings of pattern tasks and how early competencies on these tasks are related to later development (Mulligan., et. al. 2020). We may learn more about the rich mathematical heritage of this society and utilize it as the foundation for an instructional material exemplar through studying the mathematical ideas and methods used by the Apayao weavers.

The Apayao individual's aesthetic expression and mathematical aptitude are represented in the loom-woven textile. The handwoven textile is accentuated with embroidered designs. The embroidery symbolizes a connected hand with 5 fingers. This depicts the industriousness of the Iyapayao (Ocampo, et. al, 2022). The beautiful designs that adorn the fabrics are made by the weavers using a variety of mathematical concepts like symmetry, tessellation, and geometric transformations. They convey stories, values, and cultural identity by carefully arranging shapes, colors, and themes.

In the design of Apayao textiles, symmetry is very important. Reflective symmetry, in which patterns are mirrored along a central axis, is a technique used by the weavers to produce designs that are harmonious and attractive to the eye. Repeated geometric patterns and motifs, such triangles, diamonds, and zigzag lines, are examples of this symmetry. Students can grasp the accuracy and complexity required in the production of these fabrics by learning the underlying mathematical principles of symmetry.

Another mathematical idea employed frequently in Apayao textile design is tessellation, the art of putting shapes together without any gaps or overlaps. Shapes like squares, rectangles, and triangles are

expertly arranged by the weavers to create seamless patterns that span the entire cloth. This precise tessellation procedure demonstrates the weavers' mathematical prowess since it calls for careful consideration of size, angles, and proportions.

Apayao textiles use geometric transformations like translations, rotations, and reflections to produce vibrant and eye-catching designs. The weavers create a sense of movement and rhythm throughout the fabric by applying these modifications to the basic designs. These modifications can be studied by learners to help them comprehend how the textiles' overall aesthetic value is influenced by them.

Through this exposure to weaving, students will not just be more equipped and knowledgeable on the application of these mathematical concepts in the real world, but able to transfer knowledge to other mathematical areas (Vasquez., et. al., 2020). We can encourage a greater understanding of mathematics and culture by developing instructional materials that highlight the mathematical patterns and concepts found in Apayao loom woven fabric. This multidisciplinary method encourages cultural awareness and preservation in addition to allowing learners to study mathematical principles in a practical setting.

In conclusion, the complex connection between mathematics, art, and culture is illustrated by the Apayao weavers' use of mathematical patterns in their loom-woven textiles. They demonstrate their mathematical brilliance and artistic expression using symmetry, tessellation, and geometric transformations. We may encourage learners to explore these mathematical patterns and foster a stronger knowledge and appreciation for the cultural heritage of the Apayao local communities by creating an instructional material exemplar in ethnomathematics.

Conceptual Framework

The framework consisted of two (2) elements that combine to the integration of the Apayao Loom Weaving and Mathematical patterns. Capturing a picture of the textile is the first step as a basis for determining the patterns. The researcher believes that the designs of Apayao Loom Woven are composed of different patterns. Then, the Geometric Concept consists of points, lines, shapes that are commonly found in our surroundings. These concepts are useful in loom weaving to create different designs and patterns. Symmetry Analysis shows different types of symmetry patterns (Line, Mirror, Reflection, Rotational). Its four (4) types make unique, appealing, and meaningful designs. Finally, the research will develop an instructional material to be validated by different experts and integrated to the worktext which is Mathematics in the Modern World.

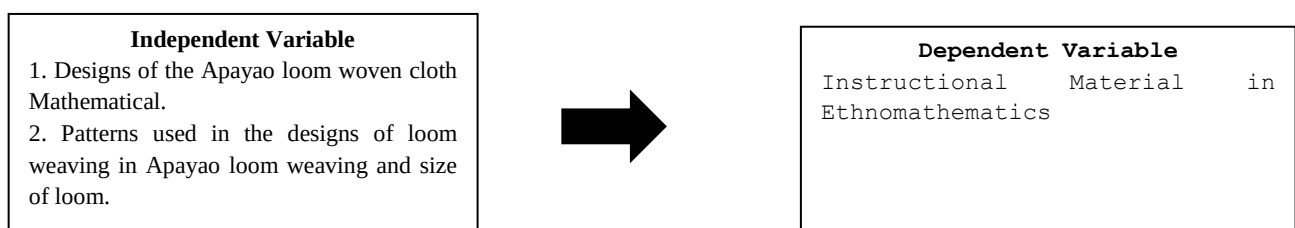


Figure 1. Paradigm of the study that shows the relationship between independent and dependent variables.

Statement of the Problem

This study aimed to determine the design and the mathematical patterns of Apayao loom weaving.

Specifically, it answered the following questions:

1. What are the designs of the Apayao loom woven cloth?
2. What are the mathematical patterns used in the designs of the loom weaving in Apayao?
3. Develop and validated an instructional material to discuss showcasing mathematical patterns on Apayao loom woven cloth in Ethnomathematics.

METHODOLOGY

Research Design

The study used mixed methods particularly Research (R) and Development (D) and descriptive analysis.

The researcher made use of Research (R) and Development (D) by Borg and Gall as cited by Ocampo, et.al (2015) and Irorita and Ocampo (2016), Ocampo et. al (2016) in presenting the different geometric concepts and symmetry present in the weaving design. Also, it presents the different crystallographic patterns present in the woven cloth of Apayao. This research consisted of literature search and studies of experts on Apayao hand woven textiles, and Crystallographic Pattern Analysis of the Loom Woven Clothes of Apayao.

While descriptive survey was adopted to present the validity of the output of the study – Instructional Material.

Locale of the Study

The study on the application of mathematical patterns in the design of Apayao loom woven cloth, as the basis for an instructional material exemplar in ethnomathematics, conducted in the Apayao region of the Philippines. The Apayao region is in the Cordillera Administrative Region in the northern part of Luzon Island. Specifically, Capagaypayan, Luna, Apayao. Its population as determined by the 2020 Census was 615. This represented 2.89% of the total population of Luna. It is also the place where most of the loom woven materials are produced.

The choice of this locale is significant because it is the home of the Apayao local community, renowned for their traditional weaving practices. By focusing on the Apayao region, the study aims to explore the specific cultural and artistic traditions of the Apayao people, including their weaving techniques and the mathematical patterns incorporated into their cloth designs.

Conducting the study in the Apayao region allows researchers to directly interact with the weavers, artisans, and community members who possess invaluable knowledge and expertise in the field of Apayao weaving. By immersing themselves in the local context, researchers can gain a deep understanding of the cultural significance of mathematical patterns in the design process, as well as the historical and social aspects that shape this artistic tradition.

The unique setting of the Apayao region provides an ideal opportunity to examine the intricate relationship between mathematics, culture, and art. It allows for a comprehensive exploration of the ways in which mathematical principles are applied to create visually captivating patterns in Apayao loom woven cloth.

Respondents and Sampling Procedure

The main respondents of this study were the twenty- five (25) professors/teachers from Apayao State College, who validated the developed instructional material in Mathematics in the Modern World. The primary respondents were the skilled weavers of the Apayao indigenous community who possess knowledge and expertise in the traditional weaving practices. These weavers provided insights into the application of mathematical patterns in the design process and share their experiences, techniques, and cultural perspectives related to weaving.

A purposive sampling technique was employed in selecting weavers who have extensive experience and expertise in Apayao weaving. This was done to ensure that the respondents have in-depth knowledge and insights into the application of mathematical patterns in the design of Apayao loom woven cloth.

Local experts, community leaders, or scholars who have specialized knowledge in Apayao weaving and its mathematical aspects may be included as key informants. They can provide additional perspectives and enrich the study through their expertise and insights. Prior to data collection, informed consent will be obtained from all participants, ensuring that they are aware of the purpose, procedures, and potential outcomes of the study. Participants were oriented about their rights to withdraw their participation at any stage without consequences.

The sampling procedure described above ensured that the study includes weavers who possess relevant knowledge and expertise in Apayao weaving and can provide valuable insights into the application of mathematical patterns in the design process. It also considers the ethical considerations of informed consent and respect for the participants' rights throughout the research process and the validated instructional materials exemplar.

Research Instrument

The study used the analysis of the existing findings of related studies and literature. Observation records applied, and pictures of the woven cloth engaged to support the study.

A validation tool (see page 116) given to the team of validators was used in validating the developed instructional material. The tool was adopted from the CID Office of the Division Office of Apayao. The validation was gathered through online platforms using google form.

