

The art of Samoan Siapo

By Paul Tauiili

EDCS 606

with

Dr. Don Rubinstein

Dr. Sandy Dawson

Dr. Neil Pateman

Dr. Joe Zilliox



Source: (Neich & Pendagrast 1997)

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Introduction

This paper is focused on describing the rich art of *siapo* making in Samoa and the mathematical concepts derived from its designs and production. It begins with a historical look at *siapo* in the Samoan culture and the methods used to conduct this research. It is followed by a detailed description of how Samoan *siapo* is processed from raw bark to finished work of art and the differences between two distinct types of Samoan *siapo*: a) *siapo elei* and b) *siapo mamanu*. And finally it focuses on exploring the mathematics involved in the art of Samoan *siapo*.

Cultural Significance

Siapo is a Samoan word for tapa or bark cloth that has been painted or imprinted with various design motifs. Although Samoan *siapo* can be distinctly recognized as a pure art form that flourishes in Samoa its origins can be traced to eastern Asia (Neich & Pendagrast, 1997). A *siapo elei* is bark cloth that is imprinted with design motifs by rubbing brown dye and powdered earth clay on a rectangular design tablet approximately 1' x 4'. Black and brown dyes are often used to emphasize design motifs by over painting certain designs after it is imprinted.

Siapo mamanu however is *siapo* that is created strictly by free hand painting design motifs on bark cloth without the design tablet. *Siapo mamanu* are also distinctly different than *siapo elei* because *siapo* makers use colored dyes not commonly found on older *siapo elei* such as red and yellow (personal communication, Regina Meredith, 3/29/2010). Therefore the two types of *siapo* differ mainly in how a design motif is applied on the bark cloth and the colors used. Later we will explore how *siapo mamanu* also differs from *siapo elei* in use of symmetry and the intricacy of designs. A sample of both a *siapo elei* and a *siapo mamanu*, are pictured below in Figure 1.1 and 1.2. What differences do you notice?



Figure 1.1 *Siapo elei*
Source: (Neich & Pendagrast 1997).

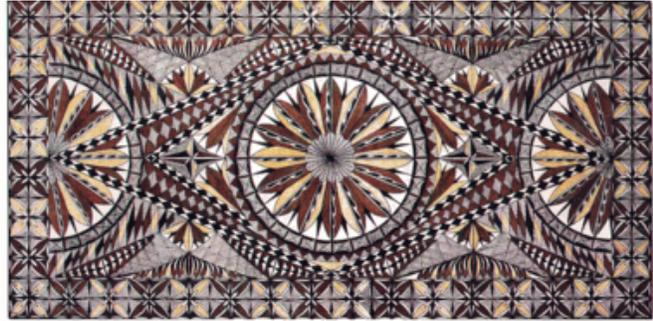


Figure 1.2. *Siapo mamanu*
Source: www.siapo.com

Siapo elei or imprinted *siapo* was also an older form of *siapo* used by Samoans primarily as clothing as seen Figure 2. Although some over painting was used to emphasize motifs as seen in Figure 1.1 they are still classified as *siapo elei* because the original design was obtained from rubbing the siapo on a design tablet. A detailed comparison and description of each will come later.



Top left: young man holding baby is wearing a *siapo elei* called a *tiputa* that has been over painted.



Top Right: two young chiefs that are both wearing *siapo elei* also called a *tiputa* with minimal over painting. These were garments worn during special cultural ceremonies.



Bottom: two young Samoan women wearing a *siapo elei* dress sewn in a European fashion.

Above left: Orator chief and family, 1890s, Palauli, Savai'i, Western Samoa. The older man in a naval jacket and cotton lovalava holds a flywhisk or *fue* as a mark of his office as a talking chief. The younger man wears a freehand painted *siapo lovalava* held in place by a tapa cloth belt.

Above right: Young men dressed as *manaia*, c. 1900s, Apia, Western Samoa. Holding their *nifo'oti* weapons and wearing *siapo lovalava* with full ceremonial *tiago* headdress, these young chiefs' sons are prepared for their role as *manaia*, when they will perform the same duties normally carried out by the *toupo'u*.

Left: Young women in tapa dresses, c. 1900s, Apia, Western Samoa. These outfits have been cut and shaped in European-style from freehand painted *siapo*.

Figure 2. *Siapo elei* used as clothing
Source: Neich & Pendagrast, 1997

Siapo elei the oldest type of *siapo* recorded and photographed was also used as a partition or *pupuni* for traditional open houses creating a separate area for nursing mothers, for privacy, or to keep out light as seen in Figure 3.



Figure 3. *siapo pupuni* approximately 30' x 15'

Source: (www.siapo.com)

Before coffins, *siapo elei* was used as a burial shroud or covering for the grave (personal communication, Tauiliili Pemerika 3/25/2010). *Siapo elei* was also used as a bed covering or mosquito net. It was used as a traditional gift for chiefs or guests during traditional ceremonies or gatherings. It was also used as ceremonial garments for chiefs as seen in Figure 1 above and for *taupou* or daughter of the high chief. *Siapo elei* wrap-arounds called *koloa* were worn by *taupou* during *ava* or kava ceremonies as seen in Figure 4 below.



Figure 4. Young Samoan girl wearing *siapo koloa*

Source: (www.siapo.com)

Siapo elei was also passed down from generation to generation and became valuable family heirlooms (Neigh & Pendagrast 1997).

Today Samoan *siapo elei* are still given as traditional gifts, worn as a ceremonial garment in special cultural gatherings, and used as a burial shroud. However Samoan *siapo* has gained use in nontraditional ways as well. It is now used in jewelry, handbags, placemats, wall hangings, and other home decor, many of which are sold to tourists, which has helped sustain its production and become a market for *siapo* makers. This was one of the ways *siapo* making evolved in the early 1900's and *siapo mamanu* the free hand painting style was developed (personal communication, Regina Meredith, 3/29/2010).

The art of *siapo* making however is slowly becoming a lost art form and only a handful of people on American Samoa are active *siapo* makers. The only *siapo* that is being produced at the moment is used mainly for an active tourist industry. For this reason it was hard to conduct research and interview actual *siapo* artists.

Methodology

How did you conduct your research?

After studying photographs of *siapo mamanu* made popular by *siapo* artist Mary Pritchard and Kolone F. Leoso and many other *siapo* makers in the village of Leone, American Samoa it was hard to ignore the explicit patterns of the motifs, the symmetry created by those motifs, and the artists vivid use of color. *Siapo mamanu* or the free hand painted *siapo* as mentioned earlier was made popular in the 1920's. Since that time many of Mary Pritchard's descendants and students carry on the legacy to keep *siapo mamanu* making alive. One such person is a college instructor by the name of Regina Meredith. Along with her experience as an art enthusiast, art instructor, and a well-known local artist, Regina was fortunate to learn the art of *siapo* making from "auntie Mary", as she affectionately calls her. Regina Meredith continues to teach her college students, elementary school teachers, and other local artists from the community about *siapo mamanu* (personal communication Regina Meredith, 3/15, 2010).

Therefore the primary source of information for this research paper were interviews conducted of experts in the art of *siapo* making, primarily Regina Meredith. I also interviewed my sister Ruth Mahuka, who also learned from workshops conducted by Mary Pritchard. Ruth helped me understand that *siapo* making for a Samoan *siapo* artist was more about the process of creating the art.

I also conducted an interview of an elder, my father Pemerika Tauiliili who has authored and published two books on the connection of Samoan culture and language to our environment.

Another important source for this research was the literature and rich photographs retrieved from journal articles, reference books, websites, and videos related to *siapo* making. References to Mary Pritchard's popularity and work as a prolific *siapo* maker are found in much of what is documented about Samoan *siapo*. The www.siapo.com website that was set up by Mary J Pritchard's granddaughter Tupito provided the majority of the photographs and explanation for the process of the *siapo* making. Without these photographs it would be impossible to explain the art of *siapo*.

When studying the mathematic concepts in the designs of *siapo mamanu* I had to turn to the Ethnomathematic's article written by Marcia Ascher on symmetric strip decorations. Rereading this important article, which was one of our resources for this course, helped me a great deal. It allowed me to revisit concepts of symmetry such as reflection, translation, rotational symmetry, horizontal symmetry, and vertical symmetry in the context of traditional ethnic art. Once I could see how the classification system worked on different strip patterns I could use a mathematical lens to identify symmetrical patterns on a proud traditional indigenous art such as *siapo*.

