Kūkuluokalani: The Modern Hawaiian Star Compass

Credit: Steve Soltysik

Grade Level: 6-8

Learning Time: 1-2 Hours

Keywords: cardinal directions, paafu, pwo, star compass

Summary & Goals:
Students will learn…

- How to box the compass using the names of the 4 cardinal directions, the 7 houses in between the cardinal directions, and the 4 main winds (quadrants) of Nāinoa Thompson’s modern Hawaiian “star compass.”
- How to use the star compass to interpret phenomena in ways that would be useful on an oceanic voyage.

Background:

SCIENTIFIC
Whereas a modern navigator uses a variety of instruments, charts, mathematical calculations, and a spherical coordinate system of latitude and longitude, a traditional navigator lacks these tools and instead employs a number of non-instrument methods in order to be able to 1) orient him- or herself and set an accurate course toward his or her destination, 2) keep track of his or her position en route and make any necessary course corrections, and 3) make landfall on the island or place along a coastline to which he or she is heading. In the words of Hawaiian navigator Nāinoa Thompson, “navigation is about understanding and watching nature. … Everything you need to guide you is in the ocean, but you need to be skilled enough to see it” (Finney & Low, 2006, p. 186).

A star compass aids in this first navigational task (i.e., orientation), serving as a mental construct to organize the astronomical, meteorological, oceanographic, and biological information upon which the navigator’s increasingly important decisions will be based. In other words a star compass is not a physical instrument (like a magnetic compass) but rather a
conceptual direction system. Although this model may be demonstrated ashore using a circle of shells on a mat or in the sand (or, in the case of this lesson, with markers and paper or paint and canvas), the star compass is merely a visual representation of how the navigator mentally divides the horizon surrounding him or her, and it is with this conceptual vision alone that he or she actually sets sail.

CULTURAL

The best-known traditional stellar navigation system in the Pacific is the one used by navigators in the Caroline Islands of Micronesia. Like their Western counterparts with their mariner’s magnetic compass (and yet independent of them), Carolinian navigators divide the horizon into 32 points or “pits” as did some ancient Polynesian navigators (e.g., in Tahiti and the Cook Islands). In the Carolinian system, these pits (comprising the paafu or “star paths”) represent the specific rising and setting points of stars. In the Tahitian and Cook Islands systems the points represent the directions from which particular winds originate.

Carolinian Paafu (Oriented with North at the Top)

(Photo source: http://upload.wikimedia.org/wikipedia/commons/thumb/2/20/Mau-star-compass.png/400px-Mau-star-compass.png)

Although not as much is known about the original Polynesian (let alone uniquely Hawaiian) navigational methods as is known about Carolinian ones, there is little doubt that Polynesians too set their courses by celestial bodies and did so skillfully enough to settle places in the Pacific as relatively distant as Hawai‘i, Rapa Nui, and Aotearoa.

During modern times it was Carolinian pwo (master navigator) Pius “Mau” Piailug who successfully navigated the traditional Polynesian double-hulled voyaging canoe Hōkūle‘a during her inaugural voyage from Hawai‘i to Tahiti in 1976. A young Hawaiian crew member named Nāinoa Thompson had looked forward to learning from Mau during Hōkūle‘a’s return trip (from Tahiti to Hawai‘i) during that same year, but when Mau instead returned to his home on Satawal, Nāinoa resorted to observing what he could while sailing...
without Mau and, upon returning to Hawai‘i, diligently studying astronomical aspects of navigation with Will Kyselka using the Bishop Museum’s Planetarium. But, in the words of Will himself, “…knowledge alone is not wayfinding,” and Nāinoa “needed a master teacher…who could help him put it together in a coherent form” (Kyselka, 1987, p. 58). After Nāinoa humbly (and repeatedly) requested his guidance, Mau returned to Hawai‘i in 1979 to train him in wayfinding and help Nāinoa to become the first Hawaiian in centuries to navigate without using modern instruments from Hawai‘i to Tahiti.

Similar to Mau’s Carolinian paafu, Nāinoa initially devised a star compass consisting of the rising and setting points of 36 stars. Nāinoa then went on to simplify it to 32 equally-spaced (i.e., 11.25-degree-wide) “houses.”

