

## Shape and Form of the Hawaiian Gourd

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The intent of this paper is to present research regarding the mathematics associated with *Lagenaria siceraria*, the Hawaiian gourd, called *ipu* or *hue*. What mathematical thinking did Hawaiians employ during cultivation, working with the fruit and in fashioning *koko*, or nets, for carrying *ipu*? Due to time constraints, rather than considering the fashioning of *koko* (learning to make the nets requires an apprenticeship to a master net-maker), the focus shifted instead to the geometry in completed *koko* and related designs on the *ipu pawehe*, gourds decorated with designs.

### The Ipu or Hue

More than any other Polynesian culture, Hawaiians developed the widest variety and greatest number of uses for the gourd. Dodge (1995) catalogs forty-three applications and describes their importance in Hawaiian life.

The conditioning of a Hawaiian was particularly influenced by the presence of gourds, and countless were the manifestations of this plant upon his life. He was brought up on the myth that the heavens were the top of an enormous gourd, that the earth was its lower half, and the celestial bodies were the seeds and pulp thereof. Throughout life he drank his water from the gourd bottles, ate his food from gourd bowls, danced to the rhythm of gourd drums, called his lover with the low notes of a gourd whistle, and at last, after death, his bones were perhaps cleaned and kept in an ossuary urn made of a gourd. (pp. 2-3)

Pre-contact Hawai'i had many varieties of gourd with fruits of different shapes and sizes, with rinds and shells of a variety of thicknesses. Some were unique to particular islands and even areas of islands. Two of the smaller varieties were the *ipu manalo*, or sweet gourd, and the *ipu 'awa 'awa*, or bitter gourd. The pulp of the sweet gourd could be eaten while the pulp of the bitter gourd was poisonous; it could be used for medicinal

purposes when highly diluted. The harder shell of the bitter gourd was used for utensils and required an elaborate cleaning process. While the sweet gourd could be used immediately after cutting off the top and cleaning out the pulp, the bitter gourd had to be cleaned, dried and then soaked. One process required the bitter gourd to be filled with salt water and changed for ten days to neutralize acidity.

A giant variety, *ipu nui*, used to make hula drums and trunks, was endemic to Hawai'i and is thought to have gone extinct before the mid-nineteenth century. However, according to Rick Barboza, a native plant specialist on O'ahu, viable seeds of the *ipu nui* were recently found in a cave, and the plant is now in cultivation once again.

### **Shape and Form in Cultivation**

Great care was given to the *ipu 'awa'awa* during its cultivation. To create *ipu* suitable for bowls, for example, a farmer would place the growing fruit upright over a *po'aha*, a ring of spread out grass or leaves, and later a board, to creating a rounded fruit that could stand unsupported. Some would be suspended by the stalk from a wooden tripod to make the fruit grow larger and more symmetrical. Two forms, one squat and one deep, were grown to make bowls. The deep *ipu* was taller than it was wide, while the squat had a diameter greater than the height; if it grew large (about twenty or more inches in diameter with a thick rind ranging 0.6-1 inch), it was given the name *ipu nui*.

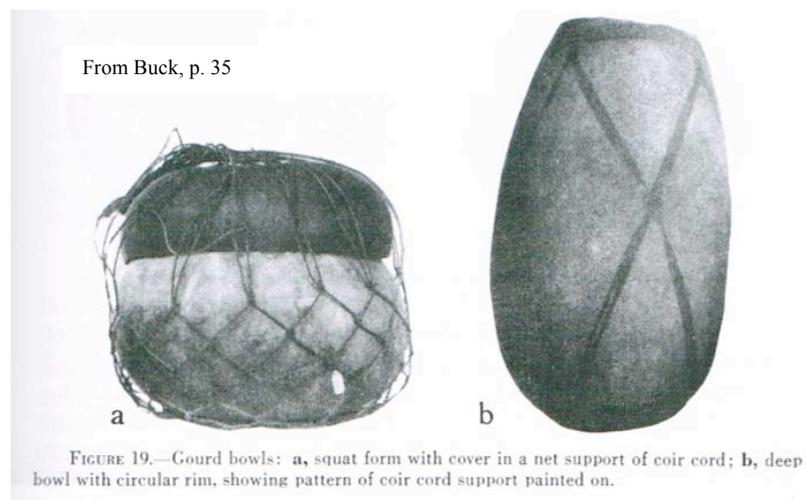
Before planting the seeds of the *ipu nui*, it was believed that a pot-bellied man should eat a large meal so that the gourd would be large and round like his stomach. While planting, he was to stoop as he carried the seed, holding his arms out as if embracing the huge fruit and drop the seed suddenly with an outward motion of the

hands, palms up so that the gourd would not be crooked or shriveled from the twisting or turning of the palms.

