Mathematics in Building the Outrigger for a Racing Canoe

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Introduction

Learning about building an outrigger (*em*) for a racing canoe (*oak in akuhtuhn*) will soon become a factor to achieving math competency in 1st, 4th, and 7th grade levels in all the five elementary schools in Kosrae. This may sound farfetched; however, based on questionnaires and a sample test, which I devised in the nature of Project Macimise and piloted to 4th graders at Malem Elementary School, data collected are very promising. Historically, "Kosrae has several different kinds of canoes, or at least it did in its history: ocean-going canoes, racing canoes, local around-the-reef canoes" (Beardsley, 1999, p.1). "Dugout canoes, with outriggers extended to the right on booms, were used for fishing and traveling around the island or through the mangrove swamp channels at high tide" (Buck, 2005, p. 19). Today, canoes one sees are mainly for carrying cargo to and from Walung, which remains accessible only by boat or canoe.

Moreover, outrigger canoes were extremely essential to the life of early Kosraeans since they depended on the sea for survival. Men used to carve the outrigger canoe from the breadfruit and other forest trees and tied it to other wooden pieces with coconut sennit. "Men carve outrigger canoe, especially racing canoe from the *ka* (*terminalia carolinensis)*, a type of forest tree seen only in the Caroline Islands" (Tulenkun, 2010). Today, canoe building has just recently begun to be taught most especially during canoe racing competitions, and models are crafted and sold to the tourists.

Description

Since this paper will focus mostly on the racing canoe, it's very imperative to mention at the very outset that building a racing canoe is a very intricate practice, and it is customarily done by only experienced canoe builders, who have become a rarity in Kosrae today. This paper will chiefly focus on one particular component of the racing canoe, which is building the outrigger. Also, it is the specific goal of this paper that it connects "local knowledge to school knowledge" (*Math in a Cultural Context*, p.1). Building an outrigger for a racing canoe involves the following stages, and the cultural mathematics involved in each stage are as follows:

First and foremost will be the *ka*-cutting stage (*pacl in pakiyac ka ah*). After the *ka* is cut down for the racing canoe, the hibiscus *tiliaceus* (*lo*) for the outrigger is likewise cut. In fact, at this initial stage, mathematics is already becoming apparent. For instance, simply looking at a bush of *lo* and comparing size and shape to determine the best one for the outrigger fosters invaluable mathematical thinking. Even before the outrigger is cut, comparisons of size are already made with existing things by looking (Owens, para. 7). Consequently, mathematics involved in the initial stage ranges from 1-digit addition and subtraction to two-digit addition and subtraction for 1st grade level. Hence, arithmetic knowledge is most significant in which the master racing-canoe builder and his support staff (the number depends on the size of the canoe) would have to be aware of the most suitable *lo* either in the vicinity where the *ka* is found or at another secluded area, which is only known by the master canoe-builder. Culturally, the outrigger builders eventually may have to resort to using one of the following cultural counting systems, which focuses on one to ten.

Kosraean counting systems (from Leeling, 2010, p.1)										
Language	1	2	3	4	5	6	7	8	9	10
Kosraean	*sie*	*luo*	*tolu*	*ahkosr*	*limekosr*	*ohnkosr*	*itkosr*	*alkosr*	*yuc*	*singuhul*
Old Kosraean	*sra*	*lo*	*tol*	*ang*	*lum*	*on*	*it*	*al*	*yuc*	*singuhul*
Kosraean Giants	*sra kah*	*rokah*	*tor tor*	*pah tah*	*si re*	*sprah re*	*re ti*	*re twa*	*sor sor*	*acng*

(Note: "Kosraean Giants" is a specialized vocabulary attributed to legendary figures, who used to settle among the Kosraeans before the island's contact with the modern world.)

As part of the tree-cutting stage after the hibiscus (*lo*) is cut, the branches are cleared. Then, they are stripped and posted vertically to be dried. The *lo* should never be laid horizontally on the ground to be dried. Otherwise, the outrigger won't be straight when dried. Hence, more addition questions arise among the outrigger builders and below are two of many.