Mau Piailug’s Carolinian Paafu (Oriented with North on the Left and South on the Right) & Nāinoa Thompson’s Hawaiian Star Compass (circa 1987)
Nāinoa Thompson’s Hawaiian Star Compass (as of 2013)
(Image source: http://pvs.kcc.hawaii.edu/ike/hookele/star_compasses.html)
(Source does not utilize modern Hawaiian orthography.)

The houses include the 4 cardinal directions in Hawaiian (according to Pukui & Elbert): ʻākau (north), hema (south), hikina (east), and komohana (west). The 4 quadrants delineated by the 4 cardinal directions are named for predominant winds that originate from those general directions: koʻolau (northeast), hoʻolua (northwest), malanai (southeast), and kona (southwest). The remaining 7 houses reflect symmetrically across the lines connecting ʻākau to hema and hikina to komohana and are distinguishable by their particular quadrant of the star compass. Each house’s name derives from a related aspect of navigation:

- Lā (Sun): the Sun rises and sets within these houses for most of the year, while oscillating between the extremes of ʻāina koʻolau and ʻāina hoʻolua (in the north) and ʻāina malanai and ʻāina kona (in the south);
- ʻĀina (land): There is symbolic significance to stars that pass exactly overhead at different places in the Pacific, even if stars in the zenith are not particularly useful for navigation (in that it is very hard to tell when a star is exactly overhead). In the Hawaiian Islands, roughly 21 degrees N latitude, the star Hōkūleʻa or Arcturus passes overhead. From Tahiti’s latitude, 17.5 degrees below the horizon, the star ʻAʻā or Sirius, passes exactly through the zenith. Hōkūle'a rises in NE ʻĀina and sets in NW ʻĀina; ʻAʻā rises in SE ʻĀina and sets in SW ʻĀina. Given the fact that these stars are helpful for finding these particular “lands” of Tahiti and Hawai‘i, the term ʻāina or land has been given to these houses where H Hōkūle’a...
and ‘Aʻā rise and set.

- **Noio** (Hawaiian noddy tern): this type of bird helps navigators make landfall since it seeks food within an approximately 40-mile-radius from its land-based nest, and the furthest extent of this house (that is, either north or south of directly *hikina* or *komohana*) is approximately 40 degrees;

- **Manu** (bird): The four houses called Manu are located halfway between each of the four cardinal points; these houses are at right angles to each other. The term *manu* draws upon the traditional Polynesian metaphor for a canoe as a bird. If you imagine a bird in the middle of the compass, with, say, its beak pointed to SW Manu, its tail will be pointed to NE Manu, the house exactly opposite SW Manu; and the wings of the bird would point to SE Manu and to NW Manu.

- **Nālani** (the heavens or the very high chiefs): while all stars reside in the “heavens,” this house is named for the brightest star that crosses through Nālani, *Ke Aliʻi o Kona i Ka Lewa* (the chief of the southern heavens) or Canopus, which rises in Nālani Malanai and sets in Nālani Kona. Canopus is the second-brightest of all the stars, after Sirius, and a key star for Pacific Navigation. Like the Southern Cross, Canopus is not visible from much of the continental US; if you are any further north than Los Angeles (32 degrees N latitude) you will not see it.

- **Nā Leo** (the voices): the quiet “voices” of the stars speak to the attentive navigator. These houses mark the risings and settings of some of the most important navigational stars. For example the star Dubhe or *Hikukahi* in the Big Dipper rises in NE Nā Leo and sets in NW Nā Leo. Dubhe, combined with Merek, the other ‘pointer star’ in the cup of the Big Dipper, points the way to the North Star. *Ka Mole Honua* or Acrux [of the Southern Cross] rises in SE Nā Leo and sets in SW Nā Leo; when Acrux is at its highest point, it and Gacrux (the top star in the long part of the cross) point the way to due south.

- **Haka** (empty): relatively few stars are visible (and thus usable) within this house that surrounds the north and south celestial poles, making it appear somewhat empty.