Data Gathering Procedure

The study on the application of mathematical patterns in the design of Apayao loom woven cloth employed various data gathering methods to gather comprehensive and relevant information. The following data gathering procedures may be utilized:

Semi-structured interviews conducted with the Apayao weavers and key informants. These interviews focused on exploring their knowledge, experiences, and perspectives regarding the application of mathematical patterns in the design process of Apayao loom woven cloth. The interviews were audio-recorded with the participants' consent and transcribed for analysis.

Direct observations of the weaving process conducted to observe and document the practical application of mathematical patterns. Researchers observed the weavers' techniques, the use of tools, the incorporation of mathematical concepts, and the overall design

process. Field notes will be taken during these observations to capture important details.

Existing literature, books, articles, and documents related to Apayao weaving, mathematical patterns, and ethnomathematics reviewed and analyzed. This provided a broader understanding of the historical and cultural context of Apayao weaving and its connection to mathematical patterns.

Photographs and videos were taken to visually capture the different stages of the weaving process, including the use of mathematical patterns in the design. These visual materials helped in illustrating and documenting the unique weaving techniques and patterns employed by the Apayao weavers.

Workshops and FGDs can be organized with the weavers and key informants to foster a collaborative environment for sharing knowledge and insights. These sessions can include hands-on activities, discussions, and feedback on the development of the instructional material exemplar.

The instructional material exemplar developed based on the gathered data validated by experts in the field of Apayao weaving, ethnomathematics, and education. Their feedback and suggestions are incorporated to enhance the quality and effectiveness of the instructional material in Mathematics in the Modern World worktext.

The data gathering procedures mentioned above provided a comprehensive understanding of the application of mathematical patterns in the design of Apayao loom woven cloth. They allowed researchers to gather rich qualitative data from various sources, including interviews, observations, documents, and collaborative sessions, ensuring a holistic approach to data collection.

Analysis of Data

During the research phase of the study, the researcher read extensive literature search from published and unpublished sources bearing information about Apayao woven cloth. Based on the

gathered literature researches, the research problems 1 and 2 were presented based on existing studies.

The validation of the developed instructional material used a 5-point Likert scale as shown below. A mean was used to describe its general validity.

Scale	Ranges	Descriptive Value
5	4.21 – 5.00	Highly Valid
4	3.41 – 4.20	Valid
3	2.61 – 3.40	Moderately Valid
2	1.81 – 2.60	Needs Improvement
1	1.00 – 1.80	Not Valid

RESULTS AND DISCUSSION

This chapter presents the gathered data supported by existing studies on the (1) the designs of the Apayao loom woven cloth, and (2) the mathematical patterns used in the designs of the loom weaving in Apayao. It also presents the developed and validated instructional material in Mathematics in the Modern World.

Designs of the Apayao Loom Woven Cloth

The original Iyapayao fabrics are indigo blue in color. Later developments added more color to the materials, such as darker hues of black, red, and blue. Small stripes are created by weaving these in and out of one other (see textile in first image on the following page). The only items made from these hand-woven materials are the aken (skirt) and abag (G-String). According to Edan and Begay (2011, 8–9), social rank among Iyapayao is not determined by color, but rather by how well-coordinated the outfit is, including the usage of jewelry like earrings and necklaces. The addition of other fashion items, such as necklaces, bracelets, bags, and others, helps to define social class. The younger Iyapayao typically wear brightly colored materials.

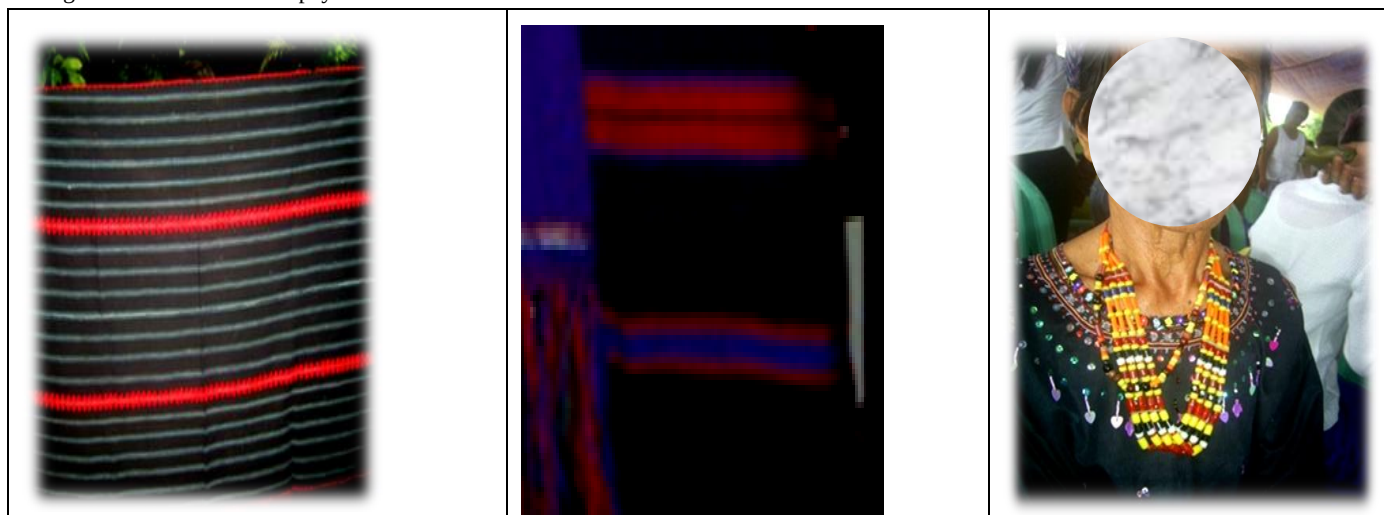


Figure 2. Showing the original hand-woven cloth of the Iyapayao. Dominant colors are white, red, blue, and black.

Embroidered patterns are used to highlight the handwoven fabric, as seen in Figure 2 on the following page. A connected hand with five fingers is depicted in the embroidery. This demonstrates the Iyapayao's work ethic. The Iyapayao people have traditionally used slash-and-burn agriculture using a four- to five-year cyclical fallow system. Additionally, they work in the blacksmithing sector and

engage in basket making, fishing, and hunting. They must put forth a lot of work to maintain this ancient way of life in order to provide food and cash for their families. The interconnection of each embroidered finger represents the Iyapayao's "Ammoyo, Inamoyo, or Tagnawa for building houses" bayanihan system. They constitute a village called Ili and are intimately related to one another.

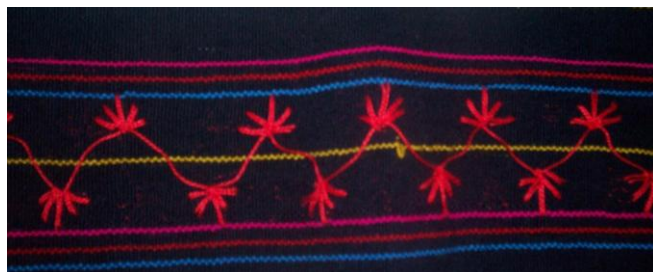


Figure 3. The embroidery symbolizes hand and fingers which depicts the industriousness of the Iyapayao.

Over time, the handwoven fabrics from Apayao have become better. Improvements were made to the Abel (loom weave) Apayao during the administration of the Honorable Betty C. Verzola (Mayor-Luna). There was a noticeable surge of new hues, including violet, white, yellow, and green. To make the materials look more beautiful, some Abel are further enhanced with silver and gold threads.



Figure 4. Some Modifications made to Improve Iyapayao Handwoven Cloth

Mathematical or Geometrical Patterns Used in the Designs of the Loom Weaving in Apayao

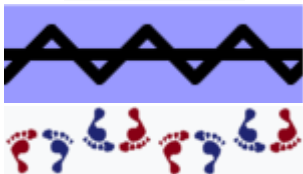
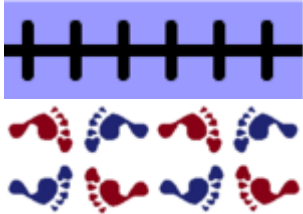
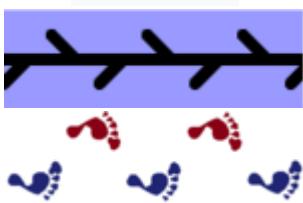
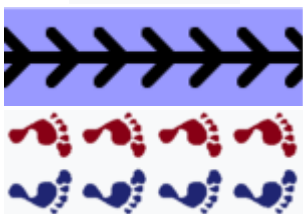
The analysis of the crystallographic pattern in the woven cloth of Apayao utilizes the different crystallographic codes for frieze patterns that was presented by using Hermann–Mauguin notation or International Union of Crystallography notation, nicknames

created by mathematician John H. Conway, and finally a description in terms of translation, reflections, and rotations.

