“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.

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?

Introduction
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.
Hōkūle‘a

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 Kāne 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).

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.

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

- Hōkūle’a 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.)
- Hōkūle’a is 17 feet 6 inches wide. (This is “at beam” meaning at the widest point.)
- You can see from the picture that Hōkūle’a 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?

Worldwide Voyage

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:
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/.

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.

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.
“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; it’s 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 keeping track of (1) distance and direction traveled; (2) one’s position north and south and east and west of the reference course and (3) the distance and direction to the destination.

3. Finding land after entering the vicinity of the destination, called a target screen or ‘the box’.”

So how is the navigation done — especially component (2) — through thousands of miles of open ocean? You can’t see land. How can you hold closely to the reference course? How can you keep track of distance and direction traveled? How can you even know if you’re going in the right direction?

By day, the navigators use their deep knowledge of the oceans. Which way do the winds blow? Which way do the prevailing currents move? Clouds in the sky, flotsam in the water, and animal behaviors can give you great insight into where land might be, and where you are in relation to it.

By night, they use the stars. In this section, you’ll learn just a tiny fraction of what these master navigators know about the stars.
**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.

![Star Compass Picture](From the Traditional Micronesian Navigation Collection. Photo taken by Steve Thomas.)

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 above.) 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:
   - ‘Ākau: 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 ‘Ākau to Hikina (clockwise), there are seven houses. They are labeled in order as you move away from ‘Ākau:
   - **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 ‘Ākau 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 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 ʻĀina Koʻolau, they will be heading in the direction ʻĀina 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 Hoʻolua. (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.
  - ʻAʻā (Sirius) rises in Lā Malanai and sets in Lā Kona. (Look at your star compass and trace out this path.)
  - Hōkūleʻa rises in ʻĀina Koʻolau and sets in ʻĀina Hoʻolua. (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 aliʻi 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... 

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.

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.

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.

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.
Instructor Notes on Math 112

Our students are future elementary school teachers, so they will most likely teach all subjects to their students. We’d like to help them think about seeing mathematics — and asking mathematical questions — in contexts that don’t come straight from the math book.

Many schools in Hawai’i encourage teachers to include learning experiences that deal with the history and culture of the people who originally settled these islands, including their descendants and how they lived. There is actually a tremendous amount of mathematics that could be brought out for elementary students in these lessons, so in this chapter we give our students one glimpse of how this can be done.

The whole chapter will take approximately two weeks of class time, but you can pick and choose from the activities to make the chapter longer or shorter.

You can find a lot of information about voyaging on Hōkūle’a at the Polynesian Voyaging Society website http://hokulea.org/ and http://pvs.kcc.hawaii.edu/. What follows is a suggested outline for working through this unit with your class, along with some relevant details that may help you in your teaching. (Note: There is a ton of information online about Hōkūle’a. If students ask you something that you can’t answer, ask them to research it and find out! Remind them that you are not a voyaging expert but a mathematics expert, so your job is to provide just a bit of context and then help them with the mathematical part of the lesson.)

Flow of the unit. This section presents one suggestion for how to manage about two week’s of class time (based on a MWF schedule). Note that each day you will check in on their progress on the project. This is really to keep their focus on the project (Problem 3 in the chapter) and encourage them to do a bit each day. It should not take a large amount of class time, unless there are significant stumbling blocks you feel you need to address. The goal is to just make sure they are making progress and on the right track, and to link them to any resources or ideas they will need.

Day 1. Ask students to read the first page and talk with a partner about the Think / Pair / Share questions. Generate a long list of mathematical problems and questions they have about voyaging. Keep encouraging them to ask more questions. You may need to throw in some of your own questions to get them going. (How big is the canoe? How many people are on it? How long are the voyages? Where does the crew sleep? How is it powered? . . . They probably know almost nothing at this point. Of course, you may find that one or more of your students knows a lot about Hōkūle’a, so let them become the class expert, answering questions whenever they can.) You probably want to keep a record of these questions somewhere and come back to them on Day 3.

Some history that you may want to share with your students after the conversation: The “accidental drift” theory was shot down by computer simulations of wind patterns and ocean currents which concluded that a drifting canoe had no chance of reaching Hawai’i, Easter Island, and New Zealand from other parts of Polynesia or Micronesia.
The route between Tahiti and Hawai‘i passes through three ocean currents and requires sailing slightly against the wind both ways. Could the ancient voyaging canoes perform well enough to windward to make round trips? Hōkūle‘a’s 1976 round trip voyage proved that they could.

