Marine Navigation
Teaching and Learning Module Grades 6-12
Dear Educator,

We are pleased to present you with the fourth in a series of teaching and learning modules developed by the DEEPEND (Deep-Pelagic Nekton Dynamics) Consortium and their consultants. DEEPEND is a research network focusing primarily on the pelagic zone of the Gulf of Mexico, therefore the majority of the lessons will be based around this topic. Whenever possible, the lessons will focus specifically on events of the Gulf of Mexico or work from the DEEPEND scientists.

All modules in this series aim to engage students in grades 6 through 12 in STEM disciplines, while promoting student learning of the marine environment. We hope these lessons enable teachers to address student misconceptions and apprehensions regarding the unique organisms and properties of marine ecosystems. We intend for these modules to be a guide for teaching. Teachers are welcome to use the lessons in any order, use just portions of lessons, and may modify the lessons as they wish. Furthermore, educators may share these lessons with other school districts and teachers; however, please do not receive monetary gain for lessons in any of the modules. Moreover, please provide credit to photographers and authors whenever possible.

This fourth module focuses on navigating marine environments, specifically discussing aspects of historical and current human navigation and animal navigation. We have provided a variety of activities and extensions within this module such that lessons can easily be adapted for various grade and proficiency levels. Given that education reform strives to incorporate authentic science experiences, many of these lessons encourage exploration, experimentation, and discussion, to encourage students to think and act like a scientist.

Additional teaching modules, and materials such as animations, videos, and blog posts (kids and adults), will also be posted on the DEEPEND website as they become available (http://www.deependconsortium.org/). We hope you and your students dive into these materials and benefit from the adventure.

Sincerely,

K. Denise Kendall, Ph.D. on behalf of the DEEPEND Education and Outreach Team
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Navigating Marine Environments

The ability to orient and find your way through terrestrial and aquatic habitats can be a difficult task. Although challenging, marine and terrestrial animals as well as humans, possess a variety of adaptations to orient and navigate through their respective environments to locate food, find mates, avoid hostile weather and environmental conditions. In this module we will focus on how humans and animals navigate open marine waters, habitats that tend to have less structural landmarks than other environments.

Human Navigation

Mariners have been navigating marine waters for centuries. Archeological evidence suggests that Neanderthals sailed on the Mediterranean Sea over 100,000 years ago, and they may represent the first human mariners. Most early mariners used landmark navigation and sailed within sight of land, a technique known as “coasting.” Early mariners would use key landmarks along the coast to guide their voyages. These structures could be natural (e.g., mountain ranges, deltas, etc.) or man-made (e.g., cities, ports, etc.). As long as the mariners remained within sight of land they could successfully navigate to their destination; however, if they ventured too far out into open waters they were vulnerable to disorientation. Consequently, few early mariners ventured out into the open ocean. It is thought that those mariners that did leave the sight of land used birds and whales to help navigate. These mariners had to have extensive knowledge about the ranges of these animals, e.g., they only traveled a certain distance from land only lived in specific regions. Historical records show extensive documentation that this method of navigation was used by the Vikings and Polynesians.

As mariners ventured further out into the open waters they developed several instruments and techniques for navigation. However, venturing out into open waters still carried greater risks than coasting. Celestial navigation was one such navigation approach. Mariners used the stars, moons, planets, sun, and horizon to calculate current position out on the open waters. The sun was used to determine sailing direction during the day. Mariners carefully studied constellation maps to determine which stars were present in the Northern and Southern Hemispheres for nighttime navigation. However, stars, planets, and moons were only visible on clear nights. The earliest documented uses of celestial navigation are from Polynesian voyages across the Pacific Ocean.

Consequently, instruments were invented to assist in determining more accurate position calculations. These instruments aided mariners in determining their current position, as well as speed and directionality. For example, mariners used a sextant to measure the angle between objects in the sky (such as stars and suns) and horizon. The magnetic compass was first used in China during the Hang Dynasty in the first century. Navigational applications of the compass did not appear until the eleventh century (again in China) and then in Europe in twelfth century when nautical applications were discovered. With the aid of a compass, mariners could determine directionality at all hours of day and all days of the year as Earth’s magnetism was consistent throughout the day.
Methods for navigation have changed throughout history, changing with instrument advancements and mariner needs. The understanding of historic navigation remains incomplete but a rich historical record and curiosity allows us to trace many advances in navigation of open waters by humans. We will briefly discuss the use of currents and nautical charts with underlying techniques, such as dead reckoning, as these techniques are most frequent in historical records in conjunction with celestial navigation and coasting which have already been discussed.

**Currents**

Some mariners sailed along ocean currents which propelled the ships in desired directions. There are many stable ocean currents including the Gulf Stream, Labrador Current, North Equatorial Current, Equatorial Counter Current, South Equatorial Current, Peru Current, Alaska Current, and many others. Within the Gulf of Mexico, the prominent current is the Florida Loop Current which meets up with the Gulf Stream once through the Straits of Florida.