Table 1 shows the different crystallographic frieze patterns, example of Conway nickname (by John H. Conway) and with their corresponding descriptions and originally introduced by Washburn (1988). These are one-dimensional patterns present in the woven cloth which use rotation, reflection, glide reflection, and translation, hence, result in seven crystallographic codes: $p1$, $p1m1$, $p2$, $p2mg$, $p2mm$, $p11g$ and $p11m$.

Table 1. Crystallography codes for Frieze Pattern

IUC (International Union of Crystallography notation)	Example of Conway nickname	Description on the Geometric Pattern
$p1$	FFFFFFFFFF Hop	(T) Translations only: This group is singly generated, by a translation by the smallest distance over which the pattern is periodic.
$p1m1$	ΛΛΛΛΛΛΛΛ side	(TV) Vertical reflection lines and Translations: The group is the same as the non-trivial group in the one-dimensional case; it is generated by a translation and a reflection in the vertical axis.
$p2$	SSSSSSSS	(TR) Translations and 180° Rotations: The group is generated by a translation and a 180° rotation.

	spinning hop	
p2mg	V A V A V A V A  spinning sidle	(TRVG) Vertical reflection lines, Glide reflections, Translations and 180° Rotations: The translations here arise from the glide reflections, so this group is generated by a glide reflection and either a rotation or a vertical reflection.
p2mm	H H H H H H H H  spinning jump	(TRHVG) Horizontal and Vertical reflection lines, Translations and 180° Rotations: This group requires three generators, with one generating set consisting of a translation, the reflection in the horizontal axis and a reflection across a vertical axis.
p11g	F L F L F L F L  step	(TG) Glide-reflections and Translations: This group is singly generated, by a glide reflection, with translations being obtained by combining two glide reflections.
p11m	B B B B B B B B  jump	(THG) Translations, Horizontal reflections, Glide reflections: This group is generated by a translation and the reflection in the horizontal axis. The glide reflection here arises as the composition of translation and horizontal reflection.

Developed Instructional Material

Twenty-five professors were given copies of the developed instructional material. A 5-point Likert scale from “not valid” to “highly valid” was used to rate its (1) Objectives, (2) Content, (3) Format and Language, (4) Presentation, and (5) Usefulness.

Results of the validation shows from table 5 that in general, the instructional material has 4.16 as overall rating which has a verbal description of Valid. The instructional material is Valid along its Objectives, Content, Usefulness with a numerical value of 3.97,4.11,4.09, respectively. Meanwhile, its Format and Language, Presentation with numerical value of 4.47, 4.32, respectively, show that the developed instructional material is Highly Valid.

STATEMENTS	RATING	DESCRIPTIVE VALUE
A. OBJECTIVES		
1. The objectives are clearly stated in behavioral form.	3.55	Valid
2. The objectives are well-planned, formulated, and organized.	4.05	Valid

3. The objectives stated are specific, measurable, and attainable.	4.25	Highly Valid
4. The objectives are relevant to the topics of each lesson of the modules.	3.90	Valid
5. The objectives consider the needs of the students.	4.10	Valid
Composite Mean	3.97	Valid
B. CONTENT		
1. The content is directly relevant to the defined objectives.	3.80	Valid
2. The content is simple and easy to understand.	4.18	Valid
3. The topics are fully discussed.	4.34	Highly Valid
4. The topics are supported by illustrative examples, and the practice tasks are suited to the	3.92	Valid

level of the students.		
5. Each topic is given equal emphasis in the lesson.	4.31	Highly Valid
Composite Mean	4.11	Valid
C. FORMAT AND LANGUAGE		
1. The format/layout is well-organized, which makes the lessons more interesting.	4.86	Highly Valid
2. The language used is easy to understand.	4.22	Highly Valid
3. The language used is clear, concise, and motivating.	4.19	Valid
4. The mathematical symbols used are well-defined.	4.10	Valid
5. The instruction in the instructional material is concise and easy to follow.	4.48	Highly Valid
Composite Mean	4.37	Highly Valid
D. PRESENTATION		
1. The topics are presented in a logical and sequential order.	4.36	Highly Valid
2. The topics are presented in a unique and original form.	4.24	Highly Valid
3. The learning activities are presented clearly.	4.43	Highly Valid
4. The presentation of each lesson is attractive and interesting to the students.	4.07	Valid
5. Adequate examples are given to each topic.	4.58	Highly Valid
Composite Mean	4.32	Highly Valid
E. USEFULNESS		
1. The instructional material will motivate the students to study Mathematics in the Modern World.	4.05	Valid
2. The instructional material will help the students master the topics at their own pace.	4.32	Highly Valid
3. The instructional material will allow the students to use their time more efficiently.	4.16	Valid
4. The instructional material will develop the analytical thinking and reasoning skills of students in solving problems in Mathematics in the Modern World.	3.95	Valid

5. The instructional material will serve as a supplementary material that can cater to the needs of the students.	3.98	Valid
Composite Mean	4.09	Valid
Over-all Mean	4.16	Valid

Rationale of the Developed Instructional Material

As COVID-19 poses challenge especially to education as one of the basic rights, the DepEd developed a Basic Education Learning Continuity Plan (BE-LCP), that responds to basic education challenges. One of its principles is ensure learning continuity through K-12 curriculum adjustments, alignment of learning materials, and deployment of multiple learning delivery modalities (DO no. 18, s. 2020). It is in this scenario where teachers are given the chance to reshape and redesign a new paradigm of learning that help learners develop their competence. Recently, the Department of Education released DepEd Order no. 32 s. 2020 which aims to guide teachers in creative and innovative ways of designing Optimal Learning Experiences and assessing learning progress under adverse circumstances.

In an attempt to offer excellence in teaching to the greatest number of students, many innovative teaching tools have been developed over the past three decades. Instructional material is one of the solutions employed by the Department of Education to enhance academic achievements of students. DepEd Memo No. 117, series of 2005 entitled —Training Workshop on Strategic Intervention Materials (SIMs) for Successful Learning provided teachers the training in the preparation of IMs. Therefore, teacher's initiative in crafting and utilizing instructional materials bridges these gaps towards the achievement of the educational goals: learning the concepts and mastering the skills.

The proponent designed an Instructional Material on the topic Designs and Mathematical Patterns of the Apayao loom woven cloth which is considered one of the learning competencies in Mathematics in the Modern World.

Therefore, this instructional material aims to primarily to enhance the knowledge and skills of students in the said competency in weaving cloth patterned with Apayao loom woven cloth.

The instructional material on the next page details the content, competencies, discussion, and activities.

Objectives:

1. To enhance the knowledge of students with the designs and geometrical patterns of Apayao loom woven cloth which is one of the competencies in Mathematics in the Modern World,
2. To enhance the creativity and skills of the students in weaving cloth or decorations, and
3. To provide independent learning opportunities to students.

MATHEMATICS IN THE MODERN WORLD

FOREWORD

Mathematics in the Modern World is a general education course that deals with the nature of mathematics. It is concerned with the admiration of mathematical instruments in their practical, intellectual, artistic, and practical applications in daily life. Its major goal is to teach and, in a secondary role, to train students in this field. On the educational front, it strives to provide students with the required intelligence to become leaders and contributors to the nation-building process. On the training side, it equips students with the required and adequate abilities to face the problems of daily life.

This study resource cover both the nature of mathematics and its application in the modern world, as led by CHED CMO No. 20, series of 2013. Learning activities are given in accordance with the Commission on Higher Education and the Institution's learning plans.

This material is about Geometric Designs. Almost everything in our environment contains form, line, volume, surface area, curve, and other geometric features. The way we live has been impacted by geometry. Toys with forms, patterns, and designs piqued our curiosity as children. We follow geometric concepts in all we do on a daily basis. Construction, weaving and sewing, computer imaging, art and aesthetics, and architectural design are all industries that employ geometry as a tool to accomplish their work properly.

Prepared by:

XERNICK M. FELIPE

This material was designed specially to help you develop your skills weaving and designing a cloth patterned with the Apayao loom woven cloth. As you work on the activities, you will be able to learn how to make a design of a woven cloth, weave on a cardboard loom, and create and promote your own bracelet that have designs and patterns of an Apayao loom woven cloth; thereby, improving your skills with this topic.

GEOMETRIC DESIGNS

GEOMETRIC DESIGNS



Hello! I am Teacher Xern. I will guide you on this journey. All you need to do is relax and enjoy.