And the navigation experiments conducted in 1976 and in subsequent voyages have proved the adequacy of Polynesian navigation. Also: Wilford, John Noble (18 January 2008). “Pacific Islanders’ Ancestry Emerges in Genetic Study”. Asia Pacific (The New York Times Company): DNA analysis confirms Polynesians’ relationship to Taiwanese Aborigines and East Asians.

After the discussion, students can work on making the scale drawings and the computation of how much space everyone gets. They should finish this for homework if they do not finish in class. You may want to bring tools for them to use (calculators, rulers, protractors, etc.)

For additional homework, ask students to read all of Section 2, including reading the linked web page and watching the video (or you may choose to show the video in class instead, at the start of Day 2). Emphasize that they don’t need to work on the problems, just read everything over before class so they have seen it.

Day 2. At the start of class, explain that Problem 3 (the report for the quartermaster) is a project to cover the whole rest of the unit. They should work on it a bit each day. You will check in with them at the start of each class, and they should have something to share with you (and the class) about what they’ve done, or they should have clarifying questions to ask of you.

As the instructor, you should decide on the format of the report (must it be typed? any other specifics you want to give them?) and let them know that up front. Encourage students to work out everything in a notebook, keeping track of their ideas, and then write the formal report at the end, once they have worked everything out. Before the next class, they should choose their leg of the voyage and at least make an attempt to compute how long the trip would be. The details of the provisions given in the unit are drawn from http://pvs.kcc.hawaii.edu/ike/canoe_living/modern_provisions.html. You can find more details there as well, and you can decide how much of the additional details you wish to share with your students. We intentionally left out details that we felt were either too confusing to include or that did some of the calculations we wanted students to do.

You may, of course, make different instructional choices. For the in-class activity: Have students compare their scale drawings of Hōkūle‘a with each other. Note that the directions did not say what scale to use, so students likely made very different choices. There was also a lot they didn’t know gut could estimate, for example exactly where the deck is placed relative to the front and back of the canoe and how the curvature of the two hulls looks. You may want to ask several students to share their scale drawings with the class and point out what is good and what could be improved. An optional homework assignment would be for students to make a better version that takes up most of whole page, which they will use later in the chapter.
Here is one version of a scale model, for your reference. The back of the canoe is to the left and the front is to the right in this drawing.

Following up on the scale drawings, you may want to take students outside to draw a full-scale model of the Hōkūle'a. (Bring sidewalk chalk or masking tape to mark off the outline of the canoe, and bring whatever tools you want students to use: measuring tape, rulers, string, etc.) When the deck is drawn, ask 12–16 students to all stand on it at the same time. Ask them to imagine living in this amount of space for the time of a voyage, say a month or more. Ask them to just walk around the space and think about how that would feel. If your class is large, you may want to do this twice with two different groups. (This may require a second day of class, depending on how long the earlier activities took.)

For homework, in addition to beginning the project, students should read pp. 7–8 and be ready to talk about time-lapse picture of the stars.

Day 3. Check in on students’ work on the project. Everyone should have chosen a leg of the voyage and tried to calculate the time it would take. Note that the dots on the map provided are possibly not clear enough for students to calculate distances. They’ll need to use a tool like google earth (or an old-fashioned atlas) to figure out where the dot is likely to be and then use that information to calculate distances.

You may want them to just check in with a partner or small group on how they did this and if their methods and their conclusions seem reasonable. Again, you may ask one or two students to share what they did with the whole class and provide some feedback that could be helpful to everyone. Take any whole-group questions, and provide assistance or ideas for students who had difficulty.

Note: You can find a list of Hōkūle’a’s planned ports of with longitude and latitude here: http://www.hawaiilink.net/~mms/pvs_wwv/index.php. (Scroll below the map on the page for the full list.) However, providing this list is not as engaging as having students look at the map and figure out where the stops are likely to be. We provide this information for your reference, but suggest not sharing it with students. (Of course, some of them may find it in their own research, which is fantastic!)
Similarly, one of our students found a speed-time-distance calculator here: http://www.uspowerboating.com/Home/Education/Navigation/Speed-Time-Distance/Speed-Time-Distance_Calculator.htm. Again, we provide these links for your information, but encourage you to let students do some research and find their own way. Several students opted to use that calculator as part of their final write-up, giving credit to the student who had shared it with the class for the idea. It is much more meaningful for students to find their own way to this information than to be handed one way to do it.