Earth’s waters are constantly in motion due to winds, solar heating, Earth’s rotation, and gravity. All of these forces contribute uniquely to the ocean currents. Winds direct waters on the ocean’s surface by pushing the water in the direction the wind is blowing. Solar heating influences the movement of water though water expansion. Earth’s rotation results in curve air rotational patterns, these curvature paths are referred to as Coriolis force. The Coriolis force results in clockwise circulations in the Northern Hemisphere and counter-clockwise circulations in the Southern Hemisphere. Coriolis force has no effect at the equator. Gravitational forces are responsible for the changes in tides, and concurrently result in tidal currents. Collectively these forces contribute to both stable and transient currents globally.

**Nautical Charts**

Eventually mariners began to document their voyages by creating nautical charts (i.e., maps). The oldest nautical charts date to the thirteenth century. The first charts simply outlined shorelines with additional narrations from captains. These charts later progressed as mariners integrated science (primarily astronomy) and mathematics into the documentation of their journeys.

Initial maps were highly variable and inaccurate, but did provide general directionality to mariners as a compass rose, also known as a rose of the winds, indicated map direction. The structure of a compass rose varied from a simplistic 4-point rose indicating the four cardinal (North, East, South, West) wind directions to a 32-point rose.

Some rose compasses consisted of two circles. Each circle was subdivided into degree increments from 0° to 360°. The outer circle indicated true cardinal directions by depicting true north using Polaris, the north star. Meanwhile, the inner circle
indicated magnetic cardinal directions where north was determined using the magnetic pole. Compass roses allowed mariners to set a course using a protractor, and were drawn at key locations on the map such as between ports.

Some mariners determined course by dead (deduced) reckoning. Dead reckoning took into account speed, time, and direction of travel, but failed to consider wind or current. Determination of initial (past) position is used as a reference point. This method of determining current position was prone to calculation and course errors. However, even with the inaccuracies associated with this navigation method, mariners could determine estimated current position and correct course heading as needed by referencing a nautical map.

Eventually nautical maps included longitude and latitude providing more accurate depictions of travel. Latitude was determined using celestial navigation while longitude was determined by the amount of time it took to travel between two points. Latitude and longitude could help determine distances as well as time traveled, as each interval was standardized.

Latitude is a north-south position of measure from the Earth’s equator (0° latitude), while longitude is an east-west position measured from the Prime Meridian at 0° longitude, which was established in an international agreement in 1884. While latitude was determined earlier in mariner history, the accuracy of determining latitude became more precise at the end of the 15th century. On clear nights mariners would measure the angle between Polaris and the horizon while on clear days they would measure the distance between the sun and the horizon. Throughout history there have been many instruments developed to measure latitude including the horary quadrant, mariner’s astrolabe, cross staff, kamal, nocturnal, and sundial.

Determination of longitude required more guesswork and remained more inaccurate until the eighteenth/nineteenth centuries. Most mariners would use celestial observations and vessel speed to estimate longitude. John Roger Arnold is credited with inventing the first seagoing clock, a chronometer. The invention of a mariner chronometer, also referred to as a seaworthy precision clock, allowed for more accurate determination of longitude. In fact, when these marine chronometers were used in conjunction with celestial observations they could pinpoint the location of a ship to within 100 km.

Modern Navigation

Many advances in marine navigation have occurred throughout human history. New approaches aimed at more precise ways to determine location, and therefore enable mariners to expeditiously navigate the open waters. Now, in the modern era of marine navigation, the majority of the methods rely on technology. These integral systems are capable of automatically determining current location and trajectory much quicker and more accurately than historical means. While technology has advantages, it is still important for mariners to understand and be able to use historical methods as technological systems can malfunction.

Technological advances to marine navigation began in the 1860s when telegraphic time signals were used to check chronometer accuracy. This check system enabled mariners to navigate the open waters more safely as they ensured proper functioning of the chronometer. Later in the early 1900s navigational warnings were broadcast using radio signals. More advancement came in the 1920s when radio direction finding was established. Radio
direction finding allowed mariners to pinpoint direction from a signal source by determining where the signal was strongest, therefore it was sometimes referred to as a radio compass. Advancements continued since the mid-twentieth century; we will discuss two of these advances (radar and GPS).

**Radar**

Radio detecting and ranging (radar) is an electronical means of detecting and tracking objects. To detect an object, short bursts of radio energy are transmitted. When the radio energy collides with an object it is reflected back and returns as an echo. The technology upon which radar is based was invented during World War II (1939–1945). This revolutionary advancement allowed soldiers to determine enemy location from a distance. Moreover, the functionality of radar did not depend on time of day and was minimally impacted by weather conditions. Broad applications of radar to marine navigation began in the mid-1950s.