1. How many *lo* are needed for the outrigger? "Culturally, the actual length of the outrigger should be commensurate to the distance between the first seat (*loa se meet*) and the last seat (*loa sahflah*) in the canoe" (Tulenkun, 2010).
2. What is the actual length of the racing canoe? If the length of the canoe is 6 *fahtuhm (*outstretched-arms*),* typically two hibiscus trees may be needed. Finding the length of the outrigger is customarily done through the following:
    a. A cut-out vine (*op*): One person holds the top end of the vine while the other grabs the bottom end. The length is marked by either a sharp object (a piece of wood or fingernail) or the dirt. In all, measurement of the *lo* at the cutting stage is customarily and largely based on visual memory through comparison.

b. A piece of wood: Measurement done through this improvised means resembles that of the cut-out vine.

c. A strip of hibiscus bark (*ne*): Customarily, two or more *ne* will be needed due to the length of the outrigger. The measurement done through the *ne* is generally the same as the above-mentioned means. Sometimes, the measurement could also be done with a long braided strip of coconut fiber (*fuh*).

d. Outstretched Arms (*fahtuhm*): Full extension of both arms measured from middle finger to middle finger (a fathom) is customarily used by Kosraeans, so when measuring, they get one of the aforementioned improvised means, extend their arms on top of it, and mark it. Then they use it as their main measuring tool.

e. Comparison: The *em* often has to be lifted and laid next to the canoe to be compared and measured (Tulenkun, 2010).

The subtraction concepts apparent at this stage range from cutting off the *lo* if it's too long for the racing canoe to stripping its bark. Stripping off the bark from the *lo* is crucial because it not only lessens the weight of the outrigger but also expedites its drying process. Consequently, not only the outrigger builders should know about subtraction but also learners (students) of outrigger building. For 1st graders, since they need to master subtraction, following will be two of many subtraction-oriented questions they will inevitably face in building outrigger for racing canoe.

1. What is the difference between the length of the canoe, which is 6 feet, and length of the outrigger, which is 4 feet?

If the weight of the outrigger is 90 1bs. before it's stripped and 70 lbs. after it's stripped, what's the difference? (Usually in Kosrae, finding the weight of an outrigger is determined by either hefting it or comparing it to another outrigger. A typical *lo* for a racing canoe outrigger should be lighter and older than others. The heavier ones slow the canoe, and the younger ones are easily cracked as they're dried under the sun.)

For fourth grade level mathematics at the tree cutting stage, 4th graders should know multiplication of whole numbers among many other objectives. So the following will be possible mathematical problems 4th graders will soon come across.

1. If one *fahtuhm* (fathom) is 6 feet, how many feet in 3 *fahtuhm*?
2. If the length of a racing canoe is 4 fathoms, what will be the length of each *lo*, if it takes 2 *lo* trees to build the outrigger of the racing canoe? (Hint: 1 fathom = 6 feet.).

Number of *Lo*		Length of Each *Lo*		Length of Racing Canoe
a. 1	x	_____ ft.	=	3 fathoms
b. 2	x	_____ ft.	=	4 fathoms
c. 3	x	_____ ft.	=	5 fathoms.
d. 4	x	_____ ft.	=	6 fathoms

The learning objectives for 7th grade level mathematics at this tree-cutting stage may range from knowing number sense, patterns, and algebraic thinking to understanding probability. To begin with, the 7th grade students should be able to answer the following questions:

1. For number sense:

a. What is a fathom?

b. How many feet in a fathom?

c. How many inches in a foot?

2. For patterns:

a. Building an outrigger for a racing canoe can help one learn more mathematics by recognizing and memorizing its typical pattern. For example, at this stage, specific pattern-like instructions would be as follows:

i. Write the pattern and determine how the numbers are related.

ii Find the rule that makes the pattern.

iii. Solve the problem.

a) Read the problem: The height of the *lo* has increased over the two months. During month 1, the *lo* grew from 5 feet to 7 feet. During month 2, the *lo* grew to 9 feet. If the *lo* continues to grow at this same rate, how tall will the *lo* be at the end of month 3?

b) Determine the relationship: 5 + 2, 7 + 2, 9 + 2, …

c) Write the rule: Add 2 feet for each month.

d) Solve the problem: 5 + 2 = 7, 7 + 2 = 9, 9 + 2 = X . The *lo* will be 11 feet at the end of month 3.

e) Write the pattern:

Month	0	1	2	3
Height in feet	5	7	9	? (Shea, 1995, p.104)

3. For algebraic thinking:

    a. What would be the x number of *lo* trees that will make an outrigger that can be commensurate to the actual length of the canoe? Normally, a *lo* grows to an average height of 15 feet in Kosrae, so if a canoe builder were to build a 12-seat racing canoe, which is approximately 48 feet, he obviously needs at least two *lo* trees for the outrigger. The two *lo* trees then would be carved and joined at the centermost part of the canoe, which is between the two booms. (See the photo above) The two joined ends should then be cut to make two approximately 45 degree angles and then tied or clued (Edmond, 2010).

