4. Voyaging on Hōkūle`a

“When we voyage, and I mean voyage anywhere, not just in canoes, but in our minds, new doors of knowledge will open, and that’s what this voyage is all about. . . it’s about taking on a challenge to learn. If we inspire even one of our children to do the same, then we will have succeeded.”

–Nainoa Thompson, September 20, 1999, the day of departure from Mangareva to Rapa Nui.
Chapter 4

Voyaging on Hōkūle`a

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In the 1950’s and 1960’s, historians couldn’t agree on how the Polynesian islands — including the Hawaiian islands — were settled. Some historians insisted that Pacific Islanders sailed around the Pacific Ocean, relocating as necessary, and settling the islands with purpose and planning. Others insisted that such a navigational and voyaging feat was impossible thousands of years ago, before European sailors would leave the sight of land and sail into the open ocean. These historians believed that the Polynesian canoes were caught up in storms, tossed and turned, and eventually washed up on the shores of faraway isles.

Think/Pair/Share
Talk about these questions with a partner:

1. How could such a debate ever be settled one way or the other, given that we can’t go back in time to find out what happened?

2. What kinds of evidence would support the idea of “intentional voyages”? What kinds of evidence would support the idea of “accidental drift”?

3. What do you already know about how this debate was eventually settled?
The Polynesian Voyaging Society (PVS) was founded in 1973 for scientific inquiry into the history and heritage of Hawai`i: How did the Polynesians discover and settle these islands? How did they navigate without instruments, guiding themselves across ocean distances of 2500 miles or more?

In 1973–1975, PVS built a replica of an ancient double-hulled voyaging canoe to conduct an experimental voyage from Hawai`i to Tahiti. The canoe was designed by founder Herb Kawainui Kanu and named Hōkūle`a (“Star of Gladness”).

On March 8th, 1975, Hōkūle`a was launched. Mau Piailug, a master navigator from the island of Satawal in Micronesia, navigated her to Tahiti using traditional navigation techniques (no modern instruments at all).

Think/Pair/Share

Brainstorm with a partner:

1. What are some mathematical questions you can ask about voyaging on Hōkūle`a?

2. What kinds of problems (especially mathematics problems) did the crew have to solve before setting off on the voyage to Tahiti?

3. What are you curious about, with respect to voyaging on Hōkūle`a?

When you teach elementary school, you will mostly likely be teaching all subjects to your students. One thing you should think about as a teacher: How can you connect the different subjects together? How can you see mathematics in other fields of study, and how can you draw out that mathematical content?

In this chapter, you’ll explore just a tiny bit of the mathematics involved in voyaging on a traditional canoe. You will apply your knowledge of geometry to create scale drawings and make a star compass. And you’ll use your knowledge of operations and algebraic thinking to plan the supplies for the voyage. The focus here is on applying your mathematical knowledge to a new situation.
One of the first things to know about Hōkūleʻa is what she looks like. This picture and drawing of Hōkūleʻa come from the PVS website: [http://hokulea.org](http://hokulea.org).

**Problem 1.** Here’s some information about the dimensions of Hōkūleʻa. Your job is to draw a good scale model of the canoe, like a floor plan.

- Hōkūleʻa is 62 feet 4 inches long. (This is “LOA” or “length overall” in navigation terms. It means the maximum length measured parallel to the waterline.)
- Hōkūleʻa is 17 feet 6 inches wide. (This is “at beam” meaning at the widest point.)
- You can see from the picture that Hōkūleʻa has two hulls, connected by a rectangular deck. The deck is about 40 feet long and 10 feet wide.

Imagine you are above the canoe looking down at it. Draw a scale model of what you would see. Do not include the sails or any details; you are aiming to convey the overall shape in a scale drawing.

You will use this scale drawing several times in the rest of this unit, so be sure to do a good job and keep it somewhere that you can find it later.

Note: You don’t have all the information you need! So you either need to find out the missing information or make some reasonable estimates based on what you do know.
Problem 2. Crew for a voyage is usually 12–16 people. During meal times, the whole crew is on the deck together. About how much space does each person get when they’re all together on the deck?
SECTION 3

Worldwide Voyage

To Prepare for next activity:

1. Read this description of the daily life on Hōkūle`a:
   http://pvs.kcc.hawaii.edu/ike/canoe_living/daily_life.html
2. Watch the video about the Worldwide Voyage:

From the webpage above, you learned:

“The quartermaster is responsible for provisioning the canoe — loading food, water and all needed supplies, and for maintaining Hōkūle`a’s inventory. While this is not an on board job, it is critical to the safe and efficient sailing of the canoe.”