![Radar screen on the DEEPEND’s research vessel Point Sur. Photo Credit: Chris Valdes.](image)

**GPS**

Global positioning system (GPS) is a means of tracking objects in real time through the use of satellites. The satellites orbit Earth approximately 20,000 km above the Earth’s surface. GPS was originally developed for military applications but is now commonplace in that many mobile phones and handheld GPS units receive microwave signals from the satellites. The microwave signals travel at the speed of light and the travel time between satellite and GPS unit is used to determine position. The more satellites communicating with a GPS unit, the
more accurate the location calculation is. At least three satellites are required to pinpoint a location; this is referred to as trilateration. With over 24 operational satellites (and 6 back-up satellites) orbiting the Earth continuously, it is likely that at any given time there are enough satellites above a region to determine location.

GPS location determination is considered to be extremely accurate but there are factors which can result in failure to locate or inaccurate location. For example, microwave signals can be blocked by large buildings or rock surfaces. GPS cannot be used to locate ships that have sunk as the signaling will not work underwater. GPS location can be used in conjunction with a chart plotter to show ship location, route, and to determine tracks.

Animal Navigation

Just like the earliest human mariners, some animals rely on landmarks to navigate. These visual cues allow animals to determine their location and correct course as necessary. Gray whales are often seen spy hopping out of the water along the West Coast of the United States and Canada. This sky hopping motion offers the whales a glimpse at the horizon to determine location. Some animals such as dolphins use the topography of the ocean floor to navigate. They recognize certain natural features such as trenches on the ocean floor and can determine their course, just like whales and humans use the coastline.

Other animals such as the fiddler crab navigate by keeping track of how far they have traveled. These animals do not use an instrument to measure distance from a specific point, instead they keep a running tab of what motions and strides they have made from their burrows. If danger presents itself, the fiddler crab can quickly return to its burrow by retracing its steps.

Some animals use celestial bodies such as the stars, moon, and sun to navigate. The use of celestial bodies allows these animals to travel further than the proximity of familiar landmarks. Mallard ducks are a great example of animals that rely on celestial landmarks for navigation. It is not just the presence of these celestial bodies that provides directionality, but the light that is emitted from them. For example, mallard ducks rely on the polarized light that originates from the sun rather than the position of the sun itself. The axis of this polarized light in conjunction with the ability to perform sun compass orientation allows these waterfowl to determine their current heading and desired heading. Mallard ducks are also capable of following direction cues at night through star and moon locations. Specifically, they are able to determine which direction is north by using the North Star.

While humans require a compass to detect the magnetic field, many animals are capable of detecting it without instrumentation. This form of navigation has been well documented in loggerhead sea turtles. Not only are loggerhead sea turtles capable of detecting the magnetic field but they can detect the inclination angle and intensity of the field more precisely. Hatchlings know where to go after they are hatched because they inherit a mental map with instructions that are based on cues from the magnetic field. In conjunction with the celestial navigation discussed earlier, mallard ducks also rely on magnetic fields for navigation.
While some animals innately have these abilities, others must learn navigation techniques when they are young. For example, some animals migrate with their parents or other elders to learn routes. In fact, young whooping cranes learn migration routes from Wisconsin to Florida from older whooping cranes. During these initial migrations, animals form cognitive maps of the magnetic field, landmarks, currents, and distance traveled.
Marine Environments Background for Students
Celestial Bodies

Many early mariners relied on celestial bodies for navigation. They depended on the location of the stars and Earth’s moon at night. The appearance of the night sky changed based on location and time of year. Let’s start by taking a closer look at the moon. The appearance and position of Earth’s moon changes over time because of the relationship between the moon, the Earth, and the sun. The moon does not actually light up at night, instead it reflects sunlight back to Earth.

There are four main phases of Earth’s moon: new moon, first quarter, full moon, and third quarter. During the new moon phase, the moon is not visible even though the sun is illuminating the moon. This is because we see different angles of the moon as it rotates around Earth’s orbit. During the first quarter phase we see half a circle illuminated. This illumination progressively increases until an entire circle is seen in the night sky. This is the full moon phase. Then, the illumination progressively decreases passing through the third quarter phase until no illumination is seen and the cycle starts again.

In addition to the moon, early mariners would navigate using the stars. In both the Northern and Southern Hemisphere mariners relied on stars and constellations. Most notably, in the Northern Hemisphere mariners knew the location of the North Star (Polaris) was fixed. The North Star is one of the brightest stars in the night sky. The constellations present depended on location and time of year, so an in depth knowledge of astronomy was essential.