Your Task...

1. Ready and study the lesson.
2. Do and perform all the activities. Should you still have questions/clarifications in doing the activities, seek the assistance of your subject teacher or peers.
3. Complete all the activities and note if you have learned something.
4. Promote your own output from the activity by posting it online and let other know your design.



Most Essential Learning Competencies

Content Standard

- Designs, Recognizing and analyzing geometric shapes
- Transformations
- Patterns and diagrams
- Designs, Arts & Culture



Core Idea

Almost everything in our environment contains form, line, volume, surface area, curve, and other geometric features. The way we live has been impacted by geometry. Toys with forms, patterns, and designs piqued our curiosity as children. We follow geometric concepts in all we do on a daily basis.



Learning Competency

Apply geometric concept, especially isometries in describing and creating designs; and
Contribute to the enrichment of the Filipino culture and arts using concepts in geometry

Geometric Patterns

- Depicts abstract shapes, like lines, polygons and circles
- Are observed in nature and in arts
- Nice took at because of SYMMETRY

Recognizing and Analyzing Geometric Shapes

- A Geometric Shape is defined as geometric information that still there even if scale, orientation, location and reflection are displaced from a particular geometrical object. We can say that if we move the shape, enlarge it, reflect it or rotate it, then also the shape remains the same, i.e., it does not change into another.

A **Pattern has Symmetry** if there is an **ISOMETRY** of the plane that preserves the pattern

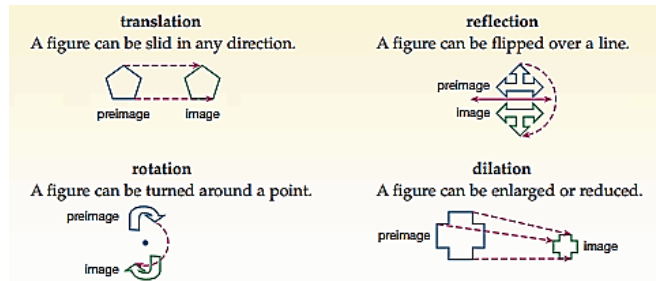
An **ISOMETRY** of the plane is a linear transformation which preserves length.

Most of the three-dimensional geometric shapes are represented by the lines joining a set of points as well as two dimensional surfaces containing those lines. For example- **cubes, cuboids, pyramids**, etc.

Few three-dimensional shapes are formed by bounded curved surfaces, such as **sphere** and **ellipsoid**.

Transformations

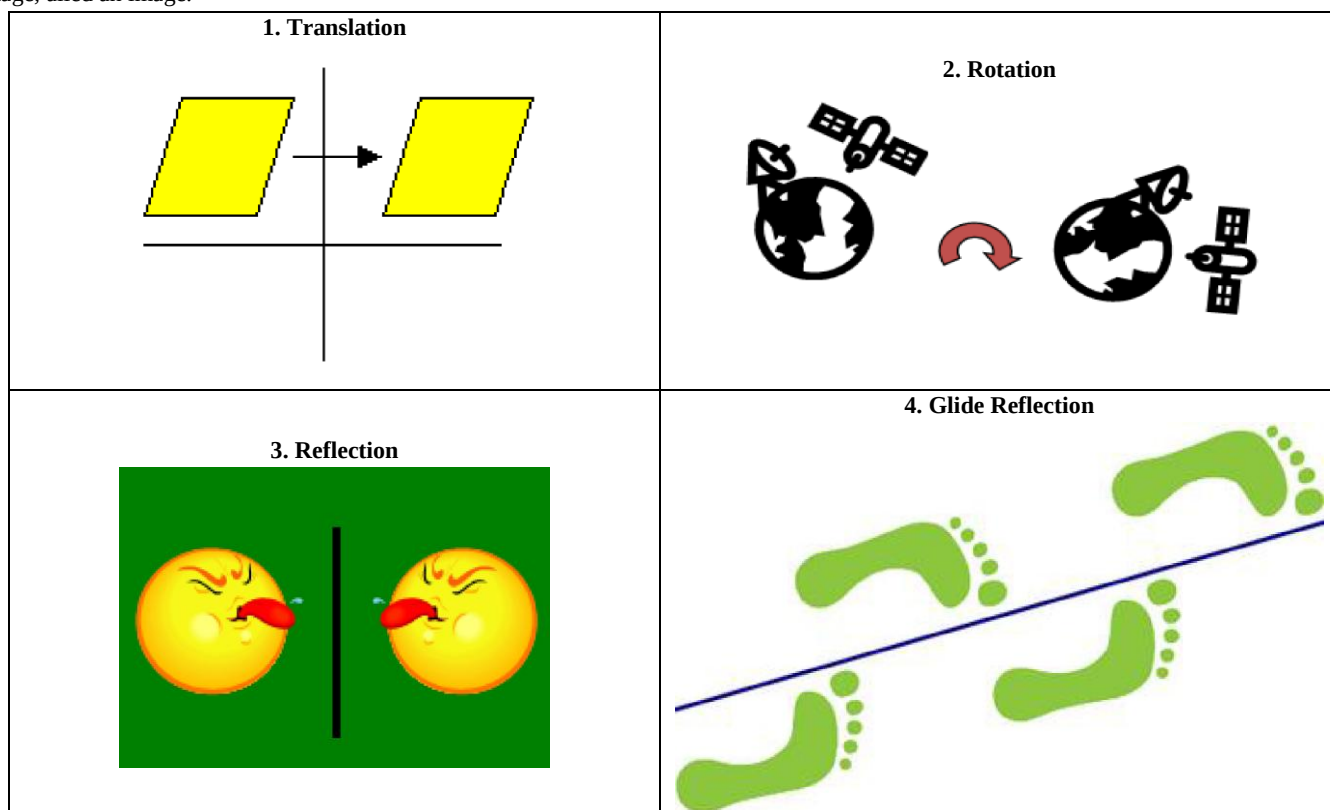
Transformation maps an initial image, called preimage, onto a final image, called an image.



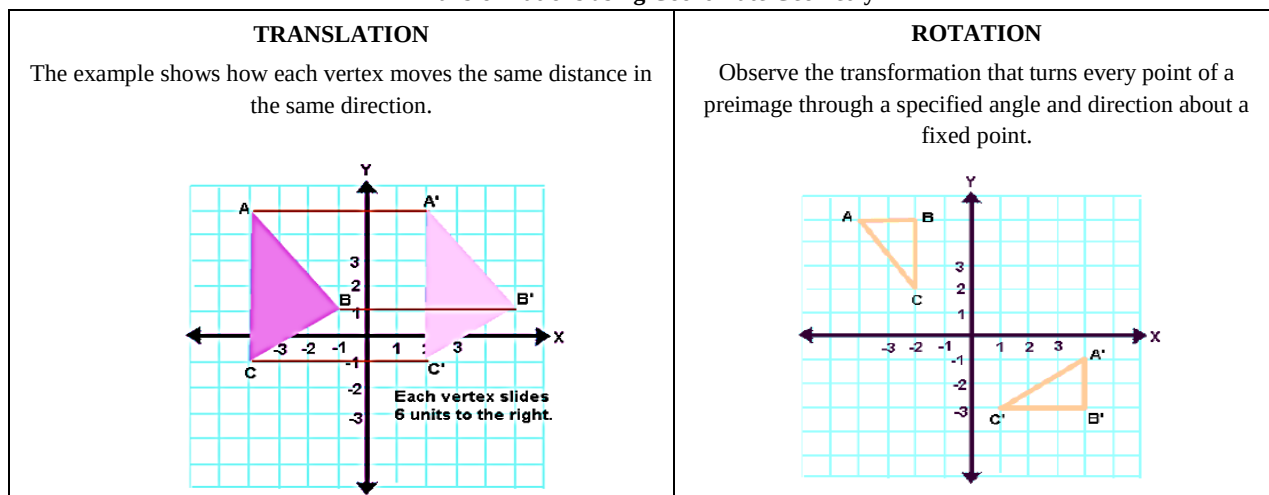
Isometry

- It is a transformation in which the resulting image is congruent to the pre-image. It is called as **RIGID TRANSFORMATION**

Four Types of Rigid Transformation

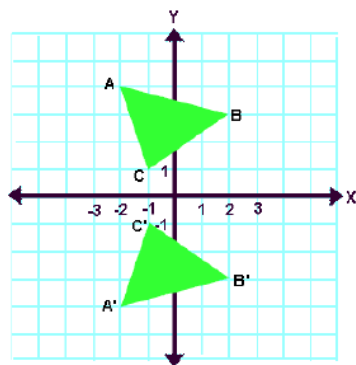


Transformations using Coordinate Geometry



REFLECTION

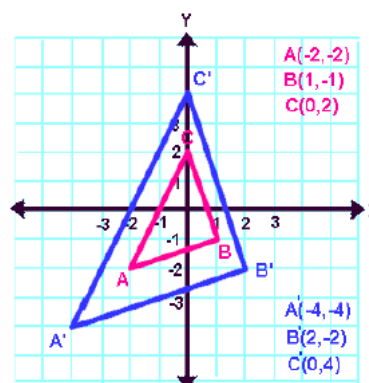
The example shows that reflection along the x-axis change the



sign of the y-coordinate.