### Shape and Form of Containers

Containers of various shapes and sizes were made from cutting the gourds. Some were categorized according to their shape, what they held or a combination of both. Some examples: small squatty, *no 'uno 'o*; larger, shallow *paka*; large and small pear-shaped *kaku* and *kiku*; big, round containers called *hulilau* for carrying food or *kapa*; long gourds, or *hokeo*, for fishing lines or for carrying *kapa* at sea.

Two forms of gourd bowls, (*'umeke pohue*), would be produced depending on whether the gourd was squat or deep. If the gourd was squat, the stalk would be cut off horizontally above the maximum diameter to retain as much height as possible. Covers would be made by cutting off the bottom of another gourd with a large enough rim to fit easily over the rim of the bowl. If deep, the stalk end would be removed horizontally to form a rim opening near the top.



Dodge (1995) discusses how water bottles, or *huewai*, could be divided into three types: (1) those for use in the household; (2) those for use at sea aboard canoes; and (3) those taken into the field or to work. Household water bottles could be further divided into two types: large and globular-shaped with a long thin neck or hourglass shaped. He found that the hourglass shape could be further organized into sub-types, and the *'olowai*, canoe water carriers, were different than all of the others. Made from long, thin gourds, a mouth would be formed by cutting off the end of its curved stem so that water would not spill out when the gourd was laid on its side.

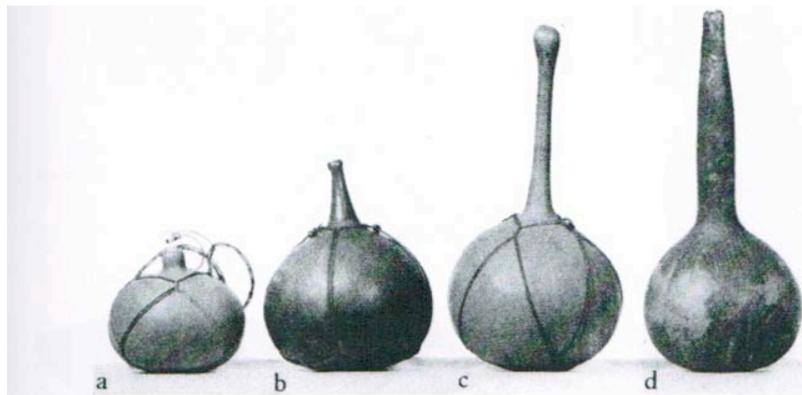


FIGURE 35.—Gourd water containers, globular with tubular neck: a, short neck, typical cord support; b, medium neck, braid support; c, long neck, typical support; d, long neck, no support.

From Buck, p.57-58

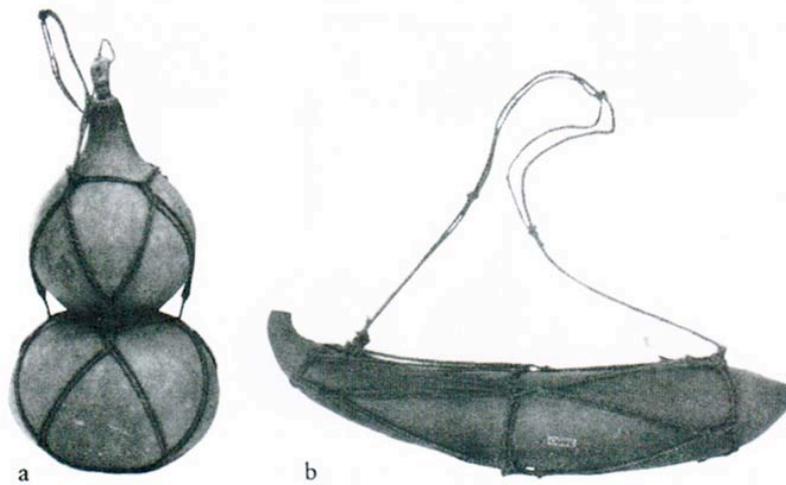


FIGURE 36.—Water gourds: a, hourglass form; b, cylindrical.