Of important note is the difference in paths taken by celestial bodies and meteorological and oceanographic phenomena. When stars, planets, the Sun, and the Moon rise in the Koʻolau (NE) quadrant, they will always set in the Hoʻolua (NW) quadrant; likewise, whenever they rise in Malanai (SE), they will always set in Kona (SW). In both cases their paths move to the quadrant directly *adjacent* but on the opposite half of the horizon (as divided by north and south). However, although winds and ocean swells may also originate from the Koʻolau quadrant, they always pass through or below the canoe (i.e., the center of the compass) into the Kona quadrant, from Malanai to Hoʻolua, etc. In other words they move into the quadrant *diagonally* opposite from their quadrant of origin.

**VOYAGING**

While on the open ocean, the navigator imagines that his or her canoe is at the center of the circle created by the unobstructed horizon. When sailing at night, the navigator orients his or her canoe by the rising or setting points of stars. As the world turns, stars appear to rise and to set in the course of the evening, much as the sun does during the day. A given
A star will always rise in one house (for example, the Pleiades will always rise in NE ʻĀina) and set in the opposite house (for example, the Pleiades will always set in NW ʻĀina). This is true throughout the regions where Hōkūleʻa voyages. So even on a night that is otherwise socked in with clouds, if you see the Pleiades setting, you know that direction must be NW ʻĀina. Then, with the star compass in your head, you can work out all of the other directions. This is an invaluable tool; while the North Star is a ‘golden’ assistant when it is visible, there are two significant problems with the North Star. First of all, the North Star is often blocked by clouds; and second of all, below the equator you never see the north star (and all of Polynesia except Hawaiʻi is below the equator). Using the star compass, and memorizing where over 200 stars rise and set, a navigator can quickly work out all of the directions if she or he can see even a single bright star or cluster of stars rising or setting.

Factoring in the effects of winds and currents (i.e., leeway and current drift, respectively), the navigator will actually choose a star course sufficiently to one side or the other of the direct course to his or her destination. Pacific navigation relies heavily on marking stars as they rise or set to determine direction; once a star gets high above the horizon, it is hard to determine direction with that star, and the experienced navigator must turn to other stars lower in the sky to continue marking direction. Because clouds may otherwise obscure important parts of the sky, the navigator must know the pattern of all the stars and constellations to be able to orient him- or herself based on any portion that is visible.
During the day the Sun and ocean swell patterns are used for orientation. The Sun is most useful in the early morning or late afternoon, when it appears close to the horizon; however, its rising and setting points shift along the horizon daily, necessitating recalibration of its bearing with respect to the fading or brightening stars that are visible at twilight. When the Sun rises too high to be a precise directional guide or is blocked by overcast skies, ocean swells can be used to keep the canoe on course. Sorting amongst the confusion of swells converging below the canoe from several directions, the navigator selects the most prominent and consistent of the swells (i.e., the long, regular ones generated by steady winds blowing over long stretches of ocean or by distant storm centers) and keeps track of their alignment with respect to horizon stars (including the Sun). These swells then serve as reference to orientation in the absence of other clues.

**BISHOP MUSEUM**

The museum’s Jhamandas Watumull (formerly Kilolani) Planetarium was the first planetarium in Polynesia, having opened in 1961, and has served as an invaluable educational resource for students of non-instrument navigation. Nāinoa Thompson learned the night sky in the Museum’s planetarium under the guidance of planetarium lecturer Will Kyselka in the 1970s. Referring to his key role in reviving Polynesian navigation, Nāinoa has said “I could not have done it without the planetarium.” The planetarium continues to serve approximately 75,000 visitors (including students) per year through its daily shows, which include *Sky Tonight* and *The Wayfinders*, during which Nāinoa’s star compass is projected along the dome’s horizon when the audience gets to try out various navigational techniques ([http://www.bishopmuseum.org/planetarium/#.Ucyku5y0QIs](http://www.bishopmuseum.org/planetarium/#.Ucyku5y0QIs)).
HCPS III

Grade 8 – Earth and Space Science

- SC.8.8.7: Describe the physical characteristics of oceans.

Common Core

Grades 6-8 Reading Literacy Science & Technical

- 6-8.RST.3: Follow precisely a multistep procedure when carrying out experiments or tasks
- 6-8.RST.4: Determine the meaning of symbols, key terms, domain-specific words and phrases

NGSS

- ESS1.B: What are the predictable patterns caused by Earth’s movement in the solar system?