A source that I consider one of the most important in inspiring me to chose a topic was a video produced by the US National Parks in American Samoa by park ranger James Gurr. The video was entitled, O Le Siapo and featured a well-known *siapo* artist from Salailua, Western Samoa by the name of Makulata Faatoafe. *Siapo* artist Makulata Faatoafe was invited to create a *siapo* from start to finish and the documentary was completed and available to the public in

February of 2010. This film provided my first experience with the whole process of *siapo* making and also inspired me to create my own *siapo* one day.

If you used a set of interview questions, what were they?

The time spent with *siapo* makers and experts on the subject were mostly casual and informal conversations with much of the discussion recorded on video for later analysis. Interview time was also spent actually creating *siapo* *mamanu* . No set interview questions were designed ahead of time however much of the information that was learned from the research of articles, photographs, websites, videos, and previous conversations became leading questions during follow up discussions. One thing that I learned about the discussion was that the questions gradually became more specific as more discussions occurred and more research was done. This was perhaps because I spent more time listening in earlier conversations. I needed to learn and understand the process of making *siapo* and its historical context first. Questions about the mathematics in *siapo* did not occur until I was better familiar with the *siapo* process but even now as I write I am formulating more questions that I wish I had time to ask.

Who did you consult?

The main source of information about the art making *siapo* *mamanu* came from local *siapo* maker Regina “Reggie” Meredith. Reggie was gracious enough to show me the process of designing the wonderful symmetrical designs on *siapo* *mamanu* and show me samples of older Samoan *siapo* *elei* and *tapa* from other islands in the Pacific: Hawaii, Tonga, Fiji, Papua New Guinea, and Easter Island. This was good so that I could observe and compare the differences in texture, color, and design.

A second source was my father who is a cultural expert and author of two books on Samoan culture. He often recalled times when he helped his mother make *siapo* over 60 years

ago and he was still able to share details of his experience with me. He has written two books on a broad range of topics especially the use of natural resources by Samoans, the cultural significance of those natural resources, and the proverbial phrases that are derived from them. Reading both his books and having conversations with him helped me appreciate the value of keeping the art of siapo making alive for generations to come and was the main reason I chose to focus on siapo for this project.

What were the difficulties that you encountered in conducting the research?

The main difficulty I encountered was the fact that siapo making is a dying art and only a few people know how to make it, how to describe it, or know enough about its history to explain it. I only found 3 resource people to interview, two artists and one cultural expert. The second difficulty was that I had very little experience myself with siapo making as it is only actively made in one or two villages in Western Samoa and in a few places here in American Samoa. I had little experience about the production, the designs, or its history so I had to learn a lot of this for the first time. It took a lot of time conversing, reading, and researching to find information on siapo making. The third difficulty I faced was the style of descriptive writing that is required for this type of paper. I had a lot of trouble finding the right words to describe siapo making, so that explanations were concise and could be understood by a wide audience. It was also difficult to find the right pictures to help explain details that sometimes words fail to capture. Luckily www.siapo.com became an invaluable source for pictures to help explain this topic.

Do you feel that your research on this topic is as complete as possible for the purposes of developing math curricula, or would you recommend further research?

A wider collection of siapo samples need to be analyzed with a more critical mathematical lens. I also feel that more siapo makers should be interviewed, observed, and recorded to get a deeper

understanding of how they use mathematics, how they create symmetry, how they use tools to measure midpoints and dissect the space in to smaller regions, or how they use both color and lines to create symmetry or asymmetry. Siapo makers need to be studied to observe how they hand paint their siapo, carve their design tablets, mix their dyes, and create their patterns and symmetrical designs. Work needs to be done on exploring the history of siapo making, the tools they used, samples of designs of old siapo, and the different artist styles that exists in different locations around Samoa and how mathematics is used in each of those different styles.

Description

What is siapo made of?

Tapa is a term that is known around the world for bark cloth. It is derived from the Samoan word tapa, which means uncolored bark cloth (Neich & Pendagrast, 1997). *Siapo* is Samoan tapa that is colored using a variety of techniques and variety of local dyes to be discussed later. Tapa is a fabric-like material made from the bark of the paper mulberry tree (*Broussonetia papyrifera*), which is known in Samoan as an *u'a* tree in Figure 4. The average mature *u'a* tree averages one and half to two inches in diameter and is about 12-15 feet in length from base to tip. Each tree trunk is cut into 6-8 foot pieces for processing.



Figure 4. *u'a* tree



Figure 5. stripping the bark of the *u'a*

Source: (www.siapo.com)

Once tree trunks are cut down the bark from the *u'a* tree is removed by cutting a slit in the bark along the grain of the tree trunk and peeling the bark from base to tip as seen in Figure 5. It takes a lot of strength to peel the bark of the *u'a* tree but a skilled person can do it alone.

Once the 6-8 foot long pieces of bark are removed, the stem is discarded. The bark is then turned inside out and rolled. The bark reveals two sides: thick, soft, white, inner bast and a thin, tough, outer bark. The thin, tough, outer bark is then peeled back and discarded as seen in Figure 6.



Figure 6. peeling back of bark to reveal soft white bast

Source: (www.siapo.com)

The soft, white, inner *u'a* bast is then soaked in water for about 10 -20 minutes to soften it for scraping as seen in Figure 7.



Figure 7. rolling of the *u'a* and soaking it in water

Source: (www.siapo.com)

The soaked white *u'a* bast is removed from the water and placed on a sloping board and rubbed along the grain of the bark with different types of seashells called *pipi*, *pa'e*, or *asi*. (O le

Siapo, National Park Film). The three seashells are used to remove any tough outer-bark that remains and to widen the soft white bast see Figure 8.



Figure 8. rubbing with seashells to spread the fibers and soften the bast.

Source: (www.siapo.com)

At this stage the damp white inner *u'a* bast begins to get wider and eventually double in width. When the inner bast has almost doubled in width then it is further stretched and thinned out by pounding it with a heavy wooden mallet or *i'e* in Figure 9 on a large wooden anvil called the *tutua* see Figure 10.



Figure 9. wooden mallet called an *i'e*

Source: (Neich & Pendagrast, 1997)

The mallet is about 1½ to 2 feet long from handle to tip and weighs about 10 pounds. The *i'e* has grooves along the length of the mallet on one side and is smooth on the other.



76. Fa'alagilagi Lealaitafea demonstrates beating



77. Beating is done methodically, slowly



78. . . . and continues until the bast is widened as desired into a sheet



79. The sheet is folded over to the width of the anvil



80. . . . the sheet is beaten again lightly



81. . . . then folded in, and rolled

Figure 10. pounding of *u'a* bast with the wooden *i'e* on the *tutua*

Source: (www.siapo.com)

Grooved sides of the mallet are used first to pound the roll of inner bast to further separate the fibers and thin out the material but the smooth surface of the *i'e* is used last to flatten any creased surfaces. Once the *u'a* is pounded to a thin consistency and is 3 to 4 times the width of the original raw bast it's unrolled and laid out flat to dry as seen in Figure 11 below. This step is repeated until the *siapo* maker has enough *u'a* to complete a selected size of *siapo*. Once the *u'a* is dry it is ready to be designed by a *siapo* maker into a fine work of art.



82. On end, the roll is hit with the smooth side



83. . . . unrolled, pulled and twisted slightly



84. The sheets are stretched, to flatten and dry



85. Gently pulled away from the center line



86. Weighted at the sides, the sheets air-dry



87. Fast drying sometimes is done outside

Figure 11. final stage of pounding the *u'a* and laying out siapo to dry.

Source: (www.siapo.com)



Figure 12. Processed *u'a* in its dried form

The holes on the dry *u'a* in Figure 12 above occur naturally as these were places on the bark where there were tiny branches. Children of *siapo* makers were often given the responsibility to remove young sprouting branches on the *u'a* tree while it was still growing so that the processed *u'a* from that tree would end up with smaller or fewer holes (personal communication, Tauiiili Pemerika, 3/25/2010). *U'a* with fewer holes and blemishes were often saved for the top and final layer of siapo (personal communication, Regina Meredith, 3/15/2010).

How is siapo designed?

The process of turning the *u'a* to a beautifully painted *siapo* is the final step of the process. There are two main types of *siapo* and they differ mainly in how the *u'a* is designed or how motifs are painted on the *u'a*. Based on the research and photos of *siapo* that I have observed and collected and interviews with *siapo* makers it is apparent that *siapo* makers in Samoa have different interpretations of the patterns, size, color, and shapes of motifs used on *siapo*. There are differences in *siapo* over different time periods, from different locations, or associated with different families or artist. Following is a description of those two types.

