

The History of Navigation





Introduction

The history of navigation is an exciting and complex story of math, science, and invention. Finding our way at sea has been an important part of a larger history of exploration, commerce, and human interaction with the sea.

The process of navigation requires good observation, an ability to relate where we are in the world to where we are on a map or chart; and an understanding of mathematics, astronomy, geography, oceanography, meteorology, and seamanship. On ships, the captain is ultimately responsible for safe navigation between ports, though the first mate helps. On sailing vessels, captains' wives sometimes helped with navigation, particularly if they were good at mathematics and astronomy.

Navigation is typically broken into three or four types of activity. The first, piloting, deals with navigation along coasts, where land aids to navigation (such as lighthouses and buoys) help one see where and where not to go. Dead reckoning is used on a more regular basis when out of sight of land. It is a form of navigation that keeps track of where the ship has been to determine its location. Celestial navigation uses the sun, moon, stars, and planets to help a captain find his location on the earth, far out of sight of land. Today, we use “artificial stars,” that is, satellites, to help us find our positions, using GPS (Global Positioning System) receivers, which is a form of electronic navigation.

This module will look at how mariners have navigated the oceans over the last five hundred years, the tools they used, and the scientists and mathematicians who helped perfect the “art” of navigation. It can also provide students the opportunity to learn how to use a chart, a compass, and a logbook.

Navigation is a complex topic, but younger students can learn many of the basic concepts that apply. Museum instructors and teachers can work together to develop a program that best fits the class needs. This module can easily be adapted to history, mathematics, and science Learning Results on many different levels. For example, one can learn navigation in the 17th and 18th centuries as part of a larger maritime history class, or a study of navigation can supplement geometry, trigonometry, logarithms, geography, astronomy, and a number of other subjects, bringing historical context to abstract studies.



General learning goals are:

- To understand concepts of direction, distance, time, and speed, and how they relate to determining where we are or where we are going;
- To learn that geography, oceanography, meteorology, mathematics, physics, and astronomy have a historically important relationship in the “art” and “science” of navigation, and to learn rudiments of these sciences, in order to understand the work of navigating;
- To make observations and measurements to define certain locations;
- To learn about the philosophers, scientists, and mathematicians who helped us understand the earth’s relationship to the sun, planets, stars, the atmosphere, and the oceans;
- To learn about the measurement tools used in navigation and their inventors;
- To understand coordinate systems used on the earth and in the sky, including latitude and longitude;
- To understand how the work of navigation has changed with major technological innovations; and
- To practice navigation, using a chart, compass, and logbook.



Outline

I. What is Navigation?

II. Navigation: A Multi-Disciplinary Skill

III. Methods of Navigation

- A. Piloting
- B. Dead Reckoning
- C. Celestial Navigation
- D. Electronic Navigation

IV. Approaches to Navigation

- A. Verbal—Sailing Directions
- B. Visual—Nautical Charts
- C. Numerical—Electronic Data

V. Measurements for Navigation

- A. On the Earth: Latitude, Longitude, Time, and Magnetic Variation
- B. In the Heavens: Declination, Right Ascension, and Equation of Time

VI. History of Astronomy: Ptolemy, Copernicus, Kepler, Galileo, Newton

VII. Navigation in the Age of Exploration: Fifteenth to Seventeenth Centuries

- A. Tools for Dead Reckoning and Piloting
- B. Guides
- C. Tools for Finding Latitude and Time
- D. Important People in the History of Navigation

VIII. Navigation in the Late Eighteenth Century

- A. Dead Reckoning Tools Unchanged
- B. Published Charts, Sailing Directions, and Almanacs
- C. Tools and Methods for Celestial Navigation
- D. Important People in the History of Navigation

IX. Navigation in the Nineteenth to Twentieth Centuries

- A. Dead Reckoning Tools
- B. Published Charts, Sailing Directions, Tables, and Navigation Books
- C. Tools and Methods for Celestial Navigation
- D. Important People in the History of Navigation

X. Navigation in the Second Half of the Twentieth Century to the Present

- A. Dead Reckoning Tools
- B. Charts, Computer Products, Web Publications
- C. Tools for Electronic Navigation

XI. Charts: Projections, Measurement, Data, and How They are Used

XII. Using a Compass

XIII. Keeping a Logbook at Sea



Learning Results, Grades K-2



Career Preparation

- B-2:** Identify preparation necessary for a career of interest.
- C-1:** Identify examples of technology being applied at home, school, or work.
- C-2:** Demonstrate the effects of technology on where people choose to live, how they communicate, how they travel, and how they acquire goods and services.

