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Research Article

Cultural Statistics: Behind The Weaving Designs of T'nalak Tapestry

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ABSTRACT

This research describes the multidisciplinary approach in between culture and mathematics/ science concepts, bounded with the different ethno modelling approaches. Like ethno modelling in math-ethno mathematics and physics-ethno physics The static value of the every IPs crafts man, evolve the statistical geometric patterns like the crystallize and geometric weaving designs, volume, areas and its skeletal designs most particularly in the geometric designs of some *T'nalak* handloom tapestry. When the artistic mind works, dynamism of neurons particles create a weaving designs and patterns with frequencies of wavelength that pointing in a symmetrical and elliptical rays of designs down to his affective and psychomotor of every *T'nalak* weavers, that's include that application of cultural statistics. The cultural statistics based on the image processing analysis based on amplitude, wavelength and string theory in perfections of the unique designs of *T'nalak* weaving patterns.

Keywords: *Artificial Intelligence (AI)-generated data, Cultural heritage, Cultural research, Cultural statistics,*

Introduction

The author's main perspective in this ethno research is based on the ethno modelling which bounded by different ethno mathematicians conceptual framework. According to Orey & Rosa (2023) that mathematical activities from outside of the school environment, the process of modelling shows us that mathematics is more than the manipulation of mathematical symbols, procedures, and practices. Further they emphasized that the application of ethnomathematical techniques along with the tools of modelling allows us to see a holistic reality to mathematics. From this perspective, one pedagogical approach that connects the cultural features of mathematics with its school/academic aspects is named ethnomodelling, which is a process of translation and elaboration of problems and questions taken from systems that are part of the reality of the members of any cultural group.

Ethnomathematics is describe as the natural designs on his masterpiece works, without prior knowledge in basic geometry of the IPs craftman artisan jive with the nature's phenomenon makes the beauty of every single details on it. The static value of it create an artistry on every weaving designs that keep wondering will this is the gift from unknown powerful masters that only the Tnalak weavers

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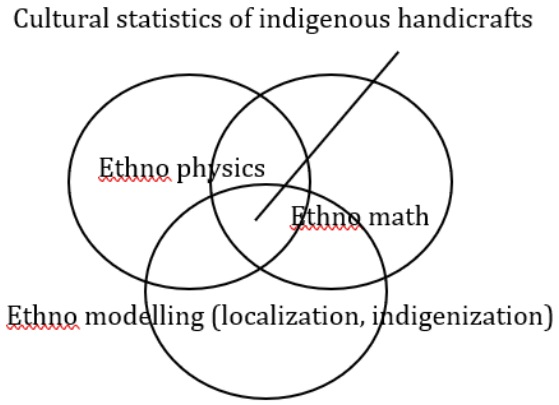
believes on it. The geometric patterns resulting from her *Bed Kekem -T'nalak* have created more sophisticated designs that lead the author to integrate the tools by *Buckley (2012)* on his study entitled "*Investigating Cultural Evolution Using Phylogenetic Analysis*" in determining the commonality of the geometric designs into *Ikat* weaving of other South Asian countries.

The dynamics of ethnomathematics, create a scientific point of references, which translate the usefulness of a particular ethno crafts which translate into ethno physics concepts. In the studies of (Arciosa, 2021; Arciosa 2022) where the Manobo Dulangan, a major IP's (Indigenous People) in the Central Mindanao, an adjacent IPs of the Tboli IP group who are the Tnalak weavers. Classical mechanics are the main science concepts of the Manoboo Dulangan, without proper knowledge in Physics. Ethno physics are very prevalent in their ethno crafts, which they do hand-made weaving in that particular ethno crafts. Try to look this ethno modelling framework as shown below;

Conceptual Framework



The future trends of Philippine Indigenous knowledge, system and practices of major Indigenous People (IPs) group like the Tbolis in central Mindanao, who are the Tnalak hand woven weavers, revolved in this conceptual framework of this research.