SIAPO ELEI

Earlier *siapo* were designed by rubbing the *u'a* on an *upeti* or a rectangular design tablet averaging 1 ½' x 4'. Older *upeti* were called leaf *upeti* because it was made from “sewing pieces of coconut midrib, bamboo strips, and sennit...” or coconut husk fibers... “in patterns on to a rectangle of pandanus leaves” (Neich & Pendagrast , 1997, p.16). Leaf *upeti* in Figure 13.1 were used as the primary design template up until the 1920's and were gradually replaced by wood carved *upeti* because of the availability of wood carving tools and its durability. A wooden *upeti* is seen in Figure 13.2.

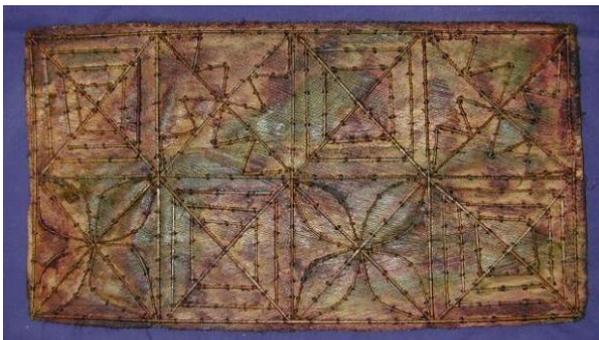


Figure 13.1. leaf *upeti* design template



Figure 13.2. wood carved *upeti* design template



Figure 14.1. Close up on the leaf upeti



Figure 14.2. close up of the back of leaf upeti

Source :(www.siapo.com)

To transfer the design of the *upeti* on to the *u'a* colored dyes were needed. *Siapo* makers would collect dyes from the *o'a* tree and red ochre (a reddish earth clay) called *ele*

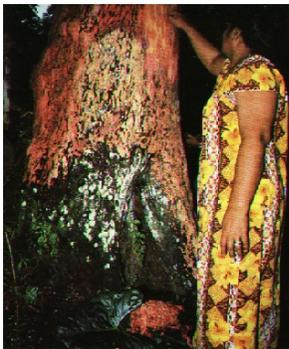


Figure 15. scraping of the bark of the *o'a* tree to obtain juice for the main reddish brown dye. *O'a* is also is used to dilute black, yellow, and bright red dyes



Figure 16. *O'a* juice squeezed from the bark

Source: (www.siapo.com)

The elei process or process of imprinting or rubbing of design template on the u'a.



Figure 17. First *o'a* is applied on the *upeti*.



Figure 18. and then a sheet of *u'a* is stretched over the *upeti*



Figure 19. The *u'a* is then swabbed back and forth with a small piece of *u'a* soaked in *o'a dye* and an imprint from the carved *upeti* appear on the *u'a* cloth.



Figure 20. another piece of *u'a* is joined to the edge of the first layer. The edges are glued together using arrowroot or *masoa* Samoa. This is also the time when holes are patched on the bottom layer with small pieces of *u'a*.



Figure 21. shavings of red clay called *ele* are rubbed on the *u'a* to darken the design. The *ele* or red clay is where the name *elei* comes from hence the name *siapo elei* for this style of siapo designing..



Figure 22. arrowroot called *masoa* Samoa is covered with a gluey substance once it is boiled and it is this substance that is spread on the first layer as glue. The second layer of *u'a* is then added and glued to the bottom layer.



Figure 23 rubbing of the top layer with *o'a* or red dye and *ele* is repeated to seal top and bottom layers together and bring out the design on the final piece.



Figure 24. *siapo elei* is removed from design template.



Figure 25. Once *siapo elei* is removed from the design tablet it was often over painted to emphasize lines, shapes, or size of a motif by adding color. This would be a *siapo* artists' preference, which line or shape to emphasize (O Le Siapo Film, US National Parks). Only black and brown dyes were used on older *siapo elei*.

Source: (www.siapo.com)

The *siapo elei* pictured above in Figure 25 has only one imprint. This size is popularly sold to tourists as wall hangings, however a *siapo elei* used in traditional Samoan settings is bigger and they are classified into size categories. The smallest size category was a *vala*. A

traditional Samoan *vala* would consist of 8 imprints of the design tablet or *upeti* as seen in Figure 26 below. Each imprinted section was called a *potu*. Can you identify the size of the original imprint? How do the shapes, colors, or patterns of the over painted motif or rubbing help you count the number of imprints in this siapo? What other patterns do you notice?

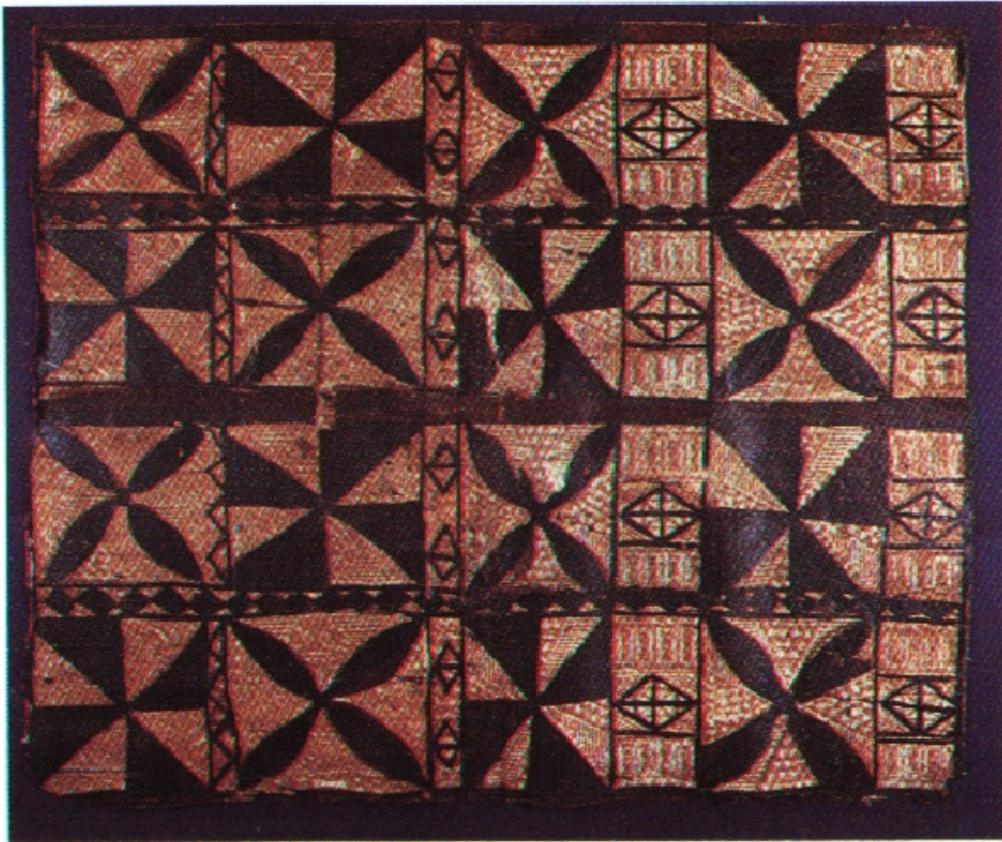


Figure 26. Traditional *siapo elei*. This size was often standard and called a *siapo vala*. It had 8 *potu*. **Source:** (www.siapu.com)

Diagram A has 2 illustrations that represent the division of a traditional *siapo elei* into 8 *potu*. Which diagram do you think accurately represents the orientation of the *upeti* or design template in Figure 26 as it is shown?

1	2
3	4
5	6
7	8

1	2	3	4
5	6	7	8

Diagram A. 2 possible representations of the division of imprints of the *siapo vala* in Figure 26.

Some *siapo vala* would be a little longer by adding two more upeti rubbings. It would have 10 *potu* as seen in the *siapo vala* below in Figure 27.



Figure 27. *siapo vala* with 10 *potu*. (**note:** a portion of the left column of Figure 27 is out of view) Source: (www.siapo.com)

Can you find the original design template? What shapes, lines, color, or patterns of the over painted motif help you identify the repeated imprint? Are there any patterns you notice about Figure 26 & 27 that are similar or different?

1	2
3	4
5	6
7	8
9	10

1	2	3	4	5
6	7	8	9	10

Diagram B. one of these represents the division of imprints in *siapo vala* above in Figure 27 as it is shown. Which one is it? Or could there be another way that these imprints were laid out other than the diagrams shown?

What sequence did siapo makers use to imprint the siapo vala?

What were *siapo* makers preferred sequences on how they would *elei* or imprint their *siapo vala*. Would they first imprint the design template from end to end and then repeat as shown in Diagram C below or were imprints made adjacent to the original imprint and then repeated as in Diagram D? Were sequences random? If there were preferences among *siapo* makers what were the factors for this preference? Would it depend on how they were taught? Or was there a norm amongst *siapo* makers? Were there practical reasons for the sequence of imprinting? Yet another mathematical question that depends on the artist's cultural knowledge. When viewing the film produced by the US National Parks the women used the sequence in Diagram C. When I asked my father what he remembered from his experiences he said they used the sequence in Diagram D. So there needs to be more research on this to determine which sequence is most commonly used and why.