Problem 3. Imagine that you are part of the crew for the Worldwide Voyage, and you are going to help the quartermaster and the captain with provisioning the canoe for one leg of the voyage. You need to write a preliminary report for the quartermaster, documenting:

1. Which leg of the trip are you focused on? (See the map on next page.)
2. How long will that leg of the trip take? Explain how you figured that out.
3. How much food and water will you need for the voyage? Explain how you figured that out.

The rest of this section contains pointers to information that may or may not be helpful to you as you make your plans and create your report. Your job is to do the relevant research and then write your report. You should include enough detail about how you came to your conclusions that the quartermaster can understand your reasoning.

Note: During Hōkūle`a’s Worldwide Voyage, you can track the progress here: http://www.hokulea.com/track-the-voyage/.
Pick a leg of the route:
Here’s a picture of the route planned for the Worldwide Voyage, which you can find at the Worldwide Voyage website: http://hokulea.org/world-wide-voyage/. On the map, the different colors correspond to different years of the voyage. A “leg” means a dot-to-dot route on the map.

After you pick a leg of the voyage, you’ll need to figure out the total distance of that leg. This tool might help (or you can find another way): http://www.acscdg.com/.

Here is some relevant information to help you figure out how long it will take Hōkūle`a to complete your chosen leg:

- Fully loaded with the maximum weight, Hōkūle`a can travel at speeds of 4–6 knots, and even 10–12 knots in strong winds. (One knot means one nautical mile per hour.)

- The first trip from Hawai`i to Tahiti in 1976 took a total of 34 days. (You probably want to use the tool above to compute the number of nautical miles.)

Plan the provisions:
Here is some information about provisions.

- Hōkūle`a can carry about 11,000 pounds, including the weight of the crew, provisions, supplies, and personal gear.

- The supplies (sails, cooking equipment, safety equipment, communications equipment, etc.) account for about 3,500 pounds.

- The crew eats three meals per day and each crew member gets 0.8 gallons of water per day.

- For a trip that is expected to take 30 days, the quartermaster plans for 40 days’ worth of supplies, in case of bad weather and other delays.
Navigation

The following is from http://pvs.kcc.hawaii.edu/ike/hookele/modern_wayfinding.html.

“A voyage undertaken using modern wayfinding has three components:

1. Design a course strategy, which includes a reference course for reaching the vicinity of one’s destination, hopefully upwind, so that the canoe can sail downwind to the destination rather than having to tack into the wind to get there. (Tacking involves sailing back and forth as closely as possible into the wind to make progress against the wind; its very arduous and time-consuming, something to be avoided if at all possible, particularly at the end of a long, difficult voyage.)

2. During the voyage, holding as closely as possible to the reference course while keep-
Think/Pair/Share
Here is a time-lapse picture of the stars in the night sky in Hawai‘i:

Photography by Ashley Deeks

- Describe what you see happening in this picture.
- What can you conclude about how the stars move through the night sky?
- How might that help a navigator find his way?

3.1. Star Compass. A fundamental tool for navigators on Hōkūle‘a and other voyaging canoes is a star compass. Here’s a picture of Mau Piailug building a star compass to teach navigation.


The object in the center of the circle represents the canoe. The rocks along the outside represent directional points. The idea is to imagine the stars rising up from the horizon in the east, traveling through the night sky, and setting past the horizon in the west. They move like they’re on a sphere surrounding the Earth (it’s called the celestial sphere).
Problem 4. Nainoa Thompson developed a star compass with 32 equidistant points around a circle. (Note this is more points than in Mau’s star compass pictured on page 9.) You will first try to make a rough sketch of Nainoa’s star compass based on this information.

1. Place 32 points around the circle so they are equally spaced.

2. The arcs between these equidistant points are called “houses.” You will label each house with its Hawaiian name. Start with the four cardinal points:
   
   ʻĀkau: North.
   Hema: South.
   Hikina: East.
   Komohana: West.

3. The four quadrants also get names. (These cover all of the houses in the quadrant, so label them in the appropriate place inside the compass.)
   
   Koʻolau: northeast.
   Malani: southeast.
   Kona: southwest.
   Hoʻolua: northwest.