English Language Arts

- C-3:** Make valid observations about the use of words and visual symbols.

Mathematics

- A-2:** Understand the many uses of numbers (e.g., prices, recipes, measurement, directions in play).
- E-3:** Use positional words to describe the relationship of two or more objects (e.g., over, under, beside, to the left).
- F-3:** Select standard and non-standard tools for determining length, time, temperature, weight, and capacity, and use them to solve every day problems.
- G-3:** Represent and describe both geometric and numeric relationships.

Science and Technology

- F-1:** Describe the way weather changes.
- G-1:** Explain the cycles of day/night and of seasons.
- G-3:** Demonstrate an understanding that the sun is one of many stars in the universe and is the closest star to earth.
- I-1:** Develop a variety of ways to describe the motion of an object.

- J-1:** Make accurate observations using appropriate tools and units of measure.
- J-2:** Ask questions and propose strategies and materials to use in seeking answers to questions.
- J-3:** Use results in a purposeful way, which includes making predictions based on patterns they have observed.
- J-4:** Identify products which were invented to solve a problem.
- L-2:** Read and write instructions to be followed or instructions which explain procedures.
- L-4:** Explain problem-solving processes using verbal, pictorial, and written methods.
- L-6:** Use objects and pictures to represent scientific and technological ideas.
- M-1:** Describe how legends, stories, and scientific explanations are different ways in which people attempt to explain the world.
- M-2:** Describe at least two inventions, what they do, how they work, and how they have made life easier.

Social Studies

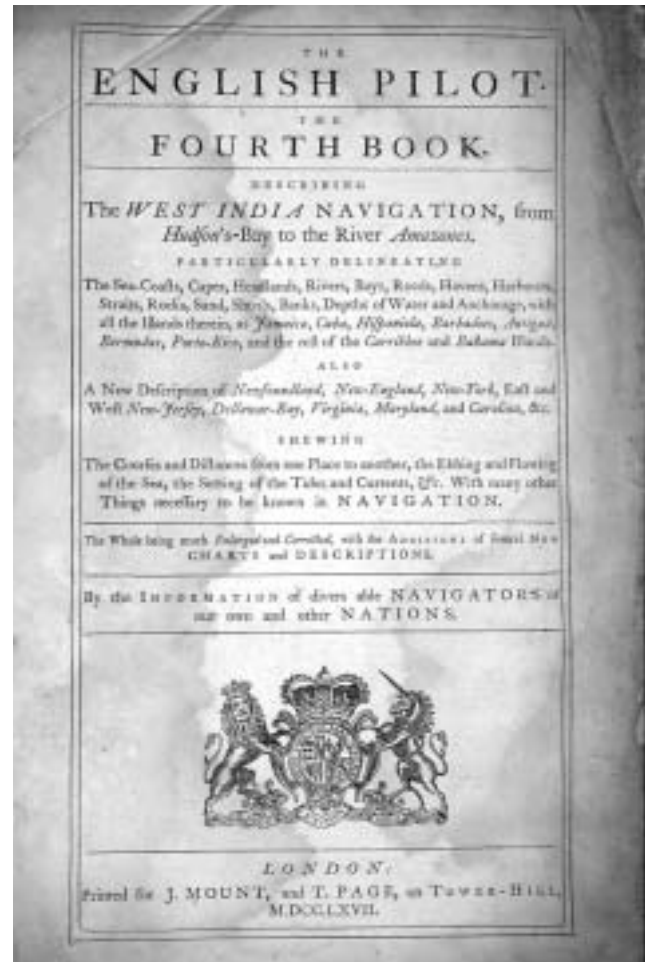
GEOGRAPHY

- A-1:** Use and construct maps and other visuals to describe geographic location, direction, size, and shape.