Buck (1957) discusses the 120 water containers at the Bishop Museum and categorizes them into three main forms: (1) the normal, globular shape with variations in the shape of the neck; (2) the hourglass form, *huewai pueo*, with two globular parts separated by a constriction; and (3) a long, cylindrical form or 'olowai. Some sources say that a departure from the general globular shape was produced when cultivators tied bandages around the green fruit as they grew, while other sources maintain that all forms were the result of natural growth (Buck, 1957; Handy, 1991; Stokes, 1906).

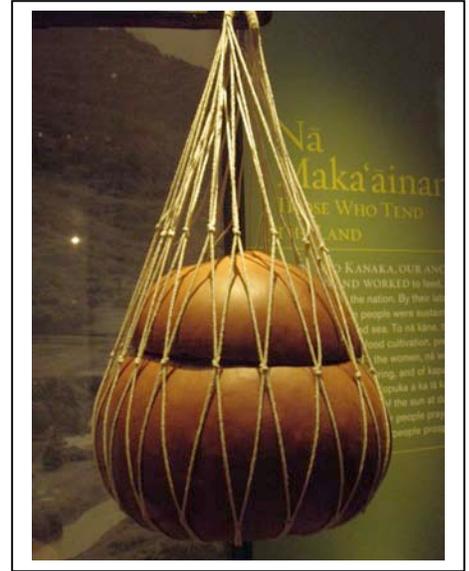
### **Some Measurement in Koko**

“The koko is a bag of cord netted or knitted in the shape, when suspended, of an inverted hemisphere superimposed by an elongated cone” (Stokes, p. 112). To fashion a koko, the netmaker began at its base to create the *piko*, or navel (also called the *kumu*, or root and *ho 'omaka*, or starting point). The main body of the net was called the general term koko, but it might also be called *hanai* or *opu*, belly. The third part, the *kakai* or *alihi*, were suspension cords connected to the outer edge of the *hanai*, and a *pu*, or handle, was made at the top of the *kakai*. A carrying stick, *auamo* or *aumaka*, could be carried across the shoulders like a yoke, and notches at each end held the *pu*. Koko would also be suspended from a wooden hook, or *kilou*, attached to the ridgepole of the hut or placed on top of a pole set in the ground.

There were two classes of koko: the *koko pu 'upu 'u*, the property of the *ali 'i*, the chiefly class, and the *koko pu 'alu* used by the commoners. *Koko pu 'upu 'u* demonstrated more sophisticated craftsmanship; the knotwork was elaborate and they were made of superior cord. The knots used for the more practical *koko pu 'alu* were the *ka*, the simple

fisherman's knot, or more rarely the *makili*, the square or reef knot. The mesh was typically large and plain.

Koko pu'alu I photographed at the Bishop Museum



Koko pu'upu'u I photographed while at the Bishop Museum



Gourds became less useful toward the end of the nineteenth century; by the 1970s, the ways of its crafts were nearly lost. I interviewed Val Ching, Jr., one of a few people

who currently work with koko. He has spent the last couple of decades re-creating koko and now is attempting to teach others so that the craft will not be lost.

A specific koko with a unique piko, called *hawele*, would be fashioned for hūewai. The cordage was valuable, and what made koko hawele especially useful is that once the gourd within the net was no longer functional, the koko could be reclaimed.

“This structure is so unique to Hawaiians, so functional,” says Ching. “They crack [the gourd]. They open this [cord] up. They’re on their way in less than one minute. They save their cord.”

The technique developed was to tie one round below the neck, carry the cord down to form a double round on the bottom and connect the top and bottom rounds by a series of four loops. The bottom round could not slip upward, owing to the convexity of the sides of the gourd; and the four connecting loops, evenly arranged, effectively fixed the upper round in position. After tying the first top round with a knot, the bottom rounds and the connecting loops were made with one continuous cord and, by interlacing the crossing, knots were avoided. (Buck, p.61)



*My photographs of the piko and hanai of Val Ching Jr. 's koko hawele for hūewai.*

When asked what mathematical thinking ancient Hawaiians employed to make koko, Ching describes his process for measuring the amount of cord he needs for a koko hawele: “What I do is figure out the base [the amount of cord to make the piko]. From there I need four times that—say this [amount] is each eye that I wanted, plus this section—so I’m going to need four of these. Double. So now I just open this up [the

cord]. And go four times this. [He measures a length of cord against his outstretched arm]. Older Hawaiians would think about length by considering the task at hand. The Hawaiians measured [with their] finger, hand.” Ching estimates that the average koko hawele today requires twenty to thirty feet of cord.