DILATION

Notice how every coordinate of the original triangle has been multiplied by the scale factor x^2 .



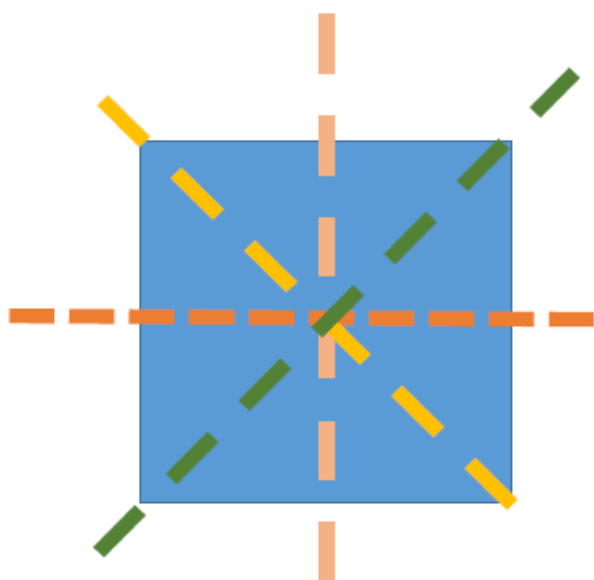
Patterns and Diagrams

A pattern is said to be a design having a certain discriminant regularity. A pattern that is drawn using geometric shapes which are typically repeating.

A wallpaper is an ideal example of geometrical pattern. These patterns are commonly seen in art as well as in nature. Natural geometrical patterns may include waves, cracks, spirals, foams, etc. Actually, there is a mathematical structure underlying in each geometrical pattern.

Symmetry Patterns

Note: a plane figure has symmetry if there is a non-trivial transformation that maps the figure onto itself. A trivial transformation refers to the identity transformation.



Types of Symmetry:

1. Line symmetry/ mirror symmetry/ reflection symmetry
2. Rotational Symmetry.
1. Line Symmetry/ Mirror Symmetry/ Reflection Symmetry
 - An object is reflected across a line, like looking in a mirror.
 - A square has four-line symmetries.
2. Rotational symmetry

- Occurs when a figure is rotated less than 360° about a point so that the image and the pre-image are indistinguishable.
- A square has 4 rotational symmetries:
 $0^\circ, 90^\circ, 180^\circ, 270^\circ$

Frieze Patterns

- It is an infinitely long strip imprinted with a design given by a repeating motif.

Note: Each frieze pattern is symmetric under a translation in the direction of the strip.

A frieze pattern may also be symmetric:

- a) About a horizontal reflection (H)
- b) About a vertical reflection (V)
- c) A rotation (R) of 180° about some point
- d) A glide reflection (G)

Or a combination of the above transformations.

7 Frieze Symmetry Types

Symmetry Type	Figure	IUC
T		p111
TV		pm11
TG		p1a1
TR		p112
THG		p1m1
TVRG		pma2
TVHRG		pmm2

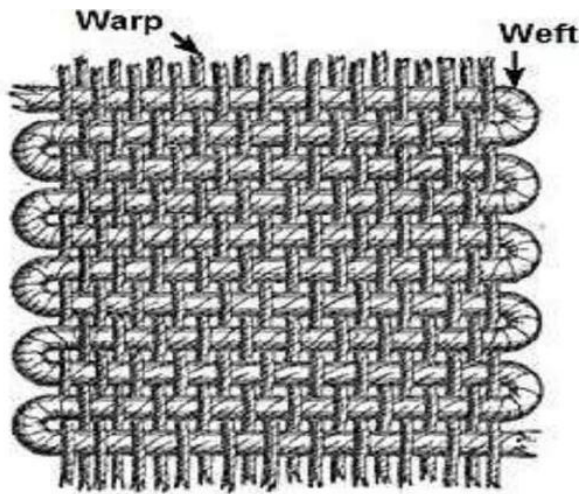
International Union of Crystallography

Observe that all the seven types begin with p. P represents translation. As we have noted before, each frieze pattern consists of translation.

The remaining 3 characters are as follows:

- m if there is vertical reflection, 1 if none
- n if there is a horizontal reflection; a if there is glide reflection, 1 if none
- 2 if there is a 180° rotation, 1 if none

DESIGNS AND GEOMETRIC PATTERNS ON THE APAYAO LOOM WOVEN CLOTH



Weaving

Weaving is a method of fabric production in which two distinct sets of yarns or threads are interlaced at right angles to form a fabric or cloth.

Weaving is done by intersecting the longitudinal threads, the warp, with the transverse threads, the weft.

Warp- longitudinal threads,

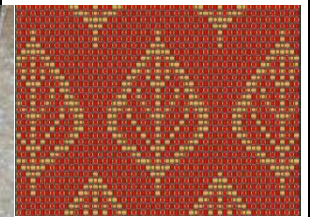
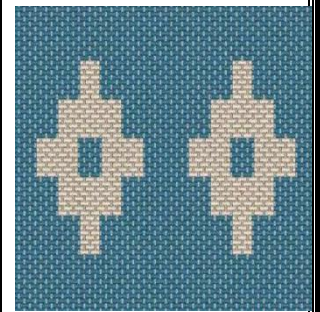
Weft- transverse threads

The **weft** is threaded through the warp using a “shuttle”,



Shuttle, in the weaving of cloth a spindle-shaped device used to carry the crosswise threads (weft) through the lengthwise threads (warp).

Designs and Patterns



Loom

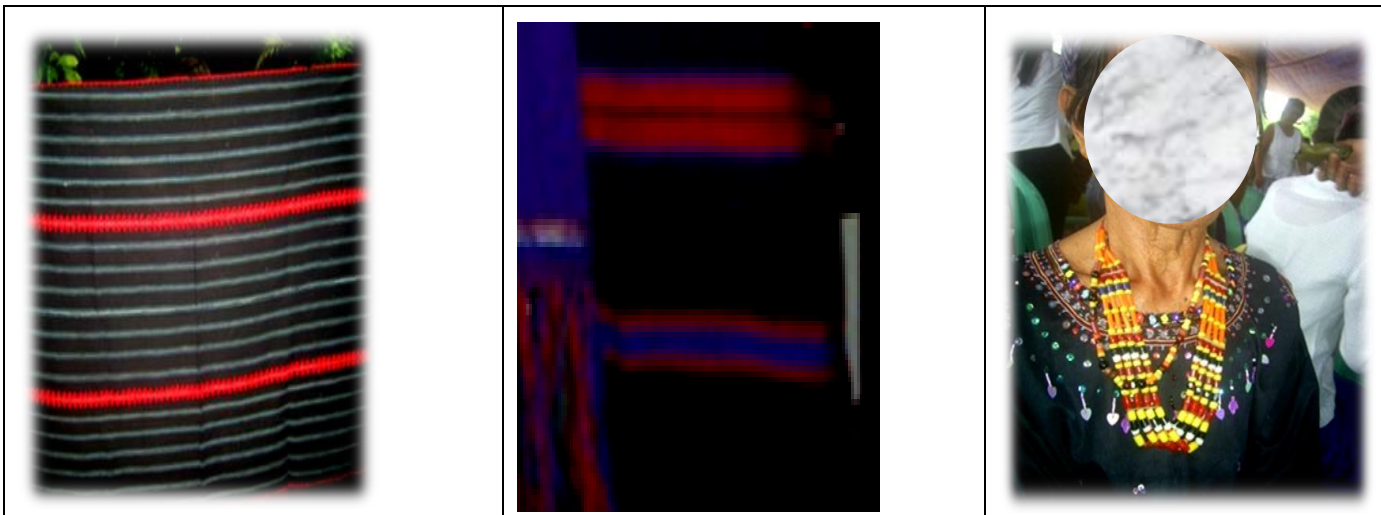
A Loom is a device used to weave cloth.