Methodology and Discussion

Ethnomathematics of Some T'nalak Designs

The craftsmanship of some *T'boli* weavers in *Lake Sebu South Cotabato, Mindanao, Philippines* can't equalize the arts value into a common commodity for anyone to buy and display in the four (4) corners of their living rooms. The arts that are embedded in the tapestry of abaca on super tiny strip masterpieces are hand woven by the elder women whose main goals are to create a *T'nalak* based on their dreams and aspirations. The galore of the different designs that have geometric patterns, describes the uniqueness of their results that amaze the eyes of the beholder. The imagination of creativity fascinates the author's jerk of intelligence which triggers the aura of its own version of interpretation, and, pauses the rays of how's and why's. The author's interests focus on the making of the *T'nalak* tapestry which roots on the origins of the tradition, customs and culture. Speaking of the culture where *Mindanao* is located composes the people's multi version of customs making the pot of the best people who compose the community. In the cream of the crafts, these tri-people (Islamized group, indigenous people group and Christian group) try to exist and show to the world their best abilities and dominate their rooted cultures. It's always the dominant culture which puts in the glitters in mediocre society ,where the author wants to reinvestigate , reinvent the treasures of the indigenous knowledge, skills and practices of the neglected group of people- the indigenous one. It might be the answer to the uncertainties of this society 4.0.

The author's mind is trying to search the bounties and richness of these one of a kind of craft arts of the *T'boli*, a major indigenous

group in the Southern *Philippines*. Their *T'nalak* is a kind of *Ikat* weaving (loom weaving) improvised through mechanical machines that help the weaver in creating the different types of *T'nalak*. Almost a decade, the author tried to seek the connection between the *Tnalak's* geometric patterns in the field of mathematics, and found the answers based on the analyses per section.

Section A : Phylogenetic Analysis

Bed Kekem, another type of *T'nalak* that has a double-double ellipse found in this loom-textiles. The best expert in weaving this kind of traditional cloths is in the person of *Inas Dulay Cone*, 60 years old, of *Brgy. Lamcade, Lake Sebu, South Cotabato* as shown in the picture below and was taken by the author's research assistant, *Rogie Tuando*.

Figure 1. Inas Dulay Cone, A Bed Kekem weaver of Brgy Lamcade, Lake Sebu, So.Cot., March 2018 Image credit of Rogie Tuando

Her masterpiece of weaving the *Bed Kekem* as defined in the book of *Oshima (2011),* was the design as dreamt pattern from the branches of the *Kekem* tree, a *T'boli* creation myth. The *Kekem* tree served as the way for good people to get to heaven. Further, the myth described the jealousy of a *Datu* from another tribe as he cut down the tree and its branches, believed to be submerged in Lake Sebu.

Figure 2. One of T'nalak Designs, Hand-woven by Inas Dulay Cone, Image credit from a book of Oshima (2011)

This loom textile, the *Bed Kekem*, is the most complicated among the three (3) types of *T'nalak* cloths that are analysed in these sections. The double-double ellipse composed of inner and outer shapes gave the highest impression of the author in the competency level of the

master weaver in the person of *Inas Dulay Cone.* Let us dissect this double- double ellipse loom textile, one of a kind Tnalak that has a unique symmetric patterns. Try to look at the first double ellipse used.

Figure 3. -Bed Kekem, A Ready-Made Image Coded as Mnrd and Mnrd- IN, ImageTaken from the Study of Buckley, C. (2012)

The double ellipse where outer shapes are the inverted images of *Mnrd* with inner shape – code of *Mnrd-IN*. In this regard there is a sharing of outer shapes which are also parts and parcel of the specimen 5. Try to look into this specimen 5 as shown below.

Figure 4. -Bed kekem, A Ready-Made Double Images(outer-Mnrd & Inner-HKrd-kHdS) Buckley ,C. (2012)