During the day mariners took careful note of the location of the sun. Mariners would observe where the sun rose and set to aid in determining heading. If mariners were sailing toward the rising sun, they were heading east, but if they were sailing into the setting sun they were heading west. This is because the sun rises in the east and sets in the west. With this knowledge they could also determine with directions were north and south. More complex measures of location could also be obtained from the sun’s position. For example, a variety of instruments were created to measure the altitude of the sun. By knowing the altitude of the sun, mariners could estimate latitude.
Earth’s Grid System

Early nautical maps included coordinates for latitude and longitude. These geographical tools created a grid allowing humans to more accurately depict location. But what are longitude and latitude?

Latitude is a north-south position of measure from the Earth’s equator, while longitude is an east-west position measured from the Prime Meridian.

Mariners determined latitude using celestial navigation techniques in the fifteenth century. On clear starry nights, mariners would measure the angle between the star Polaris and the horizon, while on clear days they would measure the distance between the sun and the horizon. Later, several instruments were invented to determine latitude, including the horary quadrant, mariner’s astrolabe, cross staff, kamal, nocturnal, and sundial.

Determination of longitude remained rather inaccurate until the eighteenth/nineteenth centuries when John Roger Arnold invented the first seagoing clock, a chronometer. Mariners could use celestial observations to determine longitude either in conjunction with a chronometer or unaccompanied (less accurate). Marine chronometers could pinpoint the location of a ship to within 100 km.
Historical Navigation

Did you know that Neanderthals sailed on the Mediterranean Sea over 100,000 years ago? Archeologists think Neanderthals were the first human mariners. Most early mariners used landmark navigation and sailed within sight of land. This was known as “coasting.” These mariners would observe key structures along the coast to guide their voyages. These key structures could be natural (e.g., mountain ranges, river deltas, etc.) or man-made (e.g., cities, ports, etc.). As long as these mariners remained within sight of land, they could successfully navigate to their destination; however, if they ventured too far out into open waters they risked becoming disoriented.

A few early mariners, like the Vikings and Polynesians, ventured out into the open sea. They used birds and whales to navigate. Just like structures on the coast served as landmarks, so did these animals. Mariners had knowledge of the ranges and migration patterns of these animals. Because many species only traveled a specific distance from land, mariners often could use this information to assist with navigation.

As mariners ventured further out into the open waters, navigation became more challenging. Consequently, several navigation instruments such as nautical maps, compasses, sextants, and chronometers, were invented. These instruments aided mariners in determining their current position as well as speed and directionality.

Photo Credit: Chris Valdes and Stanton Broadway.
Modern Navigation

In the modern era, marine navigation relies on major technological advances. Technological advances to marine navigation began in the 1860s when telegraphic time signals were used to check chronometer accuracy. In the early 1900s, navigational warnings were broadcast using radio signals. Many technological advances have occurred in the past century, including radar and GPS.

Radio detecting and ranging (radar) is an electronical means of detecting and tracking objects. To detect an object, short bursts of radio energy are transmitted. When the radio energy collides with an object, it is reflected back and returns as an echo. The technology upon which radar is based was invented during World War II (1939–1945). This revolutionary advancement allowed soldiers to determine enemy location from a distance. Moreover, the functionality of radar did not depend on time of day and was minimally impacted by weather conditions. Broad applications of radar to marine navigation began in the mid-1950s.

Global positioning system (GPS) is a means of tracking objects in real time through the use of satellites. The satellites orbit Earth approximately 20,000 km above Earth’s surface. GPS was originally developed for military applications, but is now commonplace in the many mobile phones and handheld GPS units receive microwave signals from the satellites. The travel time of microwave signals between a satellite and GPS unit is used to determine position. The more satellites communicating with a GPS unit, the more accurate the location calculation is. At least three satellites are required to pinpoint a location, this is referred to as trilateration. But, with over 24 operational satellites (and 6 back-up satellites) orbiting the Earth continuously, it is likely that at any given time there are enough satellites above a region to determine location.

Photo Credit: Chris Valdes
Animal Navigation

Humans are not the only organisms that rely on Earth’s magnetic field to navigate marine waters. Many animals are capable of detecting the magnetic field without instrumentation and use information from the magnetic field to navigate the open waters.

Navigation by Earth’s magnetic field has been well documented in loggerhead sea turtles. The loggerhead turtle is a threatened species that occur sub-tropical and tropical regions of the Atlantic, Pacific, and Indian Oceans, including the Gulf of Mexico. Between the months of May and August, loggerhead sea turtles nest on sandy beaches along the Gulf of Mexico. Most loggerhead sea turtles nest on shores of the state of Florida, but they can also be found on the shores of Texas, Louisiana, Mississippi, and Alabama.