When considering the mesh of the net that forms the hanai, Hawaiians measured the *maka*, or eyes, using the width of their fingers. If one finger filled the *maka*, the mesh was called *makahi*; if two fingers were needed, it was *malua*; for three fingers, *makolu*. (In modern Hawaiian, *‘ekahi* is one, *‘elua* is two, *‘ekolu* is three and *‘eha* is four.) For sizes between, the words *oene* or *oa* were added to the name of the smaller mesh. For example, *makahi oene* is about one and one-half inches, and *malua oa* is about two and one-half inches. Two sizes smaller than *makahi* had special names: *nae*, about a quarter-inch and *nukunukua ‘ula*, about one-half inch. *Mahae* was four or more inches and *malewa* was seven or more inches.

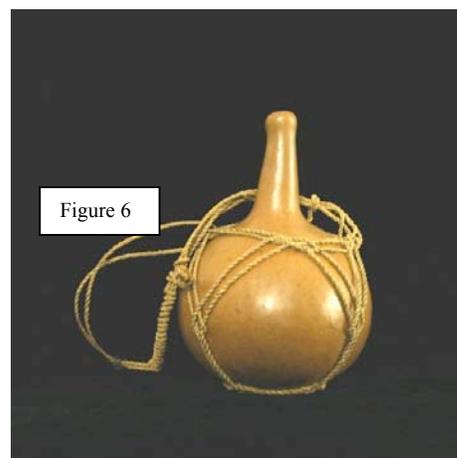
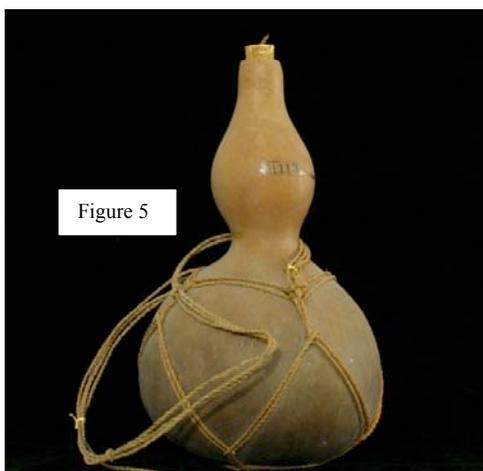
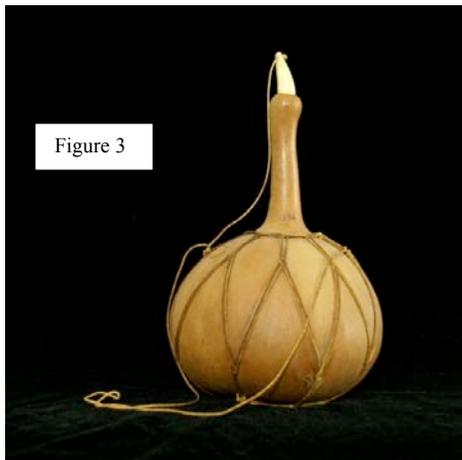
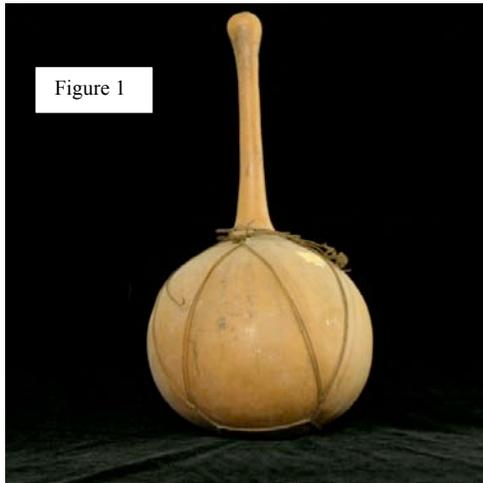
## Geometry in Koko

### Koko Hawele for Huewai

Although there were variations, it appears that most piko of the koko hawele were rectangular, perhaps because rectangles required the least amount of cord and fewest connecting loops compared with pentagonal, hexagonal and circular piko. Regardless, resulting hanai could have triangular shapes adjacent to the sides of the rectangle if the hanai began directly at the vertices of the piko (e.g., Ching’s koko hawele above and the top of the koko hawele in fig. 6 below). If there were line segments of cord, short loops, extending from the piko to the first hanai loop, then isosceles pentagons are formed (figs. 1 and 3-6 below). Regardless of the types of shapes, they all revolved around the center

of the piko, resulting in rotational symmetry and multiple vertical lines of symmetry at the vertices and midpoints of line segments of the piko.