The basic purpose of any loom is to hold the warp threads under tension to facilitate the interweaving of the weft threads.

The word “loom” is derived from the Old English “geloma” formed from ge- (perfective prefix) and loma, a root of unknown origin; this meant untensil or tool of any kind.

Apayao Woven Textiles

The color of the original Iyapayao fabrics is indigo blue. Later development includes additional color in the fabrics such as other shades of **blue, black and red**. These are woven alternately to form small stripes. These handwoven textiles are used only for aken (skirt) and abag (G- String). According to Edan and Begay (2011), there is no color distinction to show social status among Iyapayao but this depends on the completeness of the attire to include the use of accessories such as earrings, necklaces and others. Social status is distinguished through the addition of other fashion accessories such as necklaces, bracelet, bags and others. Bright colored fabrics are usually worn by younger Iyapayao.



The original hand woven textiles of the Iyapayao. Dominant colors are white, red, blue and black.

The handwoven textile is accentuated with embroidered designs as shown in the photograph on the next page. The embroidery symbolizes a connected hand with 5 fingers. This depicts the industriousness of the Iyapayao. Traditionally, Iyapayaos engaged in slash and burn agricultural system with 4 to 5 years rotational fallow system. They are also engaged in blacksmithing industry, basket weaving, fishing and hunting. This traditional livelihood requires intensive labor for them to produce food and income for their families. The interconnectedness of each embroidered fingers symbolizes the bayanihan system of the Iyapayao which is called “Ammoyo, Inamoyo, or Tagnawa for building houses. They are closely connected with each other and form themselves into village or Ili.



The embroidery symbolizes hand and fingers which depicts the industriousness of the Iyapayao.

Improvements in Apayao hand woven textiles came over time. During the time of Honorable Betty C. Verzola (Mayor-Luna), there were improvements of the *abel* (loom weave) Apayao. The influx of additional colors such as violet, white, yellow, green and others were observed. Some *abel* are also accentuated with silver and gold threads to make the fabrics more appealing.



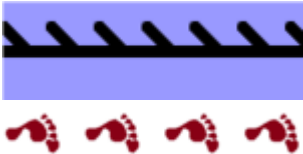
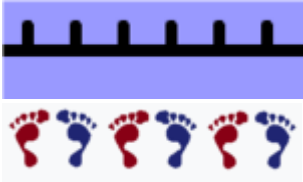
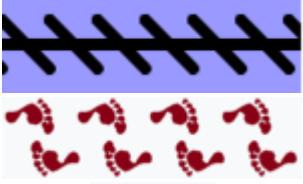
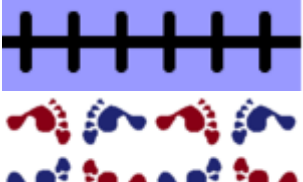
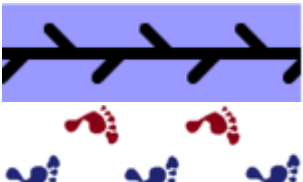
Some modifications made to improve Iyapayao handwoven textiles

Mathematical or Geometrical Patterns Used in the Designs of the Loom Weaving in Apayao

The analyzation of the crystallographic pattern in the woven cloth of Apayao utilizes the different crystallographic codes for frieze patterns that was presented by using Hermann–Mauguin notation or International Union of Crystallography (IUC) notation,

nicknames created by mathematician John H. Conway, and finally a description in terms of translation, reflections, and rotations.

The analyzation of the crystallographic pattern in the woven cloth of Apayao utilizes the different crystallographic codes for frieze patterns that was presented by using Hermann–Mauguin notation or International Union of Crystallography (IUC) notation, nicknames created by mathematician John H. Conway, and finally a description in terms of translation, reflections, and rotations.

IUC Notation	Example of Conway nickname	Geometrical Pattern Description
p1	F F F F F F F F  Hop	(T) Translations only: This group is singly generated, by a translation by the smallest distance over which the pattern is periodic.
p1m1	Λ Λ Λ Λ Λ Λ Λ Λ  sidle	(TV) Vertical reflection lines and Translations: The group is the same as the non-trivial group in the one-dimensional case; it is generated by a translation and a reflection in the vertical axis.
p2	S S S S S S S S  spinning hop	(TR) Translations and 180° Rotations: The group is generated by a translation and a 180° rotation.
p2mg	V Λ V Λ V Λ V Λ  spinning sidle	(TRVG) Vertical reflection lines, Glide reflections, Translations and 180° Rotations: The translations here arise from the glide reflections, so this group is generated by a glide reflection and either a rotation or a vertical reflection.
p2mm	H H H H H H H H  spinning jump	(TRHVG) Horizontal and Vertical reflection lines, Translations and 180° Rotations: This group requires three generators, with one generating set consisting of a translation, the reflection in the horizontal axis and a reflection across a vertical axis.
p11g	Γ L Γ L Γ L Γ L  step	(TG) Glide-reflections and Translations: This group is singly generated, by a glide reflection, with translations being obtained by combining two glide reflections.
p11m	B B B B B B B B  jump	(THG) Translations, Horizontal reflections, Glide reflections: This group is generated by a translation and the reflection in the horizontal axis. The glide reflection here arises as the composition of translation and horizontal reflection.

Activity 1. MAKE YOUR OWN DESIGN AND PATTERN

How many colors are you going to use in your pattern?

Choose between 2 and 5 colors Circle one: 2 3 4 5

Are you going to vary the thickness of your stripes?

Circle one: **Yes** (some thick and some thin) **No** (the thickness is the same)

See examples below to understand what this means:

Things to think about before drawing out your pattern: How many rows each stripe will have? The minimum is two rows (two passes back and forth, across

Your Pattern Design



(Draw your pattern here based on your answers to the questions above)

Activity 2. HOW TO WEAVE ON A CARDBOARD LOOM?



Weaving on a cardboard loom is really fun and super easy to do.

Step 1: What you'll need:



- Yarn
- Scissors

- Large plastic or metal needles
- Cardboard
- A ruler

The yarn, scissors and needles can be changed as necessary to suit the age of the person you're going to be doing the weaving with.

Step 2: Make your loom

You can really make this any size you want! With this project, I figured I'd make a coaster size weaving. I'm using a piece of cardboard 5x5 inches.

Draw a line 1/2 inch in on every side of the loom. These will be your guides and will make holding it a little easier.

Now, you'll draw the lines for the notches! In most cases you want these to be 1/4 inch apart. However, you can make them as big as you want. The wider they are the easier the weaving will be. :)

Start at the 1/2 inch line and make marks every 1/4 inch (or your chosen width) all the way across the top and the bottom of the loom.

Cut on the marks, stopping at the 1/2 line you've drawn.



Step 4: Weaving!

Now for the fun part!

Cut a length of yarn (shorter is easier to work with at first - no more than 2 feet) and thread the yarn through the needle. I like to make a knot so that it stays in the needle- it has a tendency to fall out if you don't.

You'll be using the needle to guide the yarn through the loom in an under-over pattern. (Under the first string, over the second, under the next, etc.) Once the needle has

passed through all of the strings, pull the yarn through and leave a tail of a few inches at the end. Push the yarn up on the loom so that it's about 1/4 inch away from the notches.

Bring the needle and yarn back through the loom from the side you just exited using an over-under pattern that's the opposite of your first line and pull the yarn through. (If your first line of yarn goes under the last string to the right, it needs to go over the last string to begin the second row.) Just don't pull too hard on the yarn - you don't want to warp the strings on the loom!



Push the second line of yarn up to meet the first.

Step 5: Continue + introducing new yarn once you run out

Continue each row, alternating the over-under pattern, making sure not to pull the yarn too tight.



Every few rows, it's a good idea to use your thumbs to push the yarn up the strings so that it looks nice and uniform.

When you get to the end of a color, take it to one edge of the loom and leave a tail of a few inches hanging off to the side. You can either cut a length of yarn that is the same color or introduce a new color.

Take your new length of yarn, and insert it into the same side where your ending tail is. You'll be following the same over-under rules as before. So if the tail of the yarn ended going under the last string, you'll start your new yarn going over it. Pull your yarn through and make sure to leave a tail at the end.

Continue weaving as usual. :)

I've included a few photos of introducing the new lengths of yarn - I think they explain it better than words!



Step 6: General weaving tips

They are five major things you can do to make weaving a bit easier:



Step 7: Tucking in all the loose ends

So, you've filled up your loom, but now you've got lots of crazy yarn ends everywhere. We're going to use the needle to tuck these ends down into the sides of the weaving.