When hatchlings first emerge from their nest, they must crawl from the nest to the ocean where they will feed in the benthic zones near the coastline. Loggerhead sea turtle hatchlings instinctually know where to go after they are hatched because they inherit a mental map with instructions that are based on cues from the magnetic field. Not only are loggerhead sea turtles capable of detecting the magnetic field, but more precisely they can detect the angle at which magnetic field lines intersect Earth’s surface (inclination angle) and intensity of the field.

When loggerhead sea turtles reach reproductive age (at about 30 years), most of the females return to the beach where they were born to nest.

From left to right: Loggerhead hatchlings emerging from a nest; loggerhead tracks returning to ocean; loggerhead hatchling. Photo Credit: Julia Ossler.
Setting Sail

Did you know that mariners have their own language? Today you will learn some of the most common words in their language.

The main part of a ship is called the **hull**. All of the walls are called **bulkheads** and ceilings are **overheads**. You may have heard the expression “swab the deck,” **decks** are the floors of a ship. Most ships have hallways and corridors that are called **passageways**. Some ships are large enough that they have more than one level. To get from one level to another you would go up and down stairs which are called **ladders**.

There are also special words for navigating a ship. The front of a ship is called the **bow** while the back part is called the **stern**. **Fore** refers towards the front of the ship while **aft** is used to describe directions toward the back of the ship. The **port** side of the ship (when facing the bow) is the left side of the ship while the **starboard** side is called the **starboard** side.
Marine Navigation

Since many concepts overlap between human and animal navigation, all activities are presented in the pages that follow. Suggested activity structures and extensions are included prior to all activities and worksheets.

Objectives
The activities included in this module aim to provide students with a deeper understanding of marine navigation by humans and animals.

Next Generation Science Standards applicable to activity and extensions

- MS-PS2-3. Ask questions about data to determine the factors that affect the strength of electric and magnetic forces.
- MS-PS2-5. Conduct an investigation and evaluate the experimental design to provide evidence that fields exist between objects exerting forces on each other even though the objects are not in contact.
- MS-PS4-3. Integrate qualitative scientific and technical information to support the claim that digitized signals are a more reliable way to encode and transmit information than analog signals.
- MS-ESS1-1. Develop and use a model of the Earth-sun-moon system to describe the cyclic patterns of lunar phases, eclipses of the sun and moon, and seasons.
- HS-PS3-5. Develop and use a model of two objects interacting through electric or magnetic fields to illustrate the forces between objects and the changes in energy of the objects due to the interaction.
- HS-PS4-1. Use mathematical representations to support a claim regarding relationships among the frequency, wavelength, and speed of waves traveling in various media.

Make a Compass
This lesson teaches students about the magnetic field. Prior to completing this activity, it is recommended that students learn about early instruments and nautical maps used in navigating open waters, as the compass was one of the earliest means to determine directionality. Making a compass allows students to explore Earth’s poles and to understand that magnetic poles repel each other. This activity is a great starter prior to completing other lessons as the compass, and knowledge from this activity, can be applied to other lessons and activities.

Supplies
Each group will need:
- Needle
- Bar magnet with North and South sides labeled
- Small piece of cork or Styrofoam
- Shallow dish or cup with water
Classroom Map
This lesson gives students firsthand experience in mapping. Early mariners relied on landmarks and hand-drawn maps to navigate from one point to another. First, students make note of features (landmarks) of the classroom, then they draw these features on a map. Using their map students describe which direction they must travel to reach specific places. Lastly, students are asked to compare their map with a classmate. This peer-peer check allows students to see the variation that could exist in early nautical maps.

Supplies
Each student will need:
- Worksheet
- Art supplies
- Compass (from previous lesson or store bought)

Moon and Star Journals
This lesson aims to get students outdoors and exploring the world around them. Early mariners and animals rely on celestial navigation. By asking students to observe the night sky, students gain firsthand experience of what it was like to be a mariner before technological advances. After completion of these activities, there can be a class discussion about the benefits and hindrances of relying on celestial objects for navigation (e.g., poor visibility).

Supplies
Each student will need:
- Worksheets
- Art supplies

Make a Star Chart and Sundial
This lesson aims to build on student knowledge of the night sky and its uses in navigation by bringing astronomy into the classroom. Students are asked to create their own star chart by using online resources. Students can use this star chart anytime of the year. This lesson reinforces how mariners’ knowledge of the night sky was vital to determining heading (the direction of travel). It also aims to expand student understanding of celestial navigation by integrating in the use of the sun (via a sundial). The sundial requires multiple visits outdoors on the hour, if this is not possible in a single class you could make it an activity that spans across your periods with multiple classes contributing to a single sundial. This lesson works well both before and after the moon and star journals.