The following photographs are from the Bishop Museums on-line Ethnology Database at [http://www2.bishopmuseum.org/ethnologydb/entire4.asp?NAME1=&NAME2=huewai&AREA=&MATERIAL=&MATERIAL2=&ARTNO=&Personage=&Donation\\_name=&Island\\_Group=&Island=&ISLAND3=&ISLAND2=&Submit=Start+Search&offset=0](http://www2.bishopmuseum.org/ethnologydb/entire4.asp?NAME1=&NAME2=huewai&AREA=&MATERIAL=&MATERIAL2=&ARTNO=&Personage=&Donation_name=&Island_Group=&Island=&ISLAND3=&ISLAND2=&Submit=Start+Search&offset=0)



## Koko Pu'alu and Koko Pu'upu'u

Of piko and hanai, Stokes (1906) observed and described fourteen forms among the koko pu'upu'u and koko pu'alu. However, according to Ching, there are errors in the Stokes article, and the method of tying these koko and their complex piko is forgotten today.

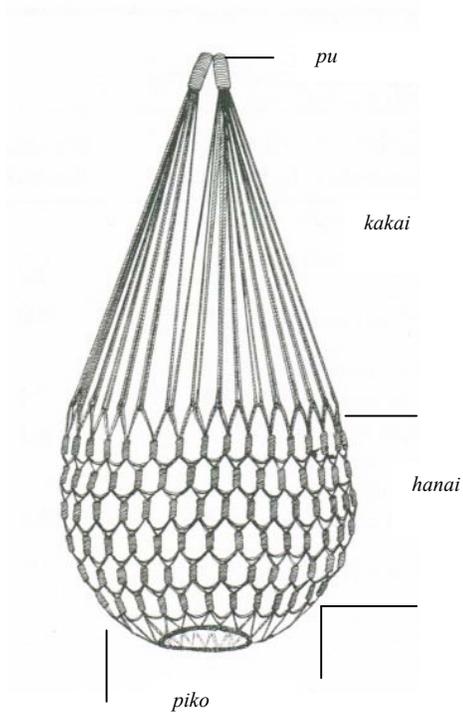


Figure of *koko pu'upu'u* from Summers, p. 84



Figure of *koko pu'alu* from Summers, p. 84

The koko pu'alu were used primarily by the *maka 'ainana*, or commoners; they were therefore less elaborate and required less cord. It was fashioned around a simple circular piko, a ring of cord to which a row or circle of loops would be attached by loops, knots or half-hitches. From this ring radiated alternating triangles and rhombi with rotational symmetry around the center of the piko. Because the koko pu'upu'u, were more elaborate, various shapes could be superimposed on an underlying matrix of acute

triangles and shapes derived from them, such as rhombi (never squares, as it appears no right angles could be formed without cord added horizontally around the gourd) and hexagons. There are many vertical lines of symmetry in both koko due to the circular shape of the piko.

When the kakai are connected to form the pu, they generally form kite shapes with the top pairs of adjacent equal line segments longer than the bottom pairs of adjacent equal line segments. This is because the top two lines of the last shape formed at the top of the hanai are looped with cord to form two line segments formed by the cord of the kakai brought together at the pu.

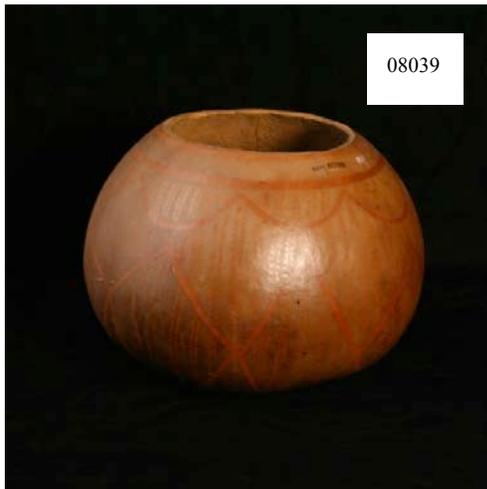
### **Geometry in Ipu Pawehe**

The exact method of creating the geometric designs on the ipu pawehe had not been known until 1980s when experimentation began, thus resurrecting the craft. One method has the craftsman scratching designs into the green ipu, filling the ipu with dyeing medium and then drying.