b. Knowing that the length of a canoe is 17 feet and one of the *lo* trees is 12 feet and wanting to find the length of the other *lo* tree since it usually takes two *lo* trees to build an outrigger for a 10-seat racing canoe, algebraic thinking eventually becomes apparent, and below may be the sequence:

i. $X + 12 = 17$

ii. Step 1 is to subtract 12 from both sides of the equation to isolate X.

a) $X + 12 - 12 = 17 - 12$

iii. Step 2 is to simplify the equation.

a) $X = 17 - 12$

iv. Step 3 is to solve the right side of the equation.

a) $17 - 12 = 5$

v. Step 4 is to rewrite the equation

a) $X = 5$

vi. Step 5 is to verify the solution by substituting for X.

a) $(5) + 12 = 17$

The Correct answer is $X = 5$ (*Super Review*, 2004, pp.117-118)

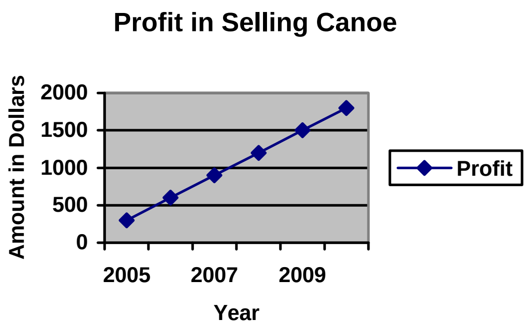
4. For probability:

7th graders would work with a line graph that shows profits from selling racing canoes over a 5-year period from 2005–2010. Currently, an *oak in akuhtuhn* is sold at $100 per *fahtuhm*.

a. Read the problem:

What was the increase in profits from 2005–2010?

b. Read the graph for facts:



Use these steps when finding the needed data

i. Locate the year on the horizontal scale along the bottom of the graph.

ii. For each year, move up the line to the dot and back to the vertical scale along the side of the graph.

iii. Write down the data:

Data: In 2005 Tulenkun earned $600 (6 X 100)

In 2006 Tulenkun earned $900 (6 X 100)

c. Solve the equation:

$900 - $600 = $300

The profits for Tulenkun increased by $300

The second stage in building an outrigger for a racing canoe is carving and streamlining (*pacl in tuhfahlfahl*) the outrigger. The thinner and lighter the outrigger is, the faster the canoe sails. When carving and streamlining, these are the mathematical steps involved:

1. First, make certain the *lo* lies horizontally on top of two elevated posts, the flat side up while the rounded side down. Also, the smaller part should face the front.
2. Second, get the proper tools, which would be simply a machete (*mitmit*) or a small ax (*tuhla*).
3. Third, attempt to carve (*tuhfahlah*) the frontal side of the *em* first before the other side. When done, the *em* should resemble a trapezoid or an anvil.
4. Fourth, grate (*koaclah*) the *em* using a *mitmit*, and then streamline (*ahkfelyelah*) it using shells.
5. Finally, the *em* should be drilled with 4 holes to be commensurate to the 4 *loks* (Y-shaped posts), drilled into the four holes on top of the *em* (Edmond, 2010).

In addition, following will be more mathematical practices prevalent in this second stage. Again, these following grade levels are obviously targeted simply because they're the main focus of Project Macimise.

1. For 1st graders, the emphasis should be on two-digit addition and subtraction. They should be mindful of the following inquiries:
   a. If two outriggers are prepared, and one takes 2 hours to carve and streamline while the other takes only 1 hour, what is the total number of hours taken in carving these two outriggers?
   b. For subtraction, the grating with the knife could be equated to subtraction. Hence, a culturally-relevant subtraction problem is "If the *lo* weighed 25 lbs. before it's skinned, carved, and streamlined, and 20 lbs. afterwards, what is the difference?

2. For 4th graders, the emphasis should be on geometry and measurement, and below are two of many culturally oriented activities they should ponder.
    a. By this stage, the final shape of a typical outrigger for a racing canoe could be seen, which resembles that of a trapezoid. The primary tool needed at this juncture to transform the *lo* into this quasi-trapezoid shape is simply a machete or an ax. Hence, for the geometry-related activities, it is important that the trapezoid formula be memorized and utilized.
    b. The measurement involved in carving and streamlining an outrigger rests entirely on ascertaining the outrigger's correct weight. Again, the Kosraean cultural practice of squatting and hefting the outrigger or any heavy objects to find its weight resembles that of the indigenous Papua New Guineans. Like the New Guineans, Kosraeans also weigh "(by hefting with the hands) the heaviness and lightness, length (long or short) and size (big or small) and finally group them in order of their size, length, and weight …" (Owens, para. 7).
3. For 7th graders, the emphasis should be on volume and surface area. At this stage, 7th graders should be able to determine volume and surface area by hefting with their bare hands the outrigger and comparing its volume with existing outriggers or simply with their vivid visual memories of a typical racing canoe outrigger.