First	Second
Third	Fourth
Fifth	Sixth
Seventh	Eighth
Ninth	Tenth

Diagram C

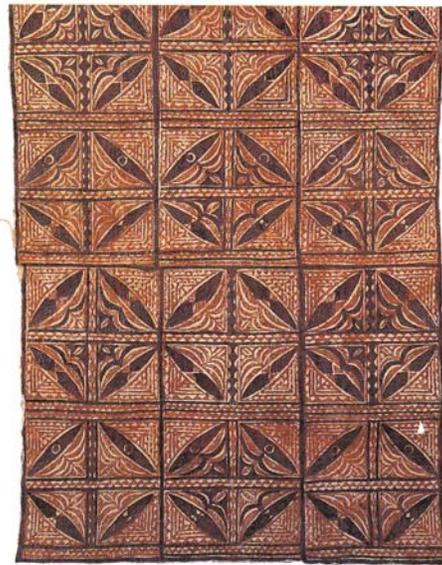
First	Sixth
Second	Seventh
Third	Eighth
Fourth	Ninth
fifth	Tenth

Diagram D

What patterns, shapes, colors, or motif designs help you identify imprint of the upeti?

Figure 28.1 sample of *siapo elei* that was imprinted with a leaf upeti. Some of the motifs or designs were emphasized by over painting .

Figure 28.2. sample of *siapo elei* that was imprinted with a wood carved upeti. Some of the motifs were over painted.



Source: (Neigh & Pendagrast, 1997) (**Note:** due to the large size of both siapo pieces only a portion is shown.

1. **Can you identify the *potu* or original design template in each *siapo*?** Figure 28.1 is done for you. If you look at the design imprint behind the over painting you can see a hexagon motif that is repeated. However for Figure 28.2 it is harder to determine.
2. **What patterns, shapes, design motifs, or color help you identify each *potu*?**
3. **Can you identify any characteristic differences or similarities in each *siapo*?**

Were the upeti used as a standard unit of measurement?

Depending on the desired size of the *siapo* the rectangular *upeti* or the imprint it left could become a unit of measurement for both the length and width of the *siapo*. The longer side of the *upeti* could serve as a unit to measure the length or width of the final piece. This would also be true for the short side of the design template. It could also be used to measure the width of length of the final *siapo vala*.

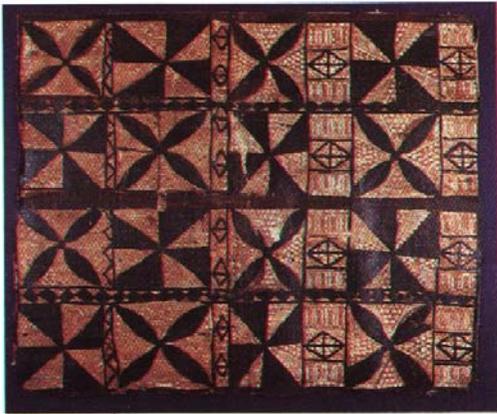


Figure 29.1. Siapo vala with 8 potu
Source: (www.siapo.com)

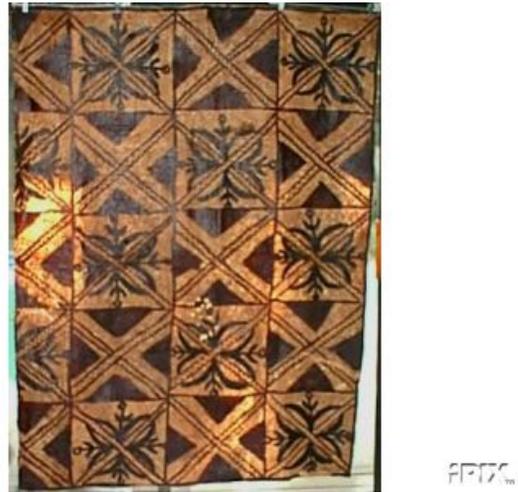


Figure 29.2. siapo vala with 10 potu

Diagram E.1 and E.2 below represents a *siapo vala* with 10 *potu* & could be classified as:

- a) a siapo vala that is 2 *upeti* long and 5 *upeti* wide as in Diagram E.1 or
- b) a siapo vala that is 5 *upeti* long and 2 *upeti* wide as in Diagram E.2

However the norm for *siapo vala* was to arrange *upeti* imprints as in E.1 so in this case which side of the *upeti* determined width? Length? (personal communication, Regina Meredith, 3/15/2010).

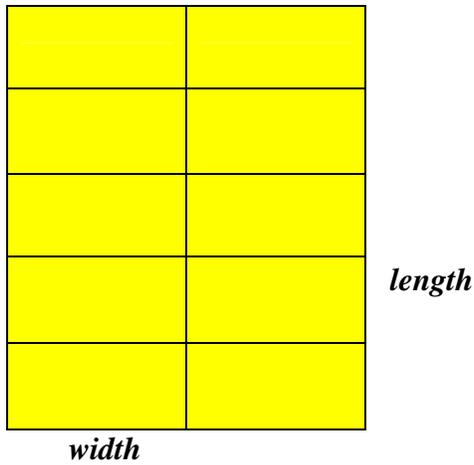


Diagram E.1

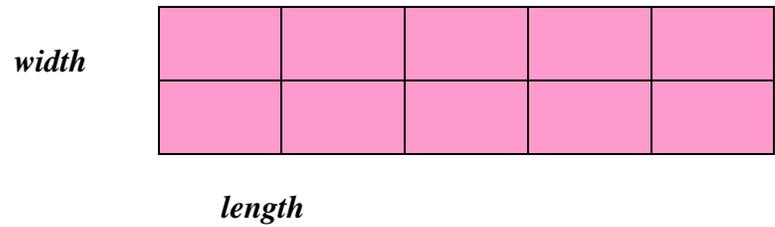


Diagram E.2 (not the norm for vala)

Diagram F.1 & F.2 below represents a *siapo vala* with 8 *potu* & could be classified as:

- a) a *siapo vala* that is 2 *upeti* long and 4 *upeti* wide, as in Diagram F.1or
- b) a *siapo vala* that is 4 *upeti* long and 2 *upeti* wide as in Diagram F.2.

Based on the *siapo vala* in Figure 29.1 above, which is an example of the normal size and arrangement of imprints for a *siapo vala* with 8 *potu*, we will ask, which side of the *upeti* determined width? length? Was it the short side or the long side of the *upeti*? Was it the same in the case for a *siapo vala* with 10 *potu*?

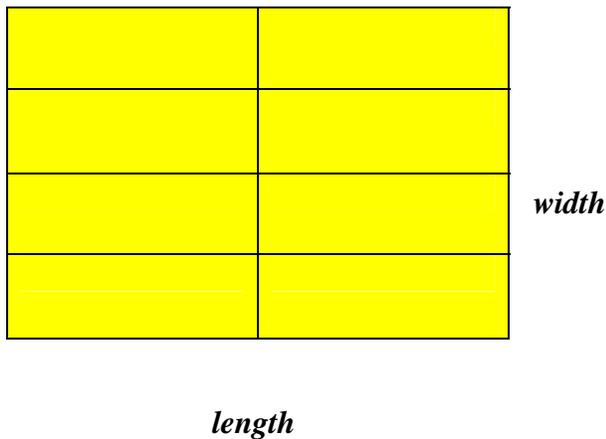


Diagram F.1

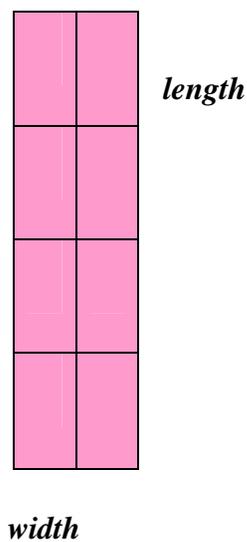


Diagram F.2 (not the normal arrangement of a *siapo vala*)

Could the upeti or design tablet be used as a unit for measuring surface area?

Diagram G below represents the *siapo vala* with 10 *potu* pictured in Figure 29.2 above. If the surface area of 1 *upeti*, design template, imprint, or *potu* is equal to 1 unit then the total surface area of this *siapo vala* is 10 units.

One unit	Two units
Three units	Four units
Five units	Six units
Seven units	Eight units
Nine units	Ten units

Diagram G

Diagram H represents the *siapo vala* with 8 *potu* pictured in Figure 29.1. If the surface area of 1 *upeti*, design template, imprint, or *potu* is equal to 1 unit then the total surface area of this *siapo vala* is 8 units.