This Figure 4 - *Bed Kekem*, has double images formed and extracted from the original appearance of the loom textiles, composing the inner and outer shapes. The inner shapes have something to do with common designs in all *T'nalak* geometric patterns. It means that the image used by *Inas Dulay Cone* in her loom woven *Bed Kekem* is also found in other types of *T'nalak*. The outer shape is also used complementarily with the specimen 4; it means the *Bed Kekem* symmetric designs are alternating in between the designs of specimen 4 and specimen 5. Try to look at the illustration number three (3) of *Bed Kekem*, the artistry and craftsmanship of the loom textiles, particularly the *Bed Kekem*. The compositions of the hand-woven textile in terms of its designs are purely derived from the aspiration of dreams and culture preservation as myths literature and story are evident in every abaca's strip that interweaves with perfect symmetric patterns and design of images. The author's versions, with perfect symmetric, geometric patterns with a combination of the figure 3 and figure 4 of the looms textile-*Bed Kekem,* are shown below. The digital photos of the *Bed Kekem,* translated with the

backbone images, can be distinguished in originality from a fake *Bed Kekem-T'nalak*. Maintaining its originality has something to do with the preservation of the indigenous knowledge, skills and practices of this ethno-linguistic group, a major indigenous group of people who do traditional loom textile weaving and found mostly in the Southern part of the *Philippines*.

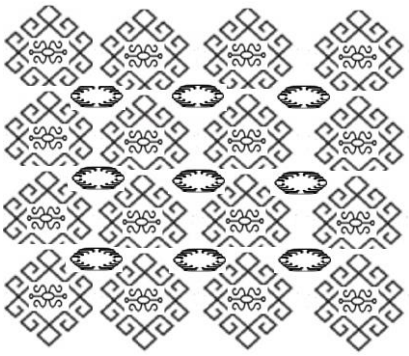


Figure 5. -Bed Kekem, and its double –double ellipse combination of specimen 4 &5 on its symmetric patterns patterns

This is the crystallographic designs of Tnalak weaving ,particularly the Bed Kekem, which shown a lot of mathematics concepts ,which even the weaver of Bed Kekem, doesn't know about this mathematical concepts.

Ethno Physics : Elliptical Analysis

The author created a theoretical equation that determines the symmetric and non-symmetric patterns of some *Ikat* weaving, particularly the *Bed Kekem*, one (1) of the *T'nalak* textile weaving of *T'boli*, an ethno-linguistic group from *Tboli, South Cotabato*. This *T'nalak* textile weaving, or the *Ikat* weaving, is done by the women T'boli elders whose artisanship was inherited from their ancestral families. This textile weaving has unique elliptical designs which are comparable to the designs made by other ethno-linguistic groups coming from all over the *Philippines* or ,even, from the neighbouring Asian countries. The author does an Elliptical Analysis (EA) whose main function is to determine symmetric or non-symmetric weaving patterns of the *T'nalak* geometric patterns in terms of the geometric designs, particularly, the ellipse. The formula has led to determining a machine-made *T'nalak* or human-made *T'nalak* in terms of the creativity, uniqueness and originality of each symmetric design of the *T'nalak* (which is called an ethno-technology). However, the percentage accuracy of the weaver of *Bed Kekem* in terms of symmetrically congruence is less than one (< 1). This implies that human beings cannot do perfect weaving. However, the accuracy percentage of machines is equal to one (1). In the study of *Arciosa & Tuando (2021)* combines quantitative and qualitative data that determine the congruency of the geometric patterns of *Bed Kekem* as one(1) of the *Ikat* weaving practices which produce *T'nalak*, the authentic Indigenous Knowledge Systems and Practices (IKSPs) of Indigenous Culture Communities(ICCs) of *Lake Sebu, South Cotabato*. In the quantitative concept, the image of *Bed Kekem* weaved patterns were converted into digitized form as bitmap file image with Paint tool. These bitmap file images are processed with SHAPE v.1.3d an image processing software used in the study of *Iwata & Ukai (2002)*. This software also contains program image processing, contour recording, derivation of Elliptic Fourier descriptors (EFDs), principal component analysis of Elliptic Fourier descriptors (EFDs), and visualization of shape variations estimated by the principal components. The proponents can easily analyze shapes in a personal computer without special knowledge about the procedures related to the method. The Principal Component Analysis (PCA) scores resulting from the procedures can be used directly as observed values of shape characteristics for

the subsequent analyses. Aside from the Principal Component Analysis (PCA), the weaving images are calculated and analyzed using Elliptic Fourier analysis (EFA).In this connection the author revised the EFA (Elliptical Fourier Analysis) into ETA (Elliptical *T'nalak* Analysis) with the combination of concepts of mathematics series, probabilities, statistics and wave motion. The results are divided into two (2) parts; (i) – Qualitative Analysis and (ii) Quantitative Analysis.