The third stage of building an outrigger for a racing canoe deals with assembling the two booms (*kiacs*) and other integral elements of the outrigger—two attaching wood (*suhkan em*) and four posts (*lok*). The *kiacs* and the integral elements are made from hard mangrove wood and they are tied to the rigger by the coconut *fuh* (Beardsley, 1999, p. 4). A bailer, made from the wood of a breadfruit tree, should also be made. Today, Kosraeans are using an empty cut-out Clorox bottle as the bailer since it is readily accessible, efficient, and can easily be made. The mathematics involved at this stage varies from number concepts, operations and graphing appropriate to 1st graders, probability/algebra and graphing appropriate to 4th graders and ratios and proportions appropriate to 7th graders.

To begin with, for 1st graders, they could learn number concepts, operations and graphing by memorizing the pattern of attached elements—the exact number of booms (*kiacs)*, attached wood (*suhkan em*), and Y-shaped posts (*lok*), which are necessary components of the attachment. The Kosraean racing canoe should always have its outrigger attached with two *kiacs*, two *suhkan em*, and four *lok*. In other words, the pattern/ratio should be 1:2:2:4 (1 *em*, 2 *kiacs*, 2 *suhkan em*, 4 *loks*). And these are all carved and built separately from the outrigger, which also fosters invaluable mathematical thinking. In addition, how these different parts are assembled to complete the entire process of building the outrigger will be the main focus from here on. The construction sequence is as follows:

1. First, sink the four *lok* into the four holes made on top of the outrigger.
2. Second, tie the bottom attaching wood to firmly hold the four *lok* together.
3. Next, tie the two *kiacs* to the right side of the canoe with the elevated frontal side (*macngsrasr*) in front of you.
4. Finally, tie the top attaching wood to hold the *kiacs* to the Y-shaped *lok*.

The tying (*kapihr*) itself has mathematical variations and patterns, and it is the most complicated aspect of building an outrigger canoe. Today only a few Kosraean master canoe-builders still have this finesse. From the first tying (tying *lok* to the *suhkan em*) to the final tying (tying the top *suhkan em* to the *kiacs* and *lok*), each tying is distinctive from each other. Some master canoe-builders are reluctant to share such a cultural practice except through familial relationships. The tying analyses below I acquired from one of my numerous uncles, who is apparently one of the few remaining master canoe-builders here in Kosrae.

1. When tying (booms) *kiacs* to the racing canoe, do the following:

    a. First, tie a knot (*kolkin kosro*) at the top end of the coconut sennit (*fuh*)

    b. Second, place the *kolkin kosro* on top of the *kiacs* and take the bottom part of the *fuh* and crisscross it over the *kiacs* to the right inward hole of canoe.

    c. Third, pull the free end underneath the *kiacs* through the left outward hole.

    d. Fourth, crisscross the *fuh* half-way on top of the *kiacs* to be supported by the *kolkin kosro* and pivot inwardly across the *kiacs* into the left hole. Finally, the free end should go under the *kias* crisscrossing outwardly to the left hole to complete one cycle.

Repeat the cycle three times. After three cycles are done, pull the *fuh* underneath the *kiacs* three times also to tighten the tying. Do the same tying to the remaining three sides of the *kiacs*. Actually, it doesn't matter which side you start with, you just have to remember the pattern of tying: 3 times crisscrossing over and under the *kiacs*.

2. Before tying the four Y-shaped outrigger posts (*lok*) to the two attaching wood (*suhkan em*), the *em* should already be bolted with the four *lok*. Again, the tying sequence should be as follows:

    a. First, again, make a *kolkin kosro* knot on both ends of the *fuh*.

    b. Second, like the *kiacs*, put the top *kolkin kosro* on top (outward side) of the *lok* and place the bottom *kolkin kosro* on top of the Y-shaped *lok* and the *suhkan em,* crisscrossing to the left and pull the *fuh* under the *suhkan em* to tighten it to the top *kolkin kosro*.

c. Finally, pull the *fuh* under the Y-shaped *lok* and *suhkan em* from the right to the left and pull the *fuh* on top of the *suhkan em* crisscrossing from left to right. Continue the cycle for three times and do the same to the other three *lok*.