The pictures illustrate this very well, but here's a breakdown of how it works:

1. Thread the end of the yarn through the needle.
2. Insert the needle into the side of the weaving, on the outside edge of the string.
3. Pull the needle through the edge of the weaving
4. Pull the yarn through, pull it tight, and cut off the end.
5. Use your fingers to rub the edges of the weaving and make things look nice and neat.

Try to pull the ends of yarn through weaving of the same color. It'll help disguise the ends.



Step 8: Taking it off the loom.

Remove the tape from the long strings on the back of the loom. Release the top loops first, and then the bottom. Hold the weaving near the top, and pull up on the top loops.

You want to pull the string through the weaving, so that the bottom loops are brought up to be flush with the bottom of the weaving, and the top loops gain extra length.

Once the weaving is scooted down to the very bottom of the strings, you can cut the top loops in the middle and tie those off.



Step 9: Finishing it up!

After tying off the loops, you'll still have two long strings to take care of. We're going to deal with them like we did with the loose ends in step seven.

The only difference here is that you will want to bring the string over the first row of the weaving and then push it through the side. By looping it over the top row of the weaving, you keep the string from getting pulled completely out of the weaving. You kind of have to anchor it in there.

And now you're done! Enjoy your coaster, placemat, loincloth, pin cushion or other completely awesome thing you've just woven.



Enrichment Activity: PROMOTE ME!



Braided bracelets are a fantastic way to upgrade your outfit. They are fashionable and stylish, enjoyable to make, and simple. Once you have a basic understanding of how to make braided bracelets, you may experiment by adding charms and beads or using various lengths of

string.

Below are some of the developed accessories/bracelets patterned with the Loom Woven Cloth of Apayao by DJ. Fronda (2019). Four of these are cut from blue striped Apayao hand woven textiles and the other two are brick red. These are accentuated with wooden beads and coconut shell.

Item	Description
 Design 1	Blue wrist band in combination with yellow, green and red stripes are accentuated with round coconut shell to emphasize its native look. Round and oblong wooden beads are also used as accents.
 Design 2	Brick red Apayao fabrics is made into wristband heightened with round and oblong shape wooden beads of red and mahogany color.
 Design 3	Brick red Apayao fabrics wrist band is heightened with round and oblong shape wooden textiles of red, blue, yellow colors arranged carefully in laddered form.



Design 4

Blue striped with red and green Apayao fabrics is accentuated with yellow and brown oblong and round wooden beads to form flowers.



Design 5

Blue and yellow striped Apayao fabrics is accentuated with small wooden flower beads aligned at the center of the fabrics.



Design 6

Simple design of wooden beads aligned at the center of the blue dominated Apayao fabrics

Now, it's your turn to be creative in creating your own bracelet.

Create your own stylish Braided Bracelets (you can have two or more bracelets), post it in your social media account (Facebook) and tag (Fb account: Xernick M. Felipe), put a caption to promote your product and use the hashtag #MMWBraidedBracelets. Below is the rubrics in assessing your output. Should you want to have a basis, refer to the sample procedures on the next page.

Rubrics:

	No evidence (1 pts)	Some Evidence (2 pts)	Making Progress (3 pts)	Meets Expectations (4 pts)	Exceeds Expectations (5 pts)
Instruction & Concepts Level of understanding about instructions and concepts (elements and principles of art) used in project.	No Evidence The artwork shows no understanding of the concepts and instructions.	Some Evidence The artwork shows little evidence of understanding the concepts and instructions.	Making Progress The art work is planned adequately; understanding of some concepts and instructions demonstrated.	Meets Expectations The artwork is planned carefully; understanding of most concepts and instructions is demonstrated.	Exceeds Expectations The artwork is planned carefully; understanding of all concepts and instructions is clearly demonstrated.
Craftsmanship/ Skill The control, selection of colour and design.	No Evidence The artwork shows very minimal art making skills and no attention to control, selection and experimentation of medium/media.	Some Evidence The artwork shows minimal art making skills and little attention to control, selection and experimentation of medium/media.	Making Progress The artwork shows average art making skills and average attention to control, selection and experimentation of medium/media.	Meets Expectations The artwork shows good art making skills with some attention to control, selection and experimentation of medium/media.	Exceeds Expectations The artwork shows outstanding art making skills, with clear attention to control, selection and experimentation of medium/media.
Social Media Reaction	50-and below reactors	51-70 reactors	71-90 reactors	91-110 reactors	111 and above reactors

How to weave a bracelet for beginners

In this, you can learn step by step how to weave a bracelet on one of our looms. We share a list of supplies needed for weaving, and specific tips and tricks for making a friendship bracelet.

Which materials do you need to weave a bracelet?

1. Weaving starter kit

You can use any size weaving loom from our collection for a bracelet. You can already make a fitting bracelet on a 20 cm loom.

If you purchase a weaving starter kit you directly get a set including weaving comb, weaving needles and warp thread.

2. Yarn

You can use any yarn that you like, but we recommend to choose one that won't be itchy. The Gordita and Lanita wool is nice and soft and great if you like a matte finish. If you prefer shiny, choose for some Perle no5 embroidery thread.

3. Scissors

A pair of embroidery scissors is always handy for cutting your yarn.

4. Measuring tape

You'll need a measuring tape to measure how long your bracelet should be to fit.

5. Tape or clamps

Once you finish weaving, a piece of tape or clamps are handy while braiding the ends.

Warp your loom

Warp your loom with a double thread. warp as wide as you want your bracelet to be.

When you're making a bracelet from wool or other stretching yarn, use cotton warp thread to warp your loom. With a non-stretching warp your final piece will be nicer.

How long should your weaving project be?

Wrap a measuring tape around your wrist where you'd like to wear the bracelet once it's finished. Measure the circumference. In my case that's almost 17 cm (~7 inch).

Deduct 2,5-5 cm (1-2 inch) from the circumference to keep space for opening and closing your bracelet. In my case that's 17 cm minus 4 cm = 13 cm. That's how you calculate the length you will weave your bracelet.

How to weave a bracelet step by step

Start with a row of knots

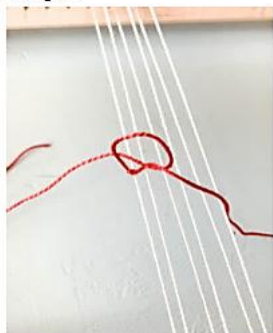
To ensure our edge stays in place, we will start with a row of knots.

Step 1



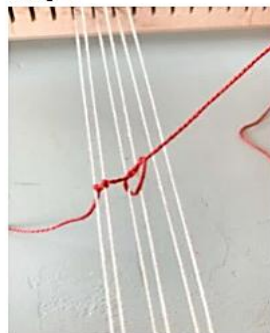
Start on one of the edges and make a simple knot around the warp thread. Pull taught.

Step 2



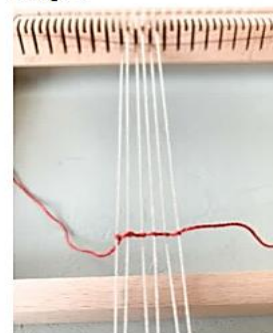
Continue to the next warp thread.

Step 3



Pull each knot tight.

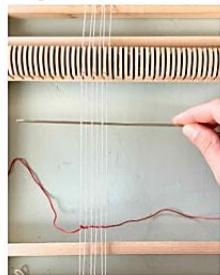
Step 4



Continue until you have made a knot around every warp thread.

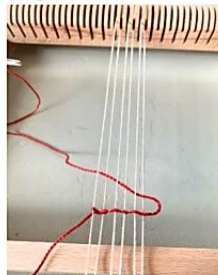
How to make a basic weave

Step 1



Use a weaving needle and go through the warp threads. Repeat: under one thread, over one thread. When you use a heddle bar you can use the bar to move half of

Step 2



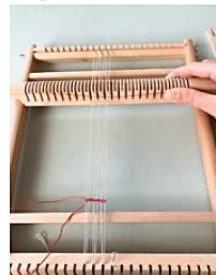
This is how you'll make your first row.

Step 3



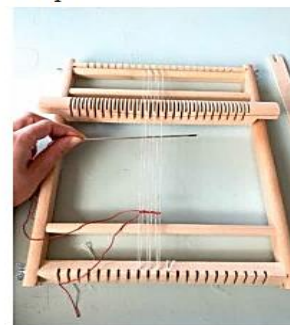
Use a weaving comb to move your woven row down.

Step 4



Turn the heddle bar to make the other half of your warp threads go up.

Step 5



Continue until you're almost finished with your thread.