Resources and Materials:

Materials:

- Butcher paper (e.g., 15” x 1,000’ for ~$42 at Office Depot)
- String (multiple pieces of at least 3 ft)
- Clear masking tape
- Yard sticks
- Sharpie markers of different colors
- Magnetic compass
- Globe of the Earth
- Chart or map of the Pacific Ocean
- Marine debris samples (e.g., netting, rope/cordage, fishing line, plastic bags, Styrofoam, bottle caps, buoyant rubbish, glass bottle, wood plank)
- Naturally-occurring debris samples (e.g., coconut, tree branch, leaves)

Photographs:

- Mau’s paafu (see CULTURAL section of BACKGROUND)
- Nāinoa’s star compass (see CULTURAL section of BACKGROUND)
- Nāinoa’s star compasses located around O‘ahu (see ELABORATE/EXTEND)

Websites:

- This site is central to the activity of understanding how the star compass works. It is...
Instructional Procedures:

Lesson 1 - Making a Star Compass

1. ENGAGE:
   - Explain to the class that, aboard a waʻa (canoe), everyone has a kuleana (responsibility). In order to make sure that everyone does his or her share of the work, the crew is divided into “watches,” each with a “watch captain” who passes along instructions from the captain of the waʻa. Designating yourself as the captain, divide the students into watches of 4 or 5 people, and choose one student from each group to serve as their group’s watch captain.
   - Task each watch with making a 6 ft x 6 ft square by taping (with the clear masking tape) several sheets of butcher paper together.
   - In order to create the center lines of the 32 equal-sized houses of the compass, have the students fold their squares from one corner to its opposite corner and make a thorough crease. (The square should now be folded in half diagonally, forming a right triangle). Next, without unfolding the paper, have the students identify the right-angled corner and meet the other 2 corners together (in order to half the triangle) and make a thorough crease. Again, without unfolding the paper, half the resultant smaller right triangle in the same way and make a thorough crease.
   - At this point, 2 more folds are required, but instead of halving the right triangle, fold the most recently created crease to align with the hypotenuse (diagonal) of the right triangle and create a new crease. Finally, fold this new crease to align with the edge that was once the hypotenuse of the aforementioned right triangle.
   - Upon unfolding their papers, the students will find them divided into 32 equally-sized creases, which represent the center lines of the each of the 32 star compass houses.
   - After finding the very center of the square (i.e., where all the creases intersect), have the students tie a pencil just under 3 ft from the end of the string. Securely holding the end of the string down on the center of the square, have them trace an approximately 3-foot-radius circle with the pencil (while holding the string taut). After this outer circle is drawn, have them wrap the string twice around the pencil (in order to shorten it) and proceed to trace another, smaller circle within the previous circle. Finally, have them reinforce the appearance of both circles using...
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a black Sharpie pen.

2. EXPLORE:

• Moving in a clockwise direction, have them now label the corners of the paper (i.e., outside of the circles) with ‘ĀKAU, HIKINA, HEMA, and KOMOHANA, explaining that these are the Hawaiian terms for north, east, south, and west (respectively).
• Without using the magnetic compass (or the GPS on a phone), task each group with orienting their compass based on a familiar cardinal direction. Have each group share what previous knowledge they used to make their educated guess.
• Once everyone has shared (but before using the magnetic compass), ask the students:
  o How many directions do you need to know in order to orient your compass?
  o If you were outside in the middle of the night (without seeing any recognizable landmarks), what could you use to help you distinguish at least one direction? (Hint: what daily event could you use?)
  o If it was the middle of the day, what could you use? (Again, what daily event could you use?)
• Using a magnetic compass or GPS (if they choose), have the students properly align their star compasses (on the floor) with respect to magnetic north.
• Again, moving in a clockwise direction, have them label the houses of their star compass: within the space between the two circles (and centering each house name across each crease—except for the ones pointing in the cardinal directions), have them write:
  o Between ‘Ākau and Hikina: Haka Ko‘olau, Nā Leo Ko‘olau, Nālani Ko‘olau, Manu Ko‘olau, Noio Ko‘olau, ‘Āina Ko‘olau, Lā Ko‘olau;
  o Between Hikina and Hema: Lā Malanai, ‘Āina Malanai, Noio Malanai, Manu Malanai, Nālani Malanai, Nā Leo Malanai, Haka Malanai;
  o Between Komohana and ‘Ākau: Lā Ho‘olua, ‘Āina Ho‘olua, Noio Ho‘olua, Manu Ho‘olua, Nālani Ho‘olua, Nā Leo Ho‘olua, Haka Ho‘olua.
• Share with students the history of Mau’s and Nāinoa’s compasses and how the Hawaiian star compass is used in modern Hawaiian navigation.