Supplies
Each student will need:
- Worksheets
- Art supplies
- Brad or pin for center of star chart
- Printout or access via Wi-Fi or textbooks to a published star chart
- Straw
Track a DEEPEND Cruise
In this lesson students track a DEEPEND cruise. This lesson can be completed over the course of a couple of weeks if a DEEPEND cruise is currently out at sea, or it can be completed in a single day by having students select an archived cruise. An extension to this activity could be to have students build their own research vessel and “sail” it across a large map. Students can then create a sailing route for their research vessel by conducting research on where they may find specific organisms. Students can then present to their peers why they chose their sampling sites and what they expect to find at each site.

Supplies
Each group will need:
- Worksheets
- Wi-Fi

Spice Map
Early mariners often relied on other mariners for directions. Some of these directions were merely verbal while others were drawn maps. This activity asks students to translate verbal instructions into a map. Students must interpret the directions given to them by their teacher, use a compass to determine cardinal direction, and then draw a map as they find their way. This lesson is a great way to build on the classroom map activity, as it required more application or cardinal directions and map creation. An extension to this activity could be to give students printed maps and ask then to describe how they would travel between two locations.

Supplies
Each group will need:
- Worksheets
- Art supplies
- Compass (from previous lesson or store bought)
- Directions from teacher to a specific location (you can place a treat or prize at the location)

GPS Signals
This lesson teaches students how microwave signals are used to determine location by sharing with them how GPS receivers and signal transmitters calculate distance. Students work through a problem set to determine distance traveled given the rate and travel time of microwave signals. This lesson is great to use when introducing trilateration and it works well to integrate principles from engineering, mathematics, and social studies disciplines.

Supplies
Each student will need:
- Worksheets
- Calculator
Longitude and Latitude and Draw Your Own World Map
This lesson focuses on the use of longitude and latitude as a means of pinpointing locations on Earth. Students are introduced to the idea that longitude and latitude divisions create a grid across the globe, and then through these activities they can see how these divisions function as a grid. Students also discover hemispheres in this lesson. You can revisit celestial navigation at this point and show students how celestial objects are unique in the different hemispheres. An extension of this activity can be to ask students to calculate distance between two points on a map.

Supplies
Each student will need:
- Worksheets
- Art supplies

Gulf of Mexico
In this lesson students pretend to be mariners. Students begin by labeling key countries, states, and bodies of water. Then, they must sail from Greenland to Texas but must determine on their own the best route. This lesson reinforces to students how important it was for early mariners to be familiar with key geographic landmarks. An extension of this activity could be to use online maps to have students observe satellite images of the Canadian and United States coastline. Students can be asked to list what landmarks they would use if they were coasting from Greenland to Texas in lieu of traveling with a nautical map.

Supplies
Each student will need:
- Worksheets
- Art supplies

Squirt’s Adventures
Squirt, the DEEPEND mascot, recently traveled around the world. However, now Squirt can’t remember exactly where he went! In this lesson students have to use a map (or online resources) to figure out where Squirt traveled. This lesson follows the latitude and longitude lesson well as it builds on information presented in that lesson. An extension to this activity is to have students find the coordinates to locations that are special to them (e.g., their school or favorite park).

Supplies
Each student will need:
- Worksheets
- Map or online resources
Getting Home and Trans-Gulf of Mexico Migration

This lesson focuses on animal navigation. There are many overlapping principles between human and animal navigation in/above open waters. In these activities, students grasp a better understanding about these overlaps. In addition to the similarities this lesson is a great place to present differences in techniques used for navigation (e.g., humans may rely on instruments while animals must not). In the getting home activity students are challenged to draw their route between school and home from memory while relating this to how animals find their way. Meanwhile, the trans-Gulf of Mexico migration activity focuses on the trek and why birds migrate over the perilous Gulf of Mexico rather than take a circum-gulf trek. These lessons interconnect important science, engineering, and technological disciplines between humans and animals.

Supplies
Each student will need:

- Worksheets
Make a Compass

Did you know that you can make a compass with only a few materials? A compass relies on the Earth’s magnetic field to determine direction. So, if you magnetize a needle and allow it to freely float, it will point to a magnetic pole!

Supplies:
- Needle
- Bar magnet with North and South sides labeled
- Small piece of cork or Styrofoam
- Shallow dish or cup
- Water

1. Magnetize the needle by rubbing it with the bar magnet 30 times. It is important that you always rub the needle in the same direction and use the “South” side of the magnet. By using the “South” side you will magnetize the needle to be north-seeking.
2. Fill the shallow dish/cup with 2 inches of water.
3. Place the shallow dish/cup on a flat surface.
4. Place the small piece of cork/Styrofoam on the surface of the water. The cork/Styrofoam will help the needle float and spin freely.
5. Place the needle on top of the cork/Styrofoam.
6. The needle will spin until it points to the north pole. What would happen if you magnetized the needle using the “North” side of the bar magnet? Try it!
Early nautical maps sketched general travel routes to help mariners with navigation. Today you will create a map of your classroom. Start by writing a description of your classroom. In your description mention where you sit, where the teacher’s desk is, where the doors are, if there are any windows, where your friends sit, etc.