One unit	Two units
Three units	Four units
Five units	Six units
Seven units	Eight units

Diagram H

What would be the surface area of larger *siapo elei* called a *siapo pupuni* (shown in Figure 30) in terms of units of *upeti*, if the *siapo pupuni* was 8 *upeti* long and 10 *upeti* wide as seen in Diagram I below?

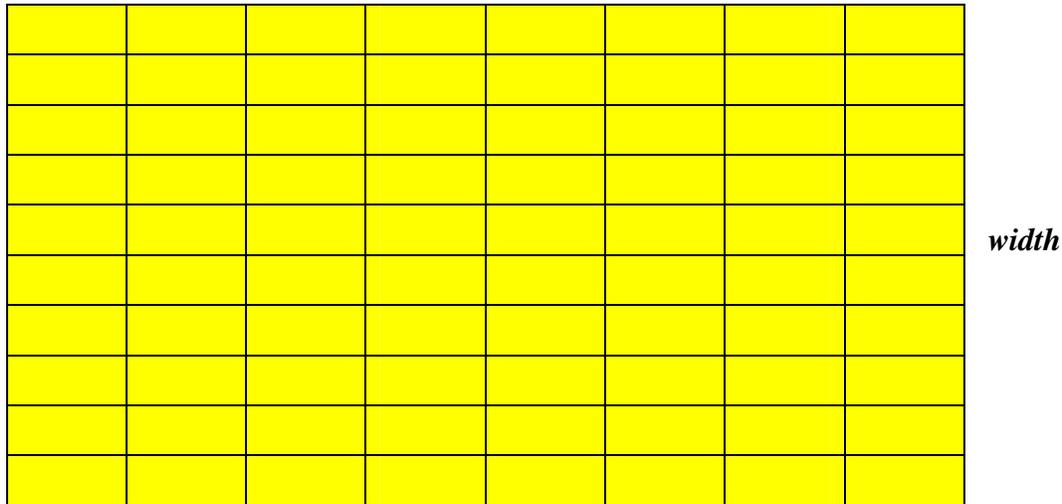


Diagram I

This measurement concept could have helped women produce several pieces of *siapo elei* that were congruent if they used the same *upeti* in the same arrangement of rubbings. But how about if they used two different *upeti* on the same *siapo* as seen in Figure 30 below?

Were upeti uniformed in length and width? Were upeti boards congruent? If so, for what purpose?

Artists in any culture, past or present, have signature styles or preferences and so did Samoan *siapo* makers (personal communication, Ruth Mahuka, 3/29/2010). *Siapo* makers from the same village or same family would have *upeti* that had different motifs or use the same motifs in different patterns. And of course this was true across the islands of Samoa and across the Pacific where *siapo* making flourished. According to Neich and Pendergrast (1997) many *upeti* boards were shared between *siapo* makers in a village or in the same family. The Figure below shows a large *siapo elei* called a *pupuni* with an alternating use of two different *upeti*

design templates. The two *upeti* used could belong to the same family or have been shared between two *siapo* makers. Would the two *upeti* used in this alternating style of rubbing have to be congruent?



Figure 30. a *siapo pupuni* that had over fifty *potu* or imprints.

Source (www.siapo.com)

Below in Diagram J we represent a *siapo vala* that could have been created using two *upeti* with different motifs or designs. 2 different *upeti* are represented by *upeti X* and *Y*. Would *upeti X* and *upeti Y* have to be congruent to be used without leaving gaps or space between the imprints?

Imprint made with design template X = 

Imprint made with design template Y = 

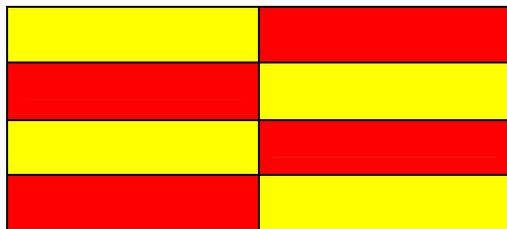


Diagram J. This diagram represents a *siapo vala* that has 8 *potu*.

Based on the diagram above, the *siapo* maker chooses to alternate the use of *upeti* X and Y. Can you make this same arrangement with two incongruent *upeti* design templates without leaving gaps between the imprints? Although many *siapo* makers would have different sized *upeti* according to Regina Meredith (personal communication, 3/29/2010). It is obvious that in the example above the two *upeti* had to be congruent so that no gaps were left between imprints. However a new question arises based on this creative design. *Siapo* makers preferred to have balance in their *siapo* (personal communication, Regina Meredith, 3/15/2010). Is there a sense of balance in this *siapo*, which uses 2 alternating *upeti*?

To try to answer that, we can look at mathematical aspects. Each *upeti* was used exactly 4 times. Therefore the imprinted surface area of the *siapo* made with *upeti* X would be equal to the imprinted surface area made with *upeti* Y. What other factors would offer a sense of balance? Could there be symmetry in this arrangement? Could there be symmetry using a different arrangement? What other mathematical concept could be applied to define this *siapo* design as being balanced? And finally what makes this arrangement of designs seem unbalanced besides a lack of symmetry

How do siapo makers define balance? Are their designs or patterns of rubbings balanced?

To explore the concept of balance further, we could ask several questions? First and foremost, how do we define balance in mathematics? The Oxford American dictionary defines “balance” as a **condition in which different elements are equal or in correct proportions** . Does this mean that elements in the *siapo elei* have to be equal? If so what elements? Other good questions arise:

1. Are there *siapo* makers that would use, or have used 2, 3, 4, or more *upeti* to create a different pattern than the one shown above in Diagram J? If so did those patterns create balance? Were they unbalanced? What factors determined this?
2. How many different patterns could *siapo* makers create with a 10 *potu siapo vala* using 2, 3, or 4 different *upeti*? Do those patterns create *siapo elei* that are balanced or unbalanced? How many patterns would seem balanced?

Siapo elei is a wonderful example of a Samoan art form that if analyzed with a mathematical lens we could interpret or analyze the unique thinking process of *siapo* makers. We could explore and discuss the mathematical decisions they made when carrying out their work. Due to the lack of access to *siapo* makers who carry on this older art form, this research project has developed more questions about *siapo elei* than I have provided in terms of explanation or answers. This is one challenge in this project but my hope is to carry this research on and seek answers to these questions.

SIAPO MAMANU

In explaining the second type of *siapo*, the *siapo mamanu*, I will be focusing on the style of *siapo mamanu* that occurred in the early 1900's on the island of Tutuila. It is acknowledged that the art of free hand painting on tapa cloth evolved throughout Samoa at different times based on evidence found in photos collected (Neich & Pendagrast, 1997). However due to the fact that I had access to a renowned expert on this style of *siapo* making, and because this style offered a mathematical uniqueness compared to the photographic analysis of other *siapo mamanu*, I chose to focus on the *siapo mamanu* style that originated on my island.

Beginning in the 1920's, a prominent *siapo* maker named Mary Pritchard, who worked with many *siapo* makers in the village of Leone, American Samoa, helped to publicize the most

common motifs found in Samoan *siapo* at the time. The motifs, she categorized, were heavily influenced by Kolone F. Leoso and many other women from the village of Leone (personal communication Reggie Meredith 4/15/2010). Kolone began to express a lot of her *siapo* making by free hand painting *siapo* designs. Kolone also found inspiration from objects in nature and her surroundings such as the breadfruit leaf, banana pod, starfish, turtle net, as well as the rose windows in the Catholic Church in Leone American Samoa. Below are pictures that help explain the process of making a *siapo mamanu*.



Figure 31. put cornstarch on a flat square or rectangular board and then spread u'a over board



Figure 32. Spread u'a and make sure there are no creases or bubbles then patch holes.



Figure 33. Apply more cornstarch and stretch top layer on bottom layer and then leave to dry while you collect fruit of pandanus to use as brush for dyes.



Figure 34. Free hand design begins followed by the finished siapo. **Source:** (www.siapo.com)

Where are the lines of symmetry? What patterns do you see? How did the artist use lines, shapes or color to achieve symmetry?

Mary was the first to identify and publish the motifs used in *siapo mamanu* in her book, *Siapo: Cloth Art of Samoa*. 12 of the most common *siapo* motifs identified by the women in Leone are pictured in Figure 35.1 – 35.12. Each of these motifs can be identified on many *siapo elei* but most of the *siapo mamanu* used these motifs exclusively. This was also clear when observing contemporary *siapo mamanu* from the 1920's- present that were influenced by the style developed in Leone, American Samoa. The importance of identifying these motifs and their geometric patterns will be discussed later in this paper.