Varying types of designs are found in the old ipu pawehe. Greiner categorized the designs on the Ni‘ihau ipu pawehe as “Those similar to the meshes of a net, or interlocking ovoid figures; horizontal lines bordering rows of triangles, diamonds, or hexagons; circles; and tattoo or petroglyph designs placed irregularly on the gourd.” (Stokes, p.74)

When examining pictures of ipu pawehe in the Bishop Museums’ on-line Ethnology Database, transformational geometry is observed. For example, in artifact 01070 below, the top row of figures shows a triangle being horizontally translated

while the third row is a horizontally reflected (although non-similar) triangle horizontally translated. The following row has a shape translated horizontally and then reflected vertically and translated again horizontally to make the bottom row showing.



The above photographs are from the Bishop Museums on-line Ethnology Database at <http://www2.bishopmuseum.org/ethnologydb/type2.asp?type=ipupawehe>

Artifact numbers 07670, 08039 and 0098 also have horizontally translated shapes in the top portion of the bowl. Below that is found the common net pattern similar to that of the koko pu'alu inscribed with decorated vertical line segments.

## Conclusions

What mathematical knowledge is needed to cultivate ipu, to create various containers, to fashion the koko and to create geometric designs on ipu? Before answering this question, it's important to note that categories and distinctions, as well as any conclusions I may reach by considering them, are drawn through my modern, Western lens. Stokes writes:

There are many attractive patterns in the koko pu'upu'u, to which no native in these days is able to attach any significance or name. One old native, after being questioned in vain, remarked disgustedly: "The *haole* (foreigners) want all the time to put a number or a name on everything, but these to the natives were just koko."

I believe that we can lose much of the culture and history of a craft by subjecting it to the critical eye of a foreigner from another time. However, for the purpose of designing a curriculum for today's students, it's necessary to examine this ancient craft using modern frames and language.

It appears that the human form was a tool for relating to objects and to the environment. When measuring the mesh of a koko, Hawaiians used the width of their fingers. They also considered the shape and form of the farmer when planting seeds with the belief that his shape would affect the shape of the fruit. When explaining how deeply taro ought to be planted, Ching outstretched his arm to show that it should be the depth between the hand and elbow; similarly, he estimated the length of cordage he needed to tie koko using his arms.

Impressing is the ability to estimate the length of cord needed to make a series of knots on the more elaborate koko. How might I consider the task at hand? What kinds of knots would I like to make? How many knots could a particular length of cord make?

How many knots would I need to meet the circumference of an ipu at its various heights? Through multiplicative thinking, proportional reasoning and addition, I may be able to decide if I have enough cord, or how much more cord I would need. Should I then continue with the originally intended knot, or consider another one? This does not include the underlying basic net mesh.

To make the net of the hanai and the decorative knots of the koko pu'upu'u, Hawaiian net-makers must have employed sequential thinking along with spatial visualization, counting and problem solving. The knitted knot, *pu'u*, according to Stokes, was an entirely Hawaiian invention that may have been adapted from contact with sailors and missionaries. However, even one of the simpler knots such as the ka, and as Ching will attest, the lashes and hitches of the koko hawele (that he worked to perfect for about seven years) take problem solving and reasoning.

Regardless of whether Hawaiians bound the fruit to create particular shapes, they had to classify by size and shape to choose particular fruit for particular uses. Different sized ipu would be used for different purposes, evidence of an understanding of volume and its dimensions. Also, their knowledge of symmetry allowed them to cultivate fruit shaped appropriately to make bowls and other containers.

In order to create the ipu pawehe, Hawaiians must have had knowledge of congruency. They created congruent shapes over and over, often translating the shapes horizontally across ipu. Some of those same shapes are then reflected on the same ipu. In addition, they created congruent shapes representational of the mesh of the less elaborate koko. Hawaiians must have employed multiplicative thinking to plan the

iteration of congruent rhomboid shapes to cover an ipu, evidence of an understanding of surface area along with its constituent lengths.

This paper presents a mere survey of the mathematics and mathematical thinking associated with the cultivation and crafts of the ipu. In order to begin to truly understand the complexities and subtleties of the Hawaiians' understanding of space, quantity, size and pattern, it would be necessary to participate in the craft. Therefore, an implication for further study is to apprentice in koko making and ipu pawehe design.

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### Interviews

Valentine K. Ching, Jr., male, Kailua, Hawaiian craftsman, April 2010

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