Maps often include a compass rose to help indicate direction. Use a compass to determine north, south, east, and west within your classroom.
Now draw a map of the classroom making sure to include the compass rose.

What direction do you face when you sit at your desk? _________________

What direction is the classroom door from your desk? _________________

What direction would you travel to get from your desk to your teacher’s desk? __________

Compare your map to a classmate’s map. Do your maps look the same? If they are different, what is different between your map and your classmate’s map?

______________________________________________________________________________
Moon Journal

Of all the objects in the night sky, the moon is one of the most visible. Many early mariners used the moon to aid in determining location and direction. Observe the night sky for 20 days. Document if you can find the moon and what the moon looks like.

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<th>Date and Time</th>
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<tr>
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<table>
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<th>Image of moon</th>
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| Image of moon |  |  |  |  |

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Star Journal

Have you ever been outside on a clear night? Many early mariners used the stars to navigate open waters. Go outside on a clear night and draw what you see. Then, reference a star chart and try to identify some of the stars and constellations in the night sky.
Make a Star Chart

**Base.** Cut out the star chart base along the dashed line. Use a star chart in your textbook or from online resources to draw the stars often seen from your location. Then, cut out the star chart top to finish your star chart.
**Top.** Cut out the star chart top on the dashed line. Then, cut out the viewing window by cutting along the dashed line. Next, poke a brad through the center of the star chart base and top to connect the two pieces.

To use your star chart, go outside between 8PM and 4AM. Align the month of year and time of night. Then look at the stars visible in the viewing window. Can you see them in the night sky?
Make A Sundial

1. Cut out the circle along the dashed line.
2. Use a pencil to poke out the black circle in the center. Insert a straw through the hole.
3. At the start of the next hour take your sundial outside. Draw a line where the straw casts a shadow and label it with the hour.
4. Leave your sundial in the same spot all day long. At the start of each hour go outside and mark the next hour.
5. After a full day you will have a completed sundial. You can take your sundial outside at any time and figure out what time it is based on the sun’s location and the shadow cast by the straw.
Track a DEEPEND Cruise

When the DEEPEND scientists set sail in the Gulf of Mexico they keep virtual cruise tracks. You can see a record of current and recent DEEPEND cruises on the DEEPEND consortium website. Just visit [http://www.deependconsortium.org/index.php/cruises/cruise-tracks](http://www.deependconsortium.org/index.php/cruises/cruise-tracks). Not only can you see where the research vessels traveled, but you can also see where they stopped to take samples and where special events occurred. To read more about sampling and special events just click on the colored dots, some of these events even have blog posts from our scientists!

On the map below trace the path of one DEEPEND cruise. Make note of any sampling sites or special events.

![Gulf of Mexico map](image)

What cruise did you choose to follow? ___________________

When did the cruise set sail? ______________________

From what location did the cruise set sail? ______________________

How many days were the scientists at sea? ______________________

What are some of the organisms the DEEPEND scientists saw on this cruise?

______________________________________________________________________________
You are a merchant selling spices. A fellow mariner tells you about a village that grows a rare spice. Use the directions provided by the mariner and a compass to find the village. As you navigate your way, draw a map making sure to highlight landmarks so you can find the village more easily in the future.
GPS Signals

GPS units rely on measuring the distance between two points: satellites orbiting Earth and the GPS receiver. Satellites that orbit Earth send out microwave signals that travel the speed of light. The GPS receiver must receive signals from at least three satellites in order to accurately determine location. For each microwave signal sent, the distance between the satellite and receiver are calculated using the relationship between distance, speed of travel, and time traveling:

Distance = Rate x Time

Since the signals sent out by satellites travel at the speed of light, we know they travel at a rate of 299,792,458 meters per second.

Practice using the equation above to calculate the distance the microwave signal travels given the following traveling times. Take careful note of the units.

1. 118 secs

2. 6 secs

3. 2 min 4 secs

4. 58 secs

5. Would the signal reach the GPS receiver faster if it travels for 138 secs or 1 min and 7 secs?
Longitude and Latitude

There is a grid system that spans Earth. This grid is composed of parallel lines that run vertically and horizontally. The vertically oriented lines which run from north to south are referred to as longitude while the horizontally oriented lines running east to west are latitude. The most prominent lines are the Prime Meridian and Equator, longitude and latitude respectively. These lines divide the Earth in half in their respective orientations, and consequently are at 0°. On the Earth below, each line represents 10°.

- Trace the Equator brown.
- Trace the Prime Meridian green.
- Color the Northern Hemisphere yellow.
- Color the Southern Hemisphere blue.
- Color the Eastern Hemisphere pink.
- Color the Western Hemisphere red.
- Trace the 40° N line purple.
- Trace the 60° E line grey.
Draw Your Own World Map

On the grid below sketch your own world map making sure to include all continents and oceans.