Siapo mamanu motifs



Figure 35.1. *Faagogo* or *Faatuli* or *Favaetuli* (seabird) tern motif

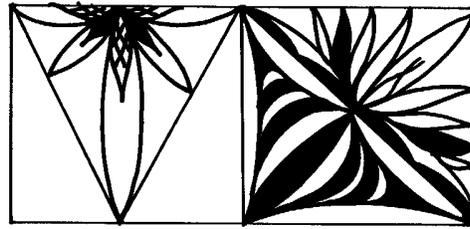


Figure 35.2. *faatumoa* or banana pod motif

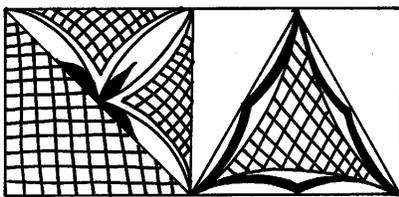


Figure 35.3 *faaaupega* or turtle net motif



Figure 35.4 *Faaaliao* or trochus shell motif

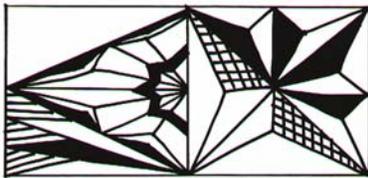


Figure 35.5 *Faalaupaogo* pandanus leaf motif

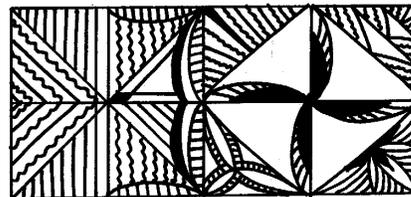


Figure 35.6 *Tusili'i* or small lines motif



Figure 35.7 *Faasigago* or male Pandanus bloom

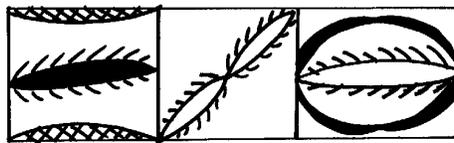


Figure 35.8 *Faaatualoa* or centipede motif



Figure 35.9 *Faalauulu* or breadfruit leaf motif

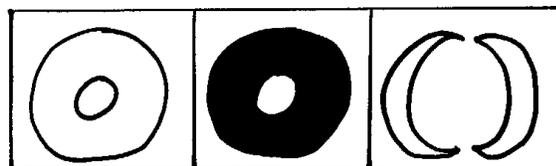


Figure 35.10 *Faamasina* or rolled pandanus leaves motif

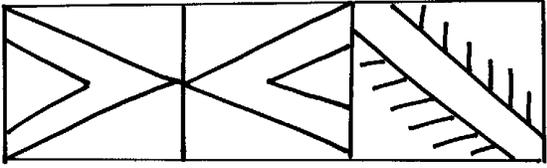


Figure 35.11 *Faaanufe* or worm motif

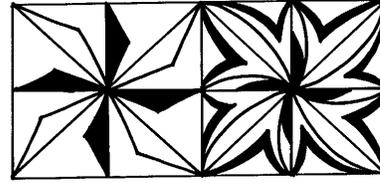


Figure 35.12 *Faaaveau* or starfish motif

(source: www.siapo.com)

The *siapo mamanu* is different from the *siapo elei* mainly because the motifs are hand-painted on the tapa cloth instead of being imprinted with an *upeti*. There is also one other major difference and that was that this *siapo* was often mounted on flat pieces of plywood. This was so that they could be mounted on walls easily once the *siapo* was made. Therefore it was primarily made for sale to tourists who would in turn hang it as they would a Mona Lisa. The free hand painting method resulted in the motif designs being distinctly emphasized and allowed *siapo* makers to be more explorative with their designs. What is also evident is that *siapo* makers took a sincere interest in using symmetry to guide the direction of lines and shapes, the placement of the motifs, and the use of colors (personal communication, Regina Meredith, 3/15/2010).

The Leone women developed norms for *siapo mamanu*. The main norm was that the 12 motifs were organized and identified (www.siapo.com). But the 12 motifs were to be used at the *siapo* artist's discretion. The result of the freedom was that motifs themselves often became smaller and more intricate as different ways to make the symmetrical designs became more complex. The second norm was that there was always an emphasis on **symmetry and balance** (personal communication, Ruth Mahuka, 4/29/2010, Regina Meredith 4/15/2010). This style of *siapo mamanu* became more popular on the island of Tutuila as different colored dyes were processed and introduced to *siapo* making. The red and yellow dyes made *siapo* *mamanu* more unique and offered a unique challenge to achieve symmetry.

Symmetry classifications of siapo mamanu

In Maria Aschers chapter 6 on symmetric strip designs she provides the name of 7 “symmetry groups” (p. 157) for designs that “do not involve color” and designs that do (p.161) these categories are shown in Figure 36 and 37 respectively (these tables can be found on p. 160, 164, &165 of her book.)

Although *siapo mamanu* have a few different characteristics than the strips analyzed by Ascher we will use these classifications to analyze the photographs of *siapo mamanu* that I have collected. We will focus on 3 of the 4 aspects mentioned in Ascher’s book: a) vertical and horizontal symmetry, b) translation, and finally c)180 degree rotation. One important note made by Ascher in terms of what I am about to do is that classifications become:

...a handy tool for analyzing and gaining insight into the internal logic of a strip’s design... but in our western analysis of strip patterns we make observations about symmetry and on that basis define categories. We cannot presume that the categories have any direct counterparts in another culture. The analysis, however, broadens our own visual vocabulary and enlarges what we are able to see. (p. 156)

Therefore we will use these classifications as a tool to look at designs on *siapo mamanu* but will not assume that if the pattern or coloring of motifs are asymmetrical based on the classifications that the *siapo* maker did not achieve some type of “balance or symmetry” (personal communication, Regina Meredith, 4/15/2010).

QuickTime™ and a
TIF (Uncompressed) decompressor
are needed to see this picture.

QuickTime™ and a
TIF (Uncompressed) decompressor
are needed to see this picture.

Figure 36. Source: (Ascher, 1991,p.160) **Figure 37 Source:** (Ascher,1991, p.164, 165))

Taking a look at HORIZONTAL or VERTICAL symmetry?

Using this classification system (Ascher, 1991), we can now take a close look at some samples of Samoan *siapo mamanu* and analyze their symmetrical patterns. Looking at the *siapo mamanu* below we can ask ourselves, what elements of symmetry can be found? Is there vertical symmetry for the whole piece? horizontal symmetry? If so how do you know? If not, what colors or shapes prohibit this? Can you find them? A red vertical and a blue horizontal line is drawn to illustrate the possible line of symmetry.

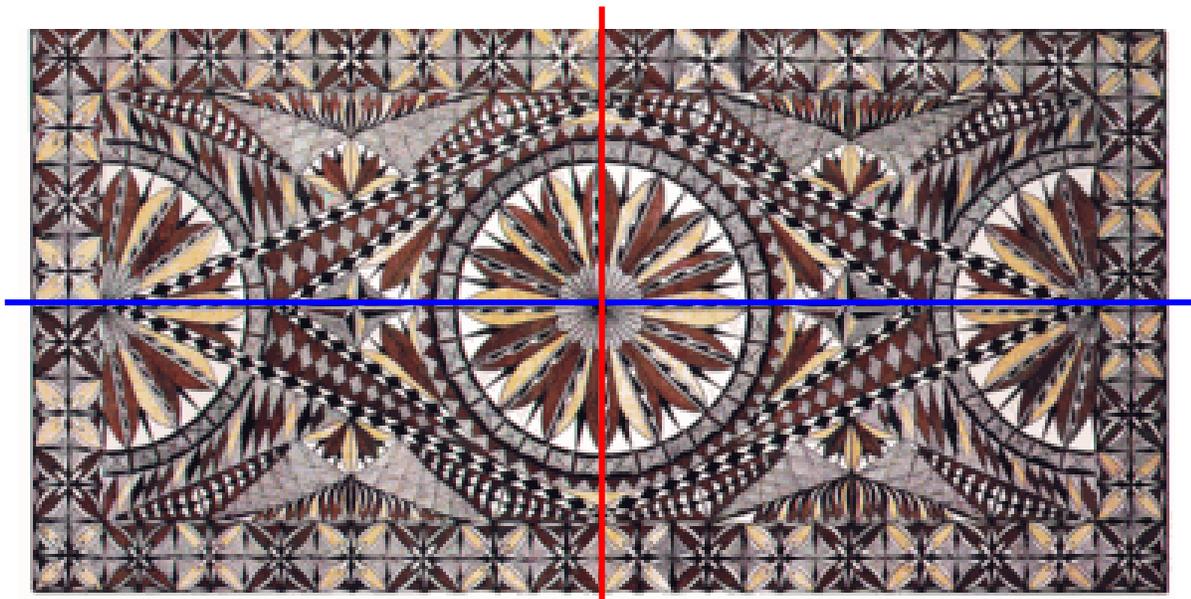


Figure 38. larger *siapo mamananu* Source: (www.siapo.com)