3. EXPLAIN:

• Task the students to discuss the following questions (within their groups), simulating the scenarios (using various props) to come up with the answers:
  o While voyaging, you encounter floating ‘ōpala (trash, e.g., netting, plastic bottles, etc.). How might these materials travel with respect to the [mental] compass that surrounds your wa’a?
  o What affect might au (surface currents) and makani (winds) have on your planned sail course?
How might you be able to detect an island without being able to see it? (Think about your experience in a pool, when someone jumps in right beside you.)

If the horizon is cloudy directly in front of and in back of your waʻa, how else might you be able to figure out your sail course?

How might the Sun, the Moon, planets, and stars be used to maintain course?

- Possible activity to demonstrate this absolutely essential issue:

I. Activity with physical star compass on the ground:
   - Review the star compass and its 32 houses
   - Focus on NE Lā
   - Explain that the sun, during prime sailing season in the spring, rises in NE Lā, moves across the sky, and sets in NW Lā (demonstrate this with the picture of the sun).
   - So if you are voyaging in May, and see the sun set, you can tell where NW Lā is, and then fill in the other directions of the compass with this knowledge.
   - At night the stars have a similar function. Stars always rise in the same house, through the Pacific, and set in an opposite house. So, as we saw in our demonstration in the first lesson, the Pleiades rise in NE ʻĀina and set in NW ʻĀina.
   - Take the big cutout of a star; say this will be the star Hōkūleʻa and we will follow it across the sky.
   - Hōkūleʻa will always rise in the direction of NE ʻĀina. In fact, Nāinoa chose the term ʻĀina because Hōkūleʻa has special importance to the ‘land’ of Hawaiʻi; in Hawaiʻi, Hōkūleʻa passes exactly overhead.
   - Review with the students: Hōkūleʻa rises in NE ʻĀina;
   - Hōkūleʻa will always set in NW ʻĀina.

- After each group has come to a consensus, have the class reconvene as a whole to discuss everyone’s various answers. Make sure that students use specific house names in their explanations. In our next lesson, we will use a ‘planetarium on a screen’ to understand in more detail how a star compass works.

Lesson 2 – Understanding How the Star Compass Works

Setting up the ‘planetarium on a screen’:

- Go to the site “Never Lost” http://www.exploratorium.edu/neverlost/; select the page ‘navigation’; then select the page ‘planetarium.’ Here is the direct link: http://www.exploratorium.edu/neverlost/#/navigation/planetarium
• This page allows you to see the night sky for any place on earth, on any time, at any time. Spend time becoming familiar with site.

• On the screen you will see the night sky with the Hawaiian Star Compass across the bottom of the screen. (If the compass is turned off, go to “direction guides” on the bottom of the left side of the screen and click “Show both,” which will show both the star compass and the western cardinal points.)

• On the left side of the screen is a globe of earth; a green dot marks the location on earth that the stars are being viewed from. Go to the tap “jump to location,” just below the earth globe, and click “Hawai‘i.” By doing this, you will see the sky from 21 degrees N, the latitude of Honolulu Hawai‘i.

• Down below the “Jump to Location” button, on the lower left of the screen, there are controls to set the time and date. Click on the time till it says 6:45 pm, and the date until it says ‘April 1’.

• Below that, under “Stars, star families and guides,” under “display star names” select “English names.”