1. What continent is located at 37° N, 96° W? ____________________
2. What ocean is located at 15° S, 29° W? ____________________
Gulf of Mexico

The Gulf of Mexico is located in North and Central America. It is surrounded by many states of the United States, as well as countries of Central America. On the map below label the Gulf of Mexico and all states/countries that surround it. Then label the Atlantic Ocean, Canada, and Greenland.

You are currently in Greenland and would like to sail to Texas. What route would you sail? Mark the route on the map with a dashed line.
Squirt’s Adventures

Squirt traveled the world to visit many famous landmarks. He kept a travel journal so he could share his adventures with his friends. But, Squirt forgot to write the landmark names in his journal! Instead, he only noted their locations using longitude and latitude coordinates. Use a map to identify which famous landmarks he visited.

<table>
<thead>
<tr>
<th></th>
<th>Longitude</th>
<th>Latitude</th>
<th>Landmark Name</th>
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<tbody>
<tr>
<td>1</td>
<td>40.7° N</td>
<td>74.0° W</td>
<td></td>
</tr>
<tr>
<td>2</td>
<td>48.9° N</td>
<td>2.3° E</td>
<td></td>
</tr>
<tr>
<td>3</td>
<td>30.0° N</td>
<td>31.1° E</td>
<td></td>
</tr>
<tr>
<td>4</td>
<td>33.9° S</td>
<td>151.2° E</td>
<td></td>
</tr>
<tr>
<td>5</td>
<td>27.2° N</td>
<td>78.0° E</td>
<td></td>
</tr>
<tr>
<td>6</td>
<td>41.9° N</td>
<td>12.5° E</td>
<td></td>
</tr>
<tr>
<td>7</td>
<td>23.0° S</td>
<td>43.2° W</td>
<td></td>
</tr>
<tr>
<td>8</td>
<td>37.8° N</td>
<td>122.5° W</td>
<td></td>
</tr>
<tr>
<td>9</td>
<td>40.4° N</td>
<td>116.6° E</td>
<td></td>
</tr>
<tr>
<td>10</td>
<td>51.5° N</td>
<td>0.1° W</td>
<td></td>
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</tbody>
</table>

11. Now find the coordinates for a famous landmark you would like to visit.

_____________________________________________________________
Getting Home

Do you know the way from your house to school? Loggerhead sea turtle hatchlings know where to go after they are hatched because they inherit a mental map with instructions that are based on cues from the magnetic field. They recognize certain natural features on the ocean floor and are able to determine their course. Other animals, such as gray whales are often seen sky hopping out of the water along the west coast of the United States and Canada as they look for landmarks to help them find their way. Some animals, such as dolphins use the topography of the ocean floor to navigate.

In the area below, draw a map from your house to school.
Trans-Gulf of Mexico Migration

Each spring, millions of birds cross the Gulf of Mexico as they migrate from their wintering grounds in the south (Central North America) and their breeding grounds in the north (Southeastern United States). The birds congregate at the Yucatan Peninsula, as this is the closest point to the Southeastern United States coastline prior to crossing the Gulf of Mexico.

This trans-gulf flight is approximately 1000 km, and must be completed non-stop as there are no landing grounds between the coasts. Traveling across the gulf can be perilous, but this is the most direct route to breeding territories as a safer trek above land (along Mexico) would take much longer. Some species will breed in the Southeastern United States while others proceed further north to the Midwest or Central/Northeastern coast.

Each fall these birds return to their wintering grounds in the south, once again crossing the Gulf of Mexico.

On the map to the right:
- Color the Yucatan Peninsula Green.
- Color Mexico Yellow.
- Trace the Southeastern United States Coast Red.
- Draw a trans-gulf migration route to the Southeastern United States from the Yucatan Peninsula in Blue.
- Draw a circum-gulf migration route to the Southeastern United States from the Yucatan Peninsula in Orange.

1. How do birds navigate on their trans-gulf migration?

_____________________________________________________________________________
_____________________________________________________________________________

2. What external factors might affect their trans-gulf migration?

_____________________________________________________________________________
References and resources for teachers and students


Smithsonian. Navigating at Sea. https://timeandnavigation.si.edu/navigating-at-sea


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   K. Denise Kendall, University of Illinois Urbana-Champaign

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Dr. K. Denise Kendall is a graduate of the Department of Ecology and Evolutionary Biology at the University of Tennessee-Knoxville (2013). She holds a Florida Professional Teaching Certificate (Biology 6–12) from the University of West Florida. Dr. Kendall is committed to the advancement of science education in K–12 and higher education through the integration of authentic scientific experiences into course curricula.