I. Qualitative Analysis - In this part the author used an ethno thematic analysis between the interview of the author and the participants who wave the *Ketumbe* and *Bed Kekem*. Using the thematic analysis can determine the originality of the Dream weavers work which parallel to the uniqueness and originality of both *T'nalak* traditional cloths like the *Ketumbe* and *Bed Kekem*. In the research paper of *Majumdar (2022)* the research analysts further argued that thematic analysis should be the initial analytic technique for every qualitative researcher to learn, as it forms the plinth for training of basic skills on qualitative analysis method that could be utilised to conduct other forms of qualitative research. There is no science or geometric lessons injected into their performance of hand-loom weaving. The inherited skills of weaving is passed to the next generations without any connection with the information technology era. The change is somewhat they are afraid of, the eradication of their textile weaving skills because the internationalization and commercialization of the other *Ikat/T'nalak* brands might lose the enthusiastic customers. This is the reason why the author introduced the IKSPs intertwine in the advancement of technology like the adoption of AI (Artificial Intelligence) in determining the original *T'nalak*, as one of the icons in ethno craft arts in the Philippine setting. The willingness and eagerness to continue what they had learned from their ancestors should be learned by the next generation of their tribes. The education is much important in preserving their hand-woven textiles traditions. In this case, the author tried to preserve and protect the originality of genuinely *T'nalak* weaving designs. Through this ethno-tech integration and mathematical modelling using unique equations per *T'nalak* designs can intertwine with the different disciplines particularly in science, mathematics and artificial intelligence. The future *T'bolis* and concerned individuals, are the author's main top priority in this matter.

II. Quantitative Analysis – In this part, where the author analysed the ,images, particularly the inner and outer elliptical analysis of the said *T'nalak* designs, the author used the *Bed kekem* specimens, the most difficult among the three(3) types of *T'nalak* as explained in Chapter 1. In analysing the details of the Elliptical Analysis (EA) ,he started from the inner and outer elliptical shapes that appear in the figure below;

A. The Inner Elliptical and Outer Elliptical Shapes of *Bed Kekem*

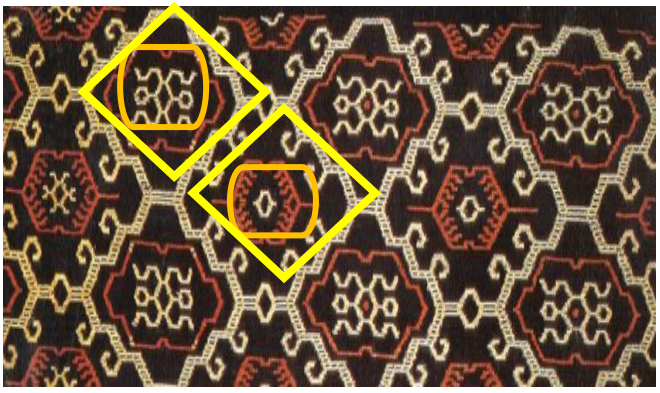


Figure 6. The Two (2)'s Inner and Outer Elliptical Shapes Formed in the Bed kekem's Tapestry. Oshima (2011)

As shown in Figure 6, the author identified the inner elliptical shapes and outer elliptical shapes of *Bed Kekem*. It shown that the outer shape has a degree of difficulty in weaving because of the series of curve lines attached to it ,while, the inner shapes have an easy way of weaving because of non-irregular lines.

B. Principal Component Analysis (PCA)

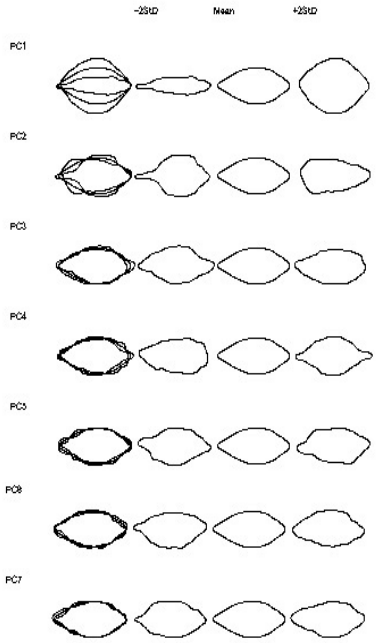


Figure 7. After the Image Processing Analysis of Bed Kekem Outer Elliptical Shapes with 7 PCA's.