The following steps explain how to weave using a heddle bar.

If you're almost finished with a thread

To keep your edges nice, it's better to ensure your thread tail does not end at the edge of your weaving project. But you also want to keep neat rows.

Step 1



When you're almost finished with a thread use the weaving needle. At the end of the row, go under two warp threads and finish going over the last warp thread.

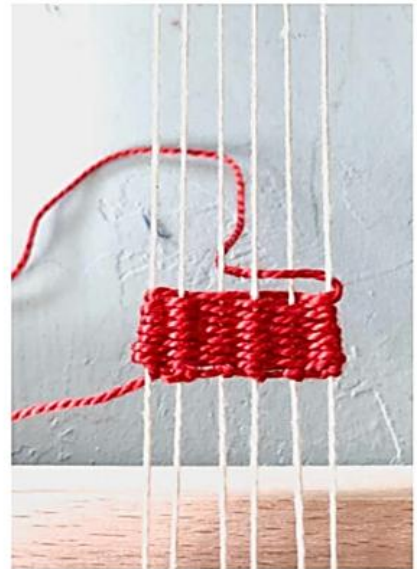
In the next steps we explain how to ensure your thread ends in the middle.

Step 2



Now go back and go under the first warp thread, over the second and under the rest of the row.

Step 3



From the front it now looks the same as a normal row, but your thread ends in the middle of a row.

How to start a new color

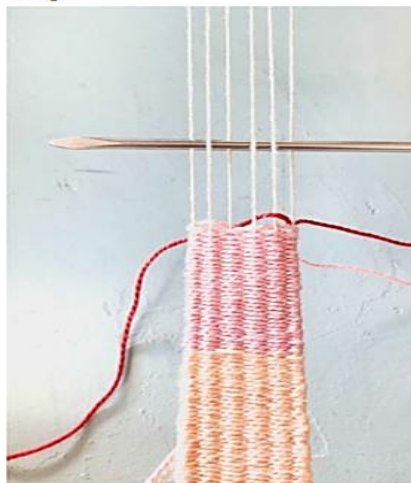
At the start of a new color, we also like to prevent that our tail stays at one of the edges. The following steps explain how to do that.

Step 1



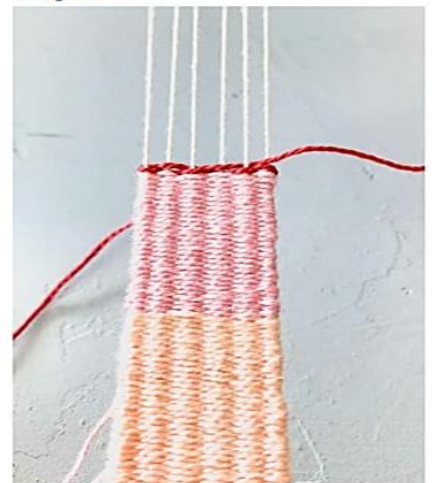
Take your weaving needle and go from left to right. Go under all warp threads until you reach the second last of the row. Go over the second last warp thread, and under the last warp thread.

Step 2



Go back from right to left. Go over the first warp thread, under the next two warp threads, and then under and over the next warp threads.

Step 3



Use a comb to move your woven rows down. It will look like pictured.

Now continue weaving as explained earlier.

Finish with a row of knots

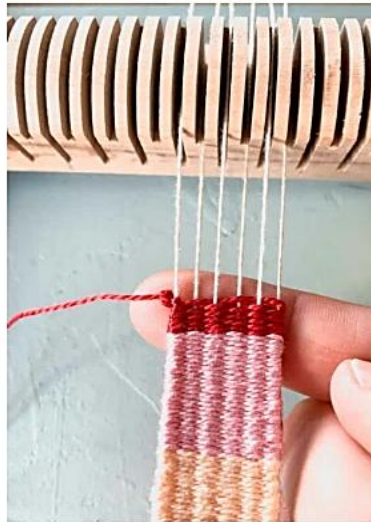
Once in a while measure the length of your weaving project. Once you have the desired length, we will finish the piece with a row of knots.

Step 1



Start making a knot around the warp thread where you finished your last row.

Step 2



Continue to the next warp thread.

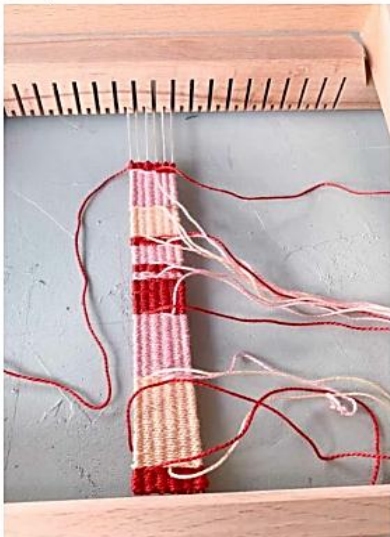
Step 3



Continue making knots until you finished the row.

How to weave in the thread ends of your bracelet

Step 1



Once you finish weaving turn your weaving loom upside down.

Step 2



As you will wear this piece, we will burry the tails diagonally under 3 stitches.

Step 3



Cut off close to the weaving project.

How to take your finished bracelet weaving from the loom and finish the ends

It's finally time to take your weaving project from the loom.

Step 5



Divide the warp threads in sets of two threads. Double knot each set close to the edge of your weaving project.

Step 6



Tape on end of your warp threads to the table with some paper tape (painter's tape). Or clip one end to a clipboard.

Step 7



Braid the warp threads.

Step 8.



Braid as far as possible and then make a knot. Cut off any excess thread. Now braid the other end of your bracelet.

Step 9.



Voilà your project is finished!

SUMMARY, CONCLUSIONS AND RECOMMENDATIONS

Summary

This study presented the gathered data supported by existing studies on the (1) the designs of the Apayao loom woven cloth, and (2) the mathematical or geometrical patterns used in the designs of the loom weaving in Apayao. It also presented the developed and validated instructional material.

The first problem in this study dealt on the designs of the Apayao loom woven cloth. Based on the gathered information and data from the existing related studies, the original hand-woven cloth of the Iyapayao. Dominant colors are white, red, blue and black.

The handwoven cloth of the Apayao is accentuated with embroidered designs with dominant colors of white, red, blue, and black. The embroidery symbolizes a connected hand with 5 fingers. There were improvements of the *abel* (loom weave) Apayao. The influx of additional colors such as violet, white, yellow, green and others were observed.

The second problem in this study dealt on the mathematical or geometrical patterns used in the designs of the loom weaving in Apayao. Based on the gathered information and from existing related studies, the crystallographic pattern in the woven cloth of Apayao utilizes the different crystallographic codes for frieze patterns that was presented by using Hermann–Mauguin notation or International Union of Crystallography notation. These are one-dimensional patterns present in the woven cloth which use rotation, reflection, glide reflection, and translation, hence, result in seven crystallographic codes: $p1$, $p1m1$, $p2$, $p2mg$, $p2mm$, $p11g$ and $p11m$.

Moreover, the third problem in this study dealt on the validity of the developed instructional material that integrates the concepts of mathematical patterns on Apayao loom woven cloth. The instructional material has 4.18 as overall rating which has a verbal description of Valid.

Conclusions

The use of mathematical patterns in the weaving of Apayao cloth demonstrates how mathematics and culture are intertwined. We can give every student a more thorough and culturally sensitive mathematics education by embracing ethnomathematics and incorporating local knowledge.

Recommendations

Based on the research conducted on the application of mathematical patterns in the design of Apayao loom woven cloth and its potential as an instructional material exemplar in ethnomathematics, the following recommendations are proposed:

1. The integration into Mathematics Curriculum: Education officials and curriculum creators should think about including ethnomathematics—more especially, the study of mathematical patterns in local weaving traditions—into the mathematics curriculum.
2. The Teacher Training and Professional Development: To improve their knowledge of ethnomathematics and its applications, teachers should be given proper training and professional development opportunities.

3. Collaboration with Local Communities: It is crucial to cooperate and form alliances with the locals of Apayao and other areas that still use traditional weaving techniques. Through this, it is made possible to portray the cultural context, viewpoints, and values of the community authentically in research and educational materials, building respect and appreciation among participants.
4. The importance of ethnomathematics and the use of mathematical patterns in local weaving traditions should be brought to the attention of educators, students, and the public. Conferences, exhibitions, publications, and internet platforms can be used to disseminate information, allowing for a larger understanding and awareness of the relevant mathematical and cultural issues.
5. A final suggestion for further research would be an exploration of effectiveness of the validated instructional material.

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