For homework, students should revise their route calculations as necessary based on what they learned in class, and they should start the next part of the project: figuring out how much food and water (in pounds) they and bring. Students will need to use the information given in the section, along with some estimation. They should be ready to share their ideas during the next class.

Now that students have drawn a scale model of Hōkūle’a and also (perhaps) had the experience of standing on a full-scale version along with a “crew,” they may have additional questions (mathematical and otherwise) that hadn’t come up before. This is a good time to revisit the list of questions they initially generated, cross off any that they know the answer to, and add any new questions.

The rest of class can be focused on navigation and the initial star compass activity. Start with a discussion of what they see in the picture of the stars, and why the stars trace out circles through the night. You might want to point out that stars rise in the east and set in the west, just like the sun. What maybe is surprising to students is that these circles are all concentric. They will soon see how this plays in to how navigators figure out where they are in the world while out on the open ocean.

Ask if anyone knows what the bright spot is at the center of the concentric circles (Hokupa’a, the North Star) and its significance for navigation (unlike the other stars, it doesn’t move, so you can always find “north” by looking for that star). Note that some of the stars don’t really “rise” and “set;” they just circle Hokupa’a. All of the stars are tracing out circles, but parts of some of the circles are obscured from our vision by the earth and parts are not. The North Star is pretty close to the horizon here in Hawai‘i. We’re about 20° north latitude, which means the North Star is almost exactly 20° above the horizon. (At the North Pole, which is 90° latitude, the North Star is directly overhead. That’s why it always shows you which way is north.)

There’s lots more information about the celestial sphere and star positions here: http://pvs.kcc.hawaii.edu/ike/hookele/celestial_sphere.html. This is not a major theme of the chapter, but if students are interested and there is time, you might encourage them to dig into more of the details. Of course, if someone in the class knows a lot about the subject, this is a good chance to let them share their expertise with the class.

Finally, have students begin Problem 4 (rough sketch of the star compass from the written directions). They should complete it for homework if there is not time in class. For your reference, you can find several versions of the star compass drawings here: http://pvs.kcc.hawaii.edu/ike/hookele/star_compasses.html.
Day 4. Check in on students’ work on the project. Again, you can have them check in with a partner or small group and then ask you questions, or you can ask for individuals to share what they did with the whole class and the solicit feedback from the other students and from you. Essentially, they should do something like the following: About how much does the crew weigh? What about their personal gear? You might remind students about the webpage they read, and that “...crew member allowed one 48 quart cooler” for their personal belongings, so estimate the weight of the cooler plus belongings. Then multiply all of that by the number of crew. They know how much water is allowed for each crew member per day. How much does water weigh? How many crew on the voyage? How many days is the voyage? Should they bring along some extra in case the voyage takes longer than predicted? How much extra? (Again, you can find more detailed answers that the crew actually uses at http://pvs.kcc.hawaii.edu/ike/canoe_living/modern_provisions.html. For example: for a 30 day voyage, they bring 40 days’ worth of water, and then begin rationing if it looks like they will start to run short.)

For the next class, students should revise their work on the food calculation as necessary, including addressing the question of the weight of the food they would bring. How much does an average meal weigh? How many meals will be served on the voyage? Don’t forget the weight of any packaging, and probably extra water for cooking. You might want to point out that fresh food will not keep long, so they can bring some for the first few days but then should rely on packaged food. Remind them also that the crew supplements their diet with fresh fish, with one crew member having the job of setting out and watching fishing lines each day. If time permits, you may want to talk about how the ancient Polynesians chose their provisions, given that “packaged food” was not an option then. You can find some information to share with them here: http://pvs.kcc.hawaii.edu/ike/canoe_living/micronesian_provisions.html. There is also a nice video about provisioning the Worldwide Voyage here: http://www.hokulea.com/hoomakaukau/. You may want to share that with your students as they work on their projects, or on the day they turn them in.

Students should start preparing the final version of the project that will be turned in.