Figure 7 shows a summary of the shape variation patterns of the *Bed Kekem's* outer elliptical shapes as reflected by the Principal Component Analysis (PCA). This seven (7) principal components out of 30 images of outer elliptical shapes determine its difficulty of the geometric patterns revealed. Here, PCA1 yielded 27.97% describing broad orbicular shapes in the positive extreme and the constricted linear shape in the negative extreme. PCA2 yielded 17.38% describing obviate shapes in the positive extreme and truncated obviate in the negative extreme. PCA3 yielded 13.36% describing an elliptical shape which has decurrently tip on its left in the positive extreme. Closely similar are the mean size and shape in the negative extreme. PCA4 yielded 11.05% describing closely the same with the mean size and shape in the positive extreme. An elliptical shape which has decurrently tip on its left is shown in the negative extreme. PCA5 yielded 9.52% describing a constricted oval shape which has a caudate tip facing downward on its left in the positive extreme and an oval shape which has a caudate tip facing upward on its left in the negative extreme. PCA6 yielded 9.13% describing an irregular oval shape form which has a caudate tip on its right in the positive extreme and forming an irregular oval shape which has a caudate tip on its left in the negative extreme. PCA7 yielded 5.95% describing a constricted oval shape which has a simple parallel tip on both sides in the positive extreme and an irregular oval shape form and a caudate tip on its left which has a simple parallel tip on its right in the negative extreme. The author analysed it as almost perfect in doing the hand-woven *Bed kekem*. This means that the weaver really mastered the geometric patterns despite that there are two(2) outer elliptical shapes that were put into the computer analysis (PCA). Let's look into the outer elliptical shapes of *Bed Kekem*. Figure 8 shows a summary of the shape variation patterns of *Bed Kekem* outer shapes reflected by the three(3) Principal Component Analysis(PCA), which reveal that the inner

shapes is less difficult in terms of the strokes used in weaving this particular image . The first three(3) principal components of outer topology showed 75.45% of the total variation. From this, PCA1 yielded 39.17% describing a broadening in shape and has lobed margins in positive extreme ,and, slightly constricted in shape and has lobed margins in negative extreme. PCA2 yielded 26.88% describing the shape as shrinking into constricted oval shape with lobed margins and twisted in its inner side in the positive extreme, and, forming a broad oval shape with lobed margins in the negative extreme. PCA3 yielded 9.40% describing a little contraction of oval shape from the mean with lobed margins and his twisted on its left region in the positive extreme, and, a little broader oval figure from the mean shape with lobed margins in the negative extreme.

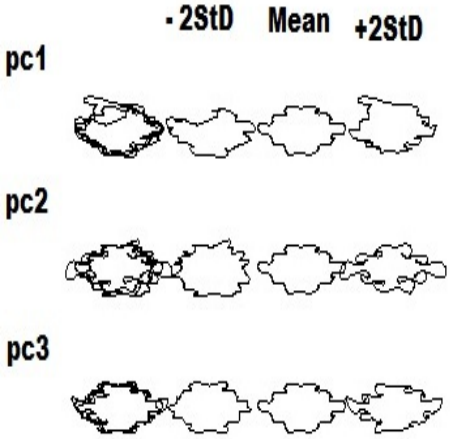


Figure 8. After the Image Processing Analysis of Bed Kekem inner shapes with 3 PCA's.

C. Kruskal-Wallis Test

This Kruskal –wallis test determines the congruency of the symmetric patterns of the inner and outer elliptical shapes that appeared in the hand-woven cloths particularly the *Bed Kekem*. The figures below can explain the congruency of the said elliptical shapes.