Activities, Grades K-2

- **Demonstrate the difference between visual and verbal directions** (chart vs. sailing directions) by making maps of the classroom or playground and then writing out the directions. What style is easier to create? To follow? Try giving verbal directions from one place in the classroom to another, using (if available) the square tiles on the floor as measuring units and direction pointers.
- **Make a model of the solar system, or use students as planets and the sun.** Show how the earth revolves around the sun. “Act out” constellations and read about their mythology.
- **Demonstrate the earth-sun relationship with a bright light and a globe.** Locate Maine and other familiar places on the globe.
- **Look at MapQuest (www.mapquest.com)** to illustrate the difference between visual and verbal directions.
- **Read *Sea Clocks: The Story of Longitude*, by Louise Borden** (see Resource List). This is a good explanation of the problem of keeping accurate time at sea. What are other ways of keeping time? Find a variety of sandglasses.
- **Take a compass outside to the playground, and experiment with directions.** Make lists of what students can see when facing north, south, east, and west. Find out how a weathervane works. Look for examples of weathervanes in your town.





Learning Results, Grades 3-4



Career Preparation

- B-1:** Use a variety of resources to learn about a personally interesting career topic.
- C-3:** Identify academic knowledge and skills required in specific careers.

English Language Arts

- C-4:** Make observations about the use of language and graphic symbols encountered in various real-life situations.
- E-5:** Give accurate directions.
- H-3:** Present information obtained from research in a way that combines various forms of information (e.g., maps, charts, photos).

Mathematics

- F-2:** Select measuring tools and units of measurement that are appropriate for what is being measured.
- H-1:** Develop and evaluate simple formulas in problem-solving contexts.

Science and Technology

- G-1:** Illustrate the relative positions of the sun, moon, and planets.
- G-3:** Describe earth's rotation on its axis and its revolution around the sun.
- G-4:** Explore the relationship between the earth and its moon.
- J-1:** Make accurate observations using appropriate tools and units of measure.

J-6: Explain how different conclusions can be derived from the same data.

K-1: Give alternative explanations for observed phenomena.

M-1: Explore how cultures have found different technological solutions to deal with similar needs or problems (e.g., construction, clothing, agricultural tools and methods).

M-2: Investigate and describe the role of scientists and inventors.

M-3: Explore how technology (e.g., transportation, irrigation) has altered human settlement.

Social Studies

HISTORY

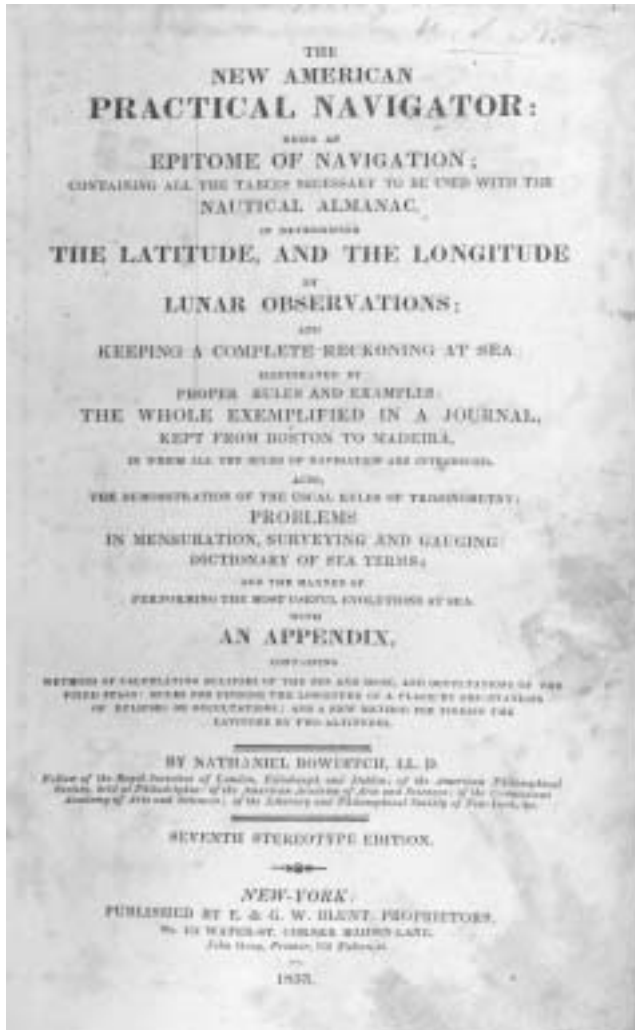
A-1: Identify similarities and differences in the characteristics of individuals who have made significant contributions to society in different eras.

GEOGRAPHY

A-1: Construct and compare maps of Maine, the United States, and regions of the world to interpret geographical features and draw conclusions about physical patterns.