4. Moving from ʻĀkau to Hikina (clockwise), there are seven houses. They are labeled in order as you move away from ʻĀkau:
   
   Haka: “empty,” describing the skies in this house.
   Nā Leo: “the voices” of the stars speaking to the navigator.
   Nālani: “the heavens.”
   Manu: “bird,” the Polynesian metaphor for a canoe.
   Noio: the Hawaiian tern (a bird)
   ʻĀina: “land.”
   Lā: “sun,” which stays in this house most of the year.

5. The compass has a vertical line of symmetry, so there are the same seven houses in the same order as you move from ʻĀkau to Komohana (counterclockwise).

6. The compass also has a horizontal line of symmetry. Use that fact to label the houses from Hema to Hikina (counterclockwise) and from Hema to Komohana (clockwise).
How is the star compass used in navigation? There are lots of ways. Here’s a (very!) quick overview:

- The canoe is pictured in the middle of the star compass, with all of the houses around.

- Winds and ocean swells move directly across the star compass from north to south or vice versa.
  - If the swells are coming from `Āina Ko`olau, they will be heading in the direction `Āina Kona. (Look at your star compass and trace out this path.)
  - If the wind is coming from Nālani Malani, it will be heading towards Nālani Ho`olua. (Look at your star compass and trace out this path.)

- Stars stay in their houses, but also in their hemisphere. They do not move across the center of the circle.

- Just like the sun, they rise in the east and set in the west.
  - `A`ā (Sirius) rises in Lā Malanai and sets in Lā Kona. (Look at your star compass and trace out this path.)
  - Hōkūle`a rises in `Āina Ko`olau and sets in `Āina Ho`o-lua. (Look at your star compass and trace out this path.)

A navigator memorizes the houses of over 200 stars. At sunrise and sunset (when the sun or the stars are rising), the navigator can use the star compass to memorize which way the wind is moving and which way the currents are moving. The navigator can then use that information throughout the day or night to ensure the canoe stays on course.

Think/Pair/Share
Look again at the time-lapse picture of the stars:

- Describe how this shows that stars “stay in their houses” and in their hemisphere as they move through the night sky.
- The star Ke ali`i o kona i ka lewa (Canopus), rises in Nālani Malanai. Where does it set?
When teaching navigation while sitting on land, it’s perfectly fine to have a rough sketch or model of the star compass. But if you really have to do the navigation, you need to make a very, very precise star compass.

Imagine Nainoa Thompson, who navigated Hōkūle`a on the final leg of her journey from Hawai`i to Rapa Nui, an island even smaller and lower than Ni`ihau. You have to be within 30 miles of Rapa Nui to see it. But a mistake of even one degree would have led to Hōkūle`a being 60 miles off course. And if you end up drifting in the open ocean and supplies run out? Well. . .

Problem 5. Now that you have a rough sketch of the star compass and know what it should look like, your job is to draw one that’s as perfect as possible. That means you want to draw:

(a) A perfect circle (well, as perfect as possible). What tools can you use to do that? What tools would ancient Polynesian navigators have had to use?

(b) Thirty-two points around the circle that are exactly evenly spaced apart. (What tools would help you? What tools would ancient Polynesian navigators have had to use?)

(c) When you have finished, label your perfectly drawn star compass with the houses.

Of course, a star compass on a piece of paper isn’t so useful when you’re out on a canoe. How do you position it properly? And how do you keep it from getting lost, damaged, or soaking wet? You paint it on the rails of the canoe, permanently!

Look back at the drawing of Hōkūle`a. Find the “kilo” (navigator’s seat) in the rear (aft) of the canoe. There is actually one navigator’s seat on either side of the deck.

Problem 6. Go back to the scale drawing of Hōkūle`a that you made in Problem 1. Add the navigator’s seats to your drawing. You will then add the star compass to the rails as follows:

(a) Start with the kilo (seat) on the left (port) side of the canoe. That will be the center of your star compass. Imagine looking to the right. You want to see the star compass markings on the rails when you look to the right. Of course, the Hōkūle`a is not a circular canoe, and the navigator doesn’t sit at the center. So how can you make the markings in the right places?

(b) Now repeat that process, using the seat on the right (starboard) side of the canoe.
Nainoa Thompson has said:

“Initially, I depended on geometry and analytic mathematics to help me in my quest to navigate the ancient way. However as my ocean time and my time with Mau have grown, I have internalized this knowledge. I rely less on mathematics and come closer and closer to navigating the way the ancients did.”

Really he is still doing a lot of mathematics; it’s just mathematics that he has internalized and that is now second nature to him. The ancient navigators may not have spoken of their navigation techniques in the same modern language we’ve been using — compass points and perfect circles and degrees. But their mathematical understanding was truly astonishing.