Kruskal-Wallis test

H (chi^2): 14.26
Hc (tie corrected): 14.26
p(same): 0.02682

Mann-Whitney pairwise comparisons,
Bonferroni corrected \ uncorrected:

	PC1	PC2	PC3	PC4	PC5	PC6	PC7
PC1		0.02563	0.00509	0.003559	0.004112	0.002838	0.002366
PC2	0.5381		0.6129	0.814	0.8362	0.8458	0.7259
PC3	0.1069	1		0.5402	0.4257	0.3579	0.5576
PC4	0.07473	1	1		0.9758	0.9582	0.9045
PC5	0.08636	1	1	1		0.8463	0.7933
PC6	0.05961	1	1	1	1		0.8367
PC7	0.04968	1	1	1	1	1	

Figure 9. Photograph of Kruskal-Wallis test of Bed Kekem Outer Elliptical Shape Analysis.

Figure 9, illustrates the Kruskal-Wallis test result which reveals that the seven(7) principal components, PC1 and PC7, PC2 and PC1, PC3 and PC1, PC4 and PC1,PC5 and PC1, PC6 and PC1, PC7 and PC1 are geometrically differ from each other. This implies that both principal components significantly differ in their designs particularly the outer elliptical shapes of the *Bed Kekem*. The pink color in Figure 41 implies that there is geometric difference between the negative and positive extremes ,and, the mean-outer elliptical shapes of the *Bed Kekem* weaving designs throughout the entire hand-woven cloths. Let's look into inner elliptical shapes of the *Bed Kekem*, are shown below.

Kruskal-Wallis test

H (chi^2): 1.442
Hc (tie corrected): 1.442
p(same): 0.9936

Mann-Whitney pairwise comparisons,
Bonferroni corrected \ uncorrected:

	PC1	PC2	PC3
PC1		0.9935	0.6278
PC2	1		0.8595
PC3	1	1	

Figure 10. Photograph of Kruskal-Wallis test of Bed Kekem Inner Elliptical Shape Analysis.

Figure 10 illustrates that the Kruskal-Wallis test reveals that no principal component has a geometric difference. It has no geometric difference between the negative and positive extremes from the mean inner shape of the *Bed kekem* weaving design. In this scenario the inner elliptical shapes got almost congruence, which the weaver of *Bed Kekem* did it perfectly and with less mistakes. The exactness of the elliptical shapes in weaving this particular designs can be tested in this Kruskal-Wallis test.

Elliptical Analysis

In determining symmetric or non-symmetric patterns of *T'nalak* textile weaving the author used the Bell shape(Normal curve) in probability and statistics as shown in Figure 43 for inner elliptical shape analysis and Figure 44 for outer elliptical shape analysis. The usual results are in the form of ellipse and is subsequently-present in the Principal Component Analysis (PCA's). It goes to significant difference per PCA using the Kruskal- Wallis Test. The author developed this kind of formula like;

$$P((S) = (PCA_1 + \ldots + PCA_n)/100 \ ;$$
$$P(NS) = 1\text{-}P(S)$$

This means that the probability of symmetry *P(S)* of weaving patterns is equal to the summation of PCAs' and divided into hundreds. Then the probability of non-symmetry *P (NS)* is equal to one and subtracted with the probability of symmetry P(S). This is explained through the figures below;

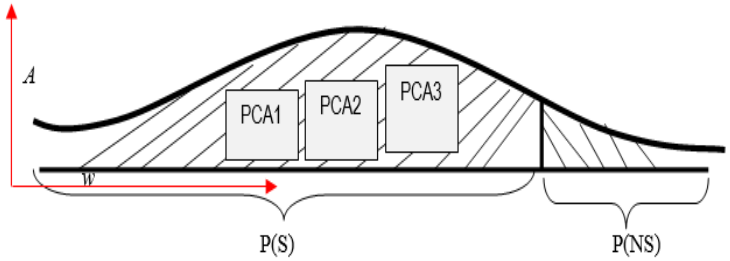


Figure 11. Probability Results of Elliptical Analysis (EA) of Inner shapes of Bed Kekem.