If your answer is “no” to the question about whether this *siapo* would be classified as horizontally or vertically symmetrical above you are correct. Which motif or color prohibits this symmetry? Notice the *Faagogo* motif (see Figure 35.1 below) in each corner and how they are different colors; The top left and bottom right are highlighted with the brown dye and top right and the bottom left one are highlighted with a yellow dye. If we take into account the two colors (brown and yellow) used to highlight the motif we might say that it is not vertically symmetrical and not horizontally symmetrical. But when a *siapo* maker designs her *siapo mamananu* the color brown and yellow are added last. The black dye is the only dye used to highlight the skeleton of the motifs. So at one point, with only the skeleton of the motif drawn, we can ask: was it symmetrical then? If we ignore the brown and yellow portions and focus on the motifs alone is it symmetrical? This is a great question that will lead to debate on the ethnomathematical point of view. But let us take a look at yet another *siapo mamananu* and ask the same question: is it vertically or horizontally symmetrical?



Figure 35.1 *faagogo, faatuli, faavaetuli*

Taking a look at the *siapo mamanu* in Figure 39 below we shall ask the same question: Does this *siapo* have vertical symmetry or horizontal symmetry? If so how do you know? If not, what colors or shapes prohibit this? A red vertical and a blue horizontal line is drawn to illustrate the possible line of symmetry.

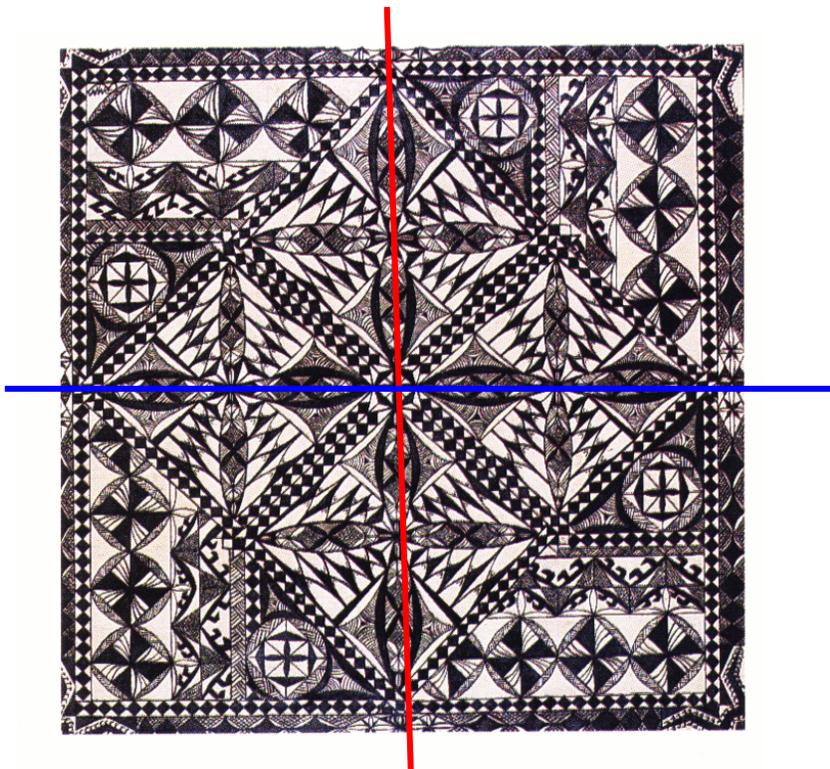
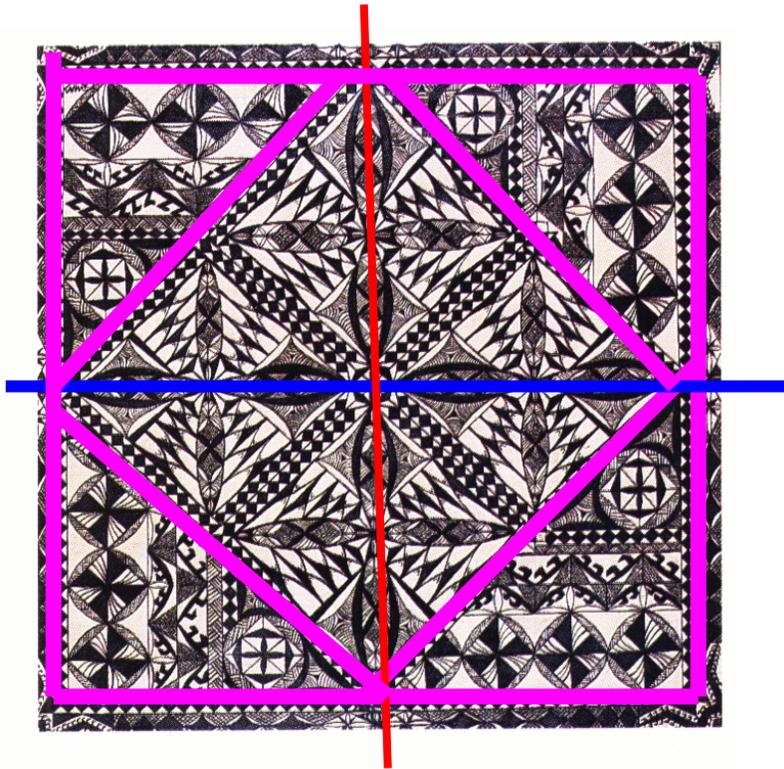


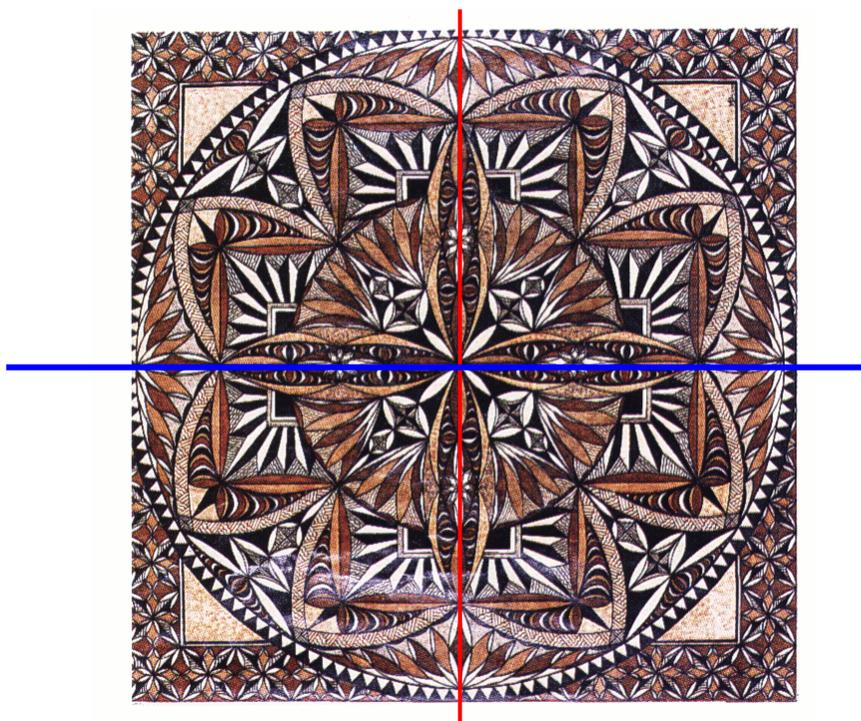
Figure 39. *siapo mamanu* made by Regina Meredith (**note:** the image is a bit slanted and a portion of the left border is cut out of view so please ignore the border when answering the question) **Source:** (www.siapo.com)

If your answer is “no” to the question about horizontal or vertical symmetry above you are correct. Which motif or color prohibits this symmetry classification to be used here?



Notice the motifs found in the four outer triangular sections of the siapo, that are enclosed in the purple lines, do not reflect across the red vertical line or the blue horizontal line. The following 2 motifs: *faaaturaloa* or centipede motif and the *faaaveau* or starfish motif are not vertically or horizontally symmetrical with its counterpart in each of the triangular sections. So by now one might ask, are there siapo mamamu that are vertically or horizontally symmetrical? Lets take a look at one more example and again draw our red and blue lines of symmetry. Here are a few questions to guide our analysis:

1. Is this *siapo mamamu* below vertically or horizontally symmetrical taking into account only the motifs that are outlined by the black dye?
2. Is this siapo mamamu below vertically or horizontally symmetrical taking into account both the motif and the use of black, brown, and yellow dyes and the areas of the u'a or tapa that are not colored?