The class activity will focus on creating a good version of the star compass. Have students pull out their rough sketches and check that they seem reasonable (they can do this with a partner). Then explain the motivation for creating a star compass that is as perfect as possible (or just have students read this in the text) and provide them with whatever tools you want them to use. One option would be to have a stash of tools (rulers, protractors, string, compasses, etc.) and tell them that they can ask you for whatever they want to use, and if you have it you’ll give it to them.

Instead of doing this in class and on paper, you might want to do the activity outside. You probably want groups of students (maybe 5–10 in each group) to build the compass. For each group, you will need a couple of long ropes and
something to mark the 32 equally spaced points along the circle (you can use students’ shoes if they are willing, rocks, or other similar objects). You will want at last five “special” objects to mark the center of the circle (the canoe) and the four compass points.

As students work, the important question is how they know they are creating precise circle divisions. Most groups will try to find the compass points first. Remind them that they need to be accurate. North must be directly across from south, and the same for east and west. The lines connect NS and EW must meet at 90° in the center of the circle. How can they be absolutely certain that this is the case? As they work, encourage them to think about the geometry they know and what they can use. For example, students might use 3-4-5 right triangles using a marked unit of length to create right angles, or they might use the standard method of construction to find the perpendicular bisector of the segment connecting north and south.

There are many other methods.

If you do the outside activity (or even the one on paper), it is quite likely that you won’t finish in one class period. Leave the last five minutes of class for discussion, even if that means interrupting them in their work when they are on a roll. Tell them they will have another opportunity the next day to create a really good star compass. Brainstorm ideas from the groups how they were using the materials and what they found challenging. Get as many ideas out as possible. Then assign for homework a paper-and-pencil version using whatever materials they can find (but not a computer), along with ideas to make the second outdoor attempt go more smoothly.

Day 5. One final check-in on students’ projects. Again, have them share with a partner and then ask questions if anything is unclear after that discussion. Remind them of the due date and of any special requirements you had. The class activity should start with a discussion of the utility of the star compass. Talk about the stars staying in their houses as they rise and set. Refer back to the time-lapse picture of the stars and show how that can be seen in the picture. Imagine the stars traveling in big circles while staying in their houses, and get explanations for why that would yield the picture you see. Let the students try the star compass activity again, putting their ideas into practice.

For homework, they should read to the end of the chapter, and think about ideas for how to tackle Problem 6. They should be ready to dive into that problem during the next class, which means having their scale drawings of Hōkūle‘a with them.

Day 6. Collect the final projects, or remind them of the due date if it is still in the future. Spend the final class on the problem of how to paint a star compass on the rails of Hōkūle‘a. (Note: the rails run along the deck of Hōkūle‘a.) You can decide how much direction to give students in this activity.
One idea is to have a star compass drawing that is only slightly larger than the scale drawing of Hōkūle'a. Overlay the scale drawing of Hōkūle'a so that the kilo (navigator's chair) is at the center of the star compass. Use a ruler or other straightedge to connect the kilo to the marked points on the star compass, and draw a mark where these points intersect the rails of the deck. (Not all of the markings will necessarily fit, but there are enough of them that the navigator can use them.) Then repeat this process moving the other kilo to the center of the circle.

**Other activities.** Depending on the time and resources you have available, you might want to include additional activities in this chapter, either in-class or optional (perhaps extra credit) out-of-class activities:

- Visit the Bishop museum and in particular to see the Planetarium show about navigating on Hōkūle'a (currently called “Wayfinders: Waves, Wind and Stars,” and showing at 1:30PM daily, but check the Bishop Museum website for any changes).
- Invite a member of the PVS to visit your class and answer questions from the students. Or, if that is not possible, have the class select a small number of their questions to send to a crew member of Hōkūle'a by email.
- Show some of the mathematically themed videos about Hōkūle'a. There are many of them available with a Google search. For example, this video shows how the crew can estimate their speed of travel while they’re sailing: [http://www.youtube.com/watch?v=3i2xP4N6mbc](http://www.youtube.com/watch?v=3i2xP4N6mbc).
- There may be other activities connected with the Worldwide Voyage, such as virtual field trips or connecting electronically with the crew. Be sure to check the website [http://www.hokulea.org](http://www.hokulea.org) to see what is going on, and have your class follow the progress of the voyage at [http://www.hokulea.com/track-the-voyage/](http://www.hokulea.com/track-the-voyage/).