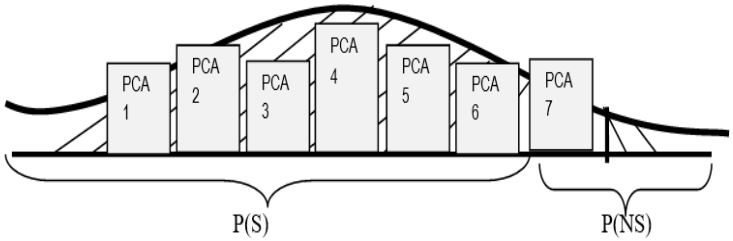


Figure 12. Probability Results of Elliptical Analysis (EA) of outer shapes of Bed Kekem.

The concept of P(x) = 1- P(x') is to determine the symmetric and non –symmetric characteristics of a *T'nalak* textile weaving with the Principal Component Analysis(PCA) as the main variable. Any weaving pattern or image is randomly subjected to computer analysis using the shape software which will create unique and varied Principal Component Analysis (PCAs) through Kriskal –Wallis test. Further using the three (3) PCA's results of the inner shape analysis with a mean(PCA_1 + …+ PCA_n) , where PCA_n depend on the degree of difficulty of the weaving stroke, has a value of *74.45%* . The Probability of symmetric weaving patterns, P(S) in inner shapes part is equal to 0.7445 while the probability of non-symmetric, P(NS) value is 0.2555. There is still a room of improvement in terms of the symmetric and non-symmetric probability values of *Bed kekem* as in the location of the images or the geometric weaving patterns and the degree of difficulty of the weaving designs. Figure 11 and Figure 12 show the identity codes of the *Bed Kekem* both its inner and outer elliptical shapes. This will be applied in the technology-based concept which anchored on the data science that mostly used the AI (Artificial Intelligence). The main purpose is to determine the authenticity, clearness and validate the work of *T'nalak* weavers who come from different Barangays of *Lake Sebu, South Cotabato, Philippines*.

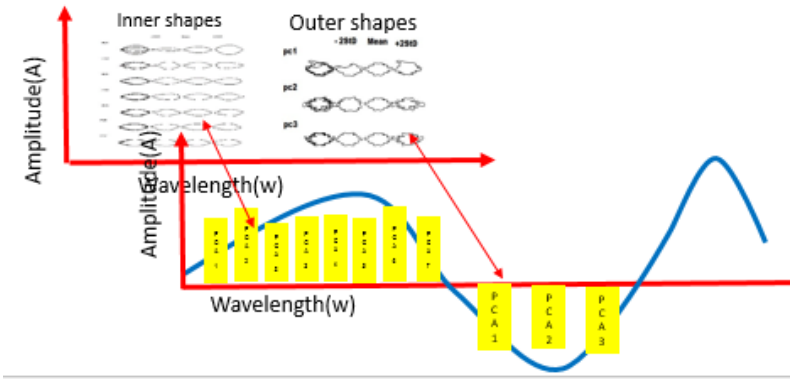


Figure 13. Ethno-Physics Application. of the Bed Kekem, weaved by Enas Dulay Cone (EDC) in dynamic motions.

This new trend of multi-disciplinary and inter-disciplinary approaches in dealing with things that only science and mathematics can profound deeply its' true meaning, showing the greatness of knowledge undertaken in this particular discipline. This is the author's great legacy in the field of physics where everything can be explained in dynamics with classical and ,even, in modern ways. Quantum physics can be good example to be interconnected because of the advancement of ideas and knowledge and can be the masterpiece of the future.

Summary and Conclusion

The integration of the major concepts in science and mathematics, which create a unique

artisan of every IP's craftsmanship, deliver its' traditions and custom purposes, make this original ethnographic research possible. The phylogenetic analysis, principal component analysis and elliptical analysis, which the author's interpreted into higher level approach, the quantumize mechanics- probabilistic motions, considered the wavelength, amplitude of its unique design before the hand-made woven happened. There is always a presence of cultural statistics in every IP's handicraft masterpiece.

Acknowledgements

The author acknowledges the major contributor of his research assistant in the name of Rogie Tuando, Principal DepEd South Cotabato. Most specially the Tnalak weaver in the name of Inas Dulay Cone.

Ethical Values

The collection of data are based on the book by Oshima, which seconded with the pre-survey data ,which only interviewed the basic information, with no ethical biases and subject for ethical standards.

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