Source: (www.siapo.com)

In this case the answer is “yes” to both questions. This siapo was painstakingly designed to make sure that motif’s shape, size, arrangement, orientation, and color were perfectly symmetrical along both imaginary lines of symmetry. Imagine the difficulty and mathematic skills involved in that task. It is not known how much measurement or what tools were used in this piece, but regardless it is amazing.

Taking a look at TRANSLATIONS?

Many siapo mamanu of this style had borders, which created the strip patterns similar to what is discussed in Ascher (1991). According to Ascher, when a design “involved color”, a more complex classification that involved “24 perfectly colored” symmetry groups was formed. Therefore we will use classifications on table 6.2 (p.164) to analyze the translation of motifs used in Samoan siapo mamanu. By taking a look at the *faagogo* or tern motif on the border of the siapo mamanu, in Figure 38 below, we can ask: Is the repeated faagogo motif an example of

translation? We can also break up this question into two parts: If we take into account the black, brown, and yellow dyes used to fill the motif, or the absence of dye, what classification can be used? If we only use the black skeleton of the motif itself, which of these classifications can be used to identify the repeated motion? Figures 39 - 42 below, represent 4 of the 24 possible classifications of the translation of the *faagogo* motif; Figure 39 and 40 represent translation when color is not involved and Figure 41 and 42 when color is involved. We will simplify this by focusing only on the *faagogo* motif in the blue rectangular section. This section we will call our strip. The red vertical lines will help us focus on the *faagogo* motif we are analyzing. Each *faagogo* motif is also numbered.

QuickTime™ and a
TIFF (Uncompressed) decompressor
are needed to see this picture.

Figure 39. Translation when color is not involved

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TIFF (Uncompressed) decompressor
are needed to see this picture.

Figure 40. Translation when color is not involved and horizontal reflection is present

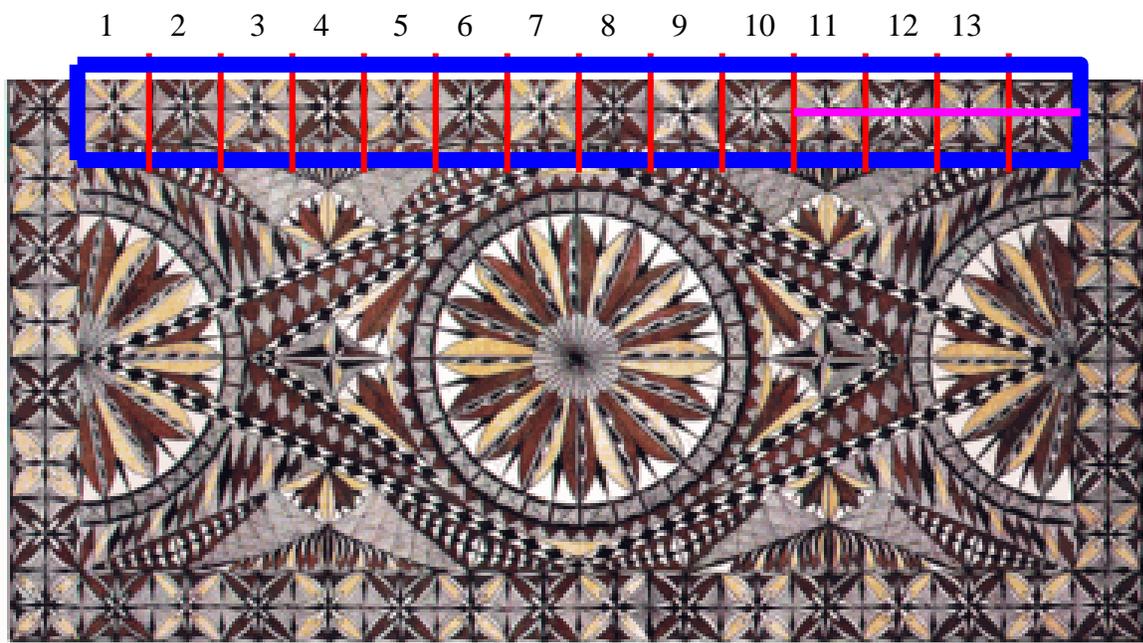
QuickTime™ and a
TIFF (Uncompressed) decompressor
are needed to see this picture.

Figure 41. Translation when color is involved and the color changes with each repeated motif

QuickTime™ and a
TIFF (Uncompressed) decompressor
are needed to see this picture.

Figure 42. Translation when color is involved and there is horizontal reflection but the color changes with each vertical reflection

Source: sections of table 6.2 (Ascher, 1991,p.164)



Which of these four classification best fits the pattern of translation when we take into account the brown, black, and yellow dyes actually used by the *siapo* artist? Which of the classifications best fits the pattern of translation when we don't take into account color of dyes used and only focus on the black outline of the motif?

When we look at section 1 the motif is brown but in section 2 what was brown is now yellow. In section 3 it is brown again. This pattern repeats itself in the strip. Although the shape of the motif remains unchanged the use of brown and yellow dyes to fill the motif alternate. This seems to match the classification in Figure 41 but does not match the classification of Figure 39. Does it fit any other classification?

When you look at the motif itself there seems to be line of horizontal symmetry that occurs within the motif. Take a look at the purple line in section numbered 11-13. This forms an imaginary horizontal line of symmetry. This would mean that it could possibly be classified as the shapes in Figure 42.

Taking a look at 180 DEGREE ROTATION?

Again we will look at a sample *siapo mamanu* to see if there are patterns drawn that would fit this classification. By looking at the *siapo mamanu* are there motifs that repeat by moving within a 180 degree rotation. The *siapo* artist accomplishes this below in a whole section consisting of various *siapo* motifs (centipede and starfish motif). Looking at the triangular section outlined in purple and using the large red dot as my point of rotation you will notice that if the motifs in the purple triangle were moved 180 degrees it would match the motifs in the yellow triangular section on the bottom. Can you find other examples of this type of rotation?

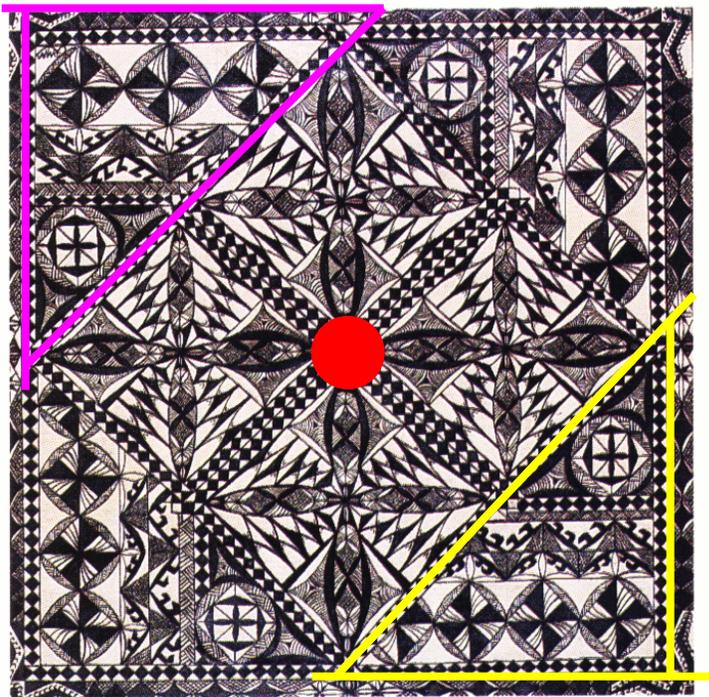


Figure 33. siapo mamanu made by Regina Meredith. Can you identify any of the 12 siapo motifs in this siapo? Source: (www.siapo.com)

Conclusion

After conducting the research on this paper I have realized that the applications of mathematics in siapo making is much broader than I originally thought. The beauty of discovering the mathematics is probably more exciting than anything. But cautiously I realize that the more mathematics I discover the more the questions need to focus on how the siapo makers envision the mathematical decisions they made.

This paper also taught me that I need to do much more interviewing and studying of siapo makers to answer the many questions that I have unanswered. My hope is that this paper serves as a launching pad to finding those answers. Much more comparison of the art of siapo making needs to be documented for future generations before the art and the mathematics behind the art is lost forever.

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(www.siapo.com, accessed 3/15-4/30, 2010)

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Ruth Mahuka (personal communication 4/29/2010)

Regina Meredith (personal communication 4/29/2010)

Tauiliili Pemerika (personal communication 4/29/2010)

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