1. ENGAGE:
• Explore the Sky!
• Project this image of the night sky, set for the latitude of Hawai‘i, onto a screen in class.
• Explain to students that they are seeing the night sky as you’d see in April around 6:45 pm; this is prime sailing season.
• Look west; point out Orion the Hunter in the west with its bright stars Betelgeuse and Rigel; Aldebaran (the bright star in Taurus); and Sirius (the bright star in Canis Major).
• Using the controls, turn the sky until you are facing North (ʻĀkau). Have the students locate the Big Dipper in the northern sky. Show how the big dipper’s pointer stars can lead them to the north star.
• Using the controller, keep turning around the sky till you are facing east. Identify Arcturus and Spica in the eastern sky.

2. EXPLORE:
• Reiterate that this is the sky we’d see from Hawai‘i on April 1 at 6:45 pm.
• To understand how sky and the sky compass work, let’s just see, first of how, how the sky changes in two hours. Let’s observe what happens to:
  - Orion, Aldebaran and Sirius in the west
  - Big Dipper and North Star in the north
  - Arcturus and Spica in the east.
• Instructions:
  - Cover over the projector so students can’t see the sky
  - Reset the time for two hours later, still April 1
  - Uncover projector
• As the students to look again to the western sky, and tell you have things have
changed between 6:45 p.m. and 8:45 p.m. Is Orion higher or lower? (lower). What around Sirius and Aldebaran (also lower). So: stars set in the west, much as the sun does during the day.

- Turn the sky around to the east. Find the Big Dipper, Arcturus and Spica. Are they higher or lower low, than at 6:45 pm? (Higher). So, things rise in the east – as the sun does during the day.

- But what about the north star: higher? Lower? Same? (Same). Yes, the North Star barely moves at all, as all the sky spins around it. (Note: run sky till Arcturus is about to set in the west, 6:20 am).

- So as the world turns, stars rise in the east and set in the west. Polynesian navigation makes use of the risings and setting of stars as an important navigational tool.

- Let’s explore how we can use the Star Compass as a tool. We’re looking now at Arcturus or Hōkūle‘a , which always sets in the house of NW Aina. Notice where ‘Āina is; notice that the house to the left of ‘Āina is Lā, and the one to the left of that is called Komohana, or West. So remember that: ‘Āina - Lā -West.”

- (Turn off star compass and western directions by selecting ‘don’t show guides’). Now, without the star compass, let’s imagine that we are drifting off course, not sure of where we are. (Turn around the sky still Arcturus comes back). There is Arcturus again – do you remember where it sets? (NW ‘Āina). And what house is to the west of Āina? (NW Lā) and what is next to Lā? (Komohana, or West). By using your knowledge of where Arcturus sets, you were able to find your directions again. This is particularly useful in situations such as when the North Star is behind the clouds or not visible.

3. EXPLAIN:

- The star compass that Nāinoa Thompson developed was split into these 32 evenly-spaced houses. This was different from the Micronesian compass, whose houses marked the actual rising and setting points of stars in one particular area of Micronesia.

- Let’s look at how this works. We say how Arcturus set in the west just before dawn in early April from Hawai‘i. This is where we are (show green dot on the globe). We’re going to change our location to Tahiti, 17 degrees below the equator (select ‘Tahiti’ for location and change time to 5 am. Keeping it April 1).

- Here we are just before dawn; notice that even though we’ve traveled 2400 miles south, Arcturus still sets in NW ‘Āina.

4. ELABORATE/EXTEND:

- Task students with constructing a more durable star compass, using drop-cloth canvas. [Instructions to follow] (Supplies should cost no more than $200).
• Have students visit one or more of the following permanent replicas of the Hawaiian star compass within the community (e.g., on O‘ahu) and give an impromptu lesson about it to family, friends, and/or passersby, documenting the event with photographs and a personal, written reflection.

(Kapi‘olani Community College)

(Photo source:  http://pvs.kcc.hawaii.edu/index/newsletters/2011/events_news.html)

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5. **EVALUATE:**

- Assign the Moon, the Sun, or either the northern or southern half of a star line to each group. Have them present the paths of their assigned celestial bodies (and how the paths might change, depending the time of year and/or latitude) and any *moʻolelo* (stories) ancient or relatively recent times associated with them.

References


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