2. When tying the top *sukan em* to the *kiacs* and *lok* do the following:
   a. "First, make two *kolkin kosro* knots at both ends.
   b. Second, make a turn around the *kiacs* or *lok* with the bottom *kolkin kosro* running underneath the *kiacs* or *lok*.
   c. Third, take a second turn around in the same direction and feed the bottom *kolkin kosro* through the eye of the second turn. Continue the cycle if it's needed.
   d. Finally, pull the *fuh* tight" (Tulenkun, 2010).

The mathematics apparent in the tying stage, which is the most crucial component of the 3rd stage—assembling—vary from knowing number sense (1st graders) to mastering patterns and ratios (4th and 7th graders). Specifically for 1st graders, they would learn to remember specific numbers used in the assembling and tying of other important parts of a properly-made *em*. Otherwise, the *em* wouldn't be properly assembled or parts could be loosened easily, which could be a recipe for disaster—the canoe could easily flip over or sink.

The final stage of building an outrigger for a racing canoe will be the painting (*sroal*). Traditionally, the mountainous area in central Kosrae known as the "Sleeping Lady" provides for this final stage of canoe building since the paint is made from a sacred reddish soil (*lap*) from Finlesr, Utwe.

> "The legend says that she was menstruating at that time and today there is a place in the deep jungle which would be between her thighs—where the bright red soil can be found. The Kosraean men used to fetch that special red soil to mix a paint for their canoes. The area was considered a semi-sacred place and only the bravest dared to go there" (Segal, 1989, p. vii).

In other words, the legend advocates this practice and says that the *lap* turns reddish due to menstruation that the lady experiences when she decides to take a rest after her walk, which explains the reclining silhouette of Kosrae's famous "Sleeping Lady," known throughout Micronesia. Mathematical practices evident in this painting stage are as follows:

1. "First, a basket full of *lap* should be gotten from Finlesr (*lap* site in Utwe, Kosrae) to the canoe-building site. The amount of *lap* varies due to the size of the canoe.
2. Second, fruits from the *atuna racemosa* (*ahset*) should also be picked, heated, and pressed to release a tar that serves as the fastener and the varnish for the *lap*.
3. Third, the *lap* will be thoroughly soaked with water to give its sacred reddish color.
4. Fourth, the *em* will be hand-painted by the *lap*.
5. Finally, the *em* will be hand-painted by the tar" (Wakuk, 2010).

More cultural mathematics is involved in obtaining the *lap* because the canoe builder or outrigger builder and his helpers must be aware of the distance to and from the sacred site, which is approximately two miles total. "When going into the sacred cave, one is expected to be only whispering since the cultural belief is that any audible chatting would awake the Sleeping Lady; therefore, the rocks suspended above, which are supported merely by roots of trees and wild vines, will fall and crush him or her" (Wakuk, 2010).

Conclusion

In conclusion, for an outrigger to be successfully constructed and its significant mathematical aspects to be well understood, the aforementioned four stages should be carefully observed and closely followed. In other words, the process of building an outrigger for a racing canoe, along with its mathematical implications would be totally forgotten and lost if we, the indigenous people, fail to see its significance. With the continuing out-migration of FSMers to Guam and the United States at the rate of about 1,000 per year, more indigenous cultural practices may soon be lost forever, which was echoed by Harvey Segal in his book entitled *Kosrae: The Sleeping Lady Awakens*. On page 33, Segal said, … "And, the old traditions were to go, to Yap." What Segal is implying is that Kosraeans had lost much of its cultural practices when their breadfruit goddess Sinlaku, who gave the Kosraeans knowledge of cultural practices, left Kosrae to Yap before the island's contact with the modern world. Thanks wholly to the initiators and all the participants of Project Macimise because cultural practices don't inevitably have to leave the indigenous "people of the islands."

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Interviewees

1. Edmond, Randy M. (48-year-old full-time computer instructor at Kosrae High School, who is a master canoe-builder from Utwe). Personal interview. April 6, 2010.

2. Tulenkun, Tulenkun W. (55-year-old full-time construction instructor at Kosrae High School, who is a master canoe-builder from Utwe). Personal interview. April 6, 2010.

3. Wakuk, Tadao M. (64-year-old self-employed tour guide, who is one of the few remaining master historians/storytellers from Kosrae). Personal interview. March 26, 2010.

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