Activities, Grades 3-4



- **Navigation skills are part of education for modern day careers** in the Navy, the Coast Guard, the Merchant Marine, and other occupations. Students who are interested in this type of career may want to investigate educational requirements, locations, and post-college options. Compare how navigation skills were learned in past centuries vs. how they are learned today.
- **Compare maps from different eras** in terms of their accuracy, visual appearance, and artistic qualities. Make a decorative map as an art project.
- **Use maps and charts** in a report of a real or fictitious voyage.
- **Use a globe, a bright light, and other balls to model the solar system.** Alternatively, use students to act as different bodies in the solar system to show the changing relationships between these bodies and to show how knowing their motion can help navigation at sea. Note how eclipses occur. Learn about the constellations and the bright stars that help navigators, making drawings of the constellations.
- **Make a map of the classroom or the playground.** Alternatively, describe in words and numbers how to get from one place to another. Which form of communication is most helpful—visual or verbal? Is this true for everyone?
- **The history of mankind’s learning about the earth and the heavens is critical to navigation.** There are many opportunities to learn more about specific historical figures: scientists, astronomers, mathematicians, explorers, and cartographers. Did these figures have characteristics in common? There are also opportunities to research myths and legends that explain scientific phenomena and to learn about the effects of these prevailing cultural beliefs on societies (for example, the day and night cycle). Technological advances in navigation played a large part in settlement, trade, and cultural change over the last few centuries.
- **Students may learn more about using a specific navigational instrument** and teach the class what he or she has learned, using a specific application. Study how measurement tools have changed over the years.
- **Make a real working compass,** with a needle, a float, a small dish of water, and a small bar magnet. Do the needles point north? Do some needles point south?



Learning Results, Grades 5–8

Career Preparation

- A-4:** Demonstrate an understanding of the relationship among personal interests, skills and abilities, and career research.
- B-1:** Develop a personal portfolio that contains critical personal, educational, and career information.
- B-2:** Compare workplace environments and the education required for different occupations.
- C-2:** Research recent technological developments and predict their possible spin-offs.
- D-1:** Identify how critical factors such as history, the environment, the economy, or personal characteristics may affect individual and family choices.

English Language Arts

- A-6:** Identify accurately both the author's purpose and the author's point of view.
- H-8:** Make limited but effective use of primary sources when researching topics.

Mathematics

- E-3:** Use a coordinate system to define and locate position.
- F-1:** Demonstrate the structure and use of systems of measurement.
- F-2:** Develop and use concepts that can be measured directly, or indirectly (e.g., the concept of rate).
- F-3:** Demonstrate an understanding of length, area, volume, and the corresponding units, square units, and cubic units of measure.
- G-1:** Describe and represent relationships with tables, graphs, and equations.
- G-2:** Analyze relationships to explain how a change in one quantity can result in a change in another.
- I-1:** Identify patterns in the world and express these patterns with rules.
- J-1:** Support reasoning by using models, known facts, properties, and relationships.
- J-2:** Demonstrate that multiple paths to a conclusion may exist.
- K-1:** Translate relationships into algebraic notation.

Science and Technology

- F-1:** Demonstrate how the earth's tilt on its axis results in the seasons.
- G-1:** Compare past and present knowledge about characteristics of stars (e.g., composition, location, life-cycles) and explain how people have learned about them.
- G-3:** Compare and contrast distances and the time required

to travel those distances on earth, in the solar system, in the galaxy, and between galaxies.

- G-5:** Describe the motions of moons, planets, stars, solar systems, and galaxies.
- I-2:** Use mathematics to describe the motion of objects (e.g., speed, distance, time, acceleration).
- J-1:** Make accurate observations using appropriate tools and units of measure.
- J-5:** Explain how personal bias can affect observations.
- K-1:** Examine the ways people form generalizations.
- L-4:** Make and use scale drawings, maps, and three-dimensional models to represent real objects, find locations, and describe relationships.
- M-1:** Research and evaluate the social and environmental impacts of scientific and technological developments.
- M-2:** Describe the historical and cultural conditions at the time of an invention or discovery, and analyze the societal impacts of that invention.

Social Studies

HISTORY

- A-2:** Identify the sequence of major events and people in the history of Maine, the United States, and selected world civilizations.
- B-2:** Demonstrate an understanding of selected themes in Maine, United States, and world history (e.g., revolution, technological innovation, migration).
- B-3:** Demonstrate an understanding of selected turning points in ancient and medieval world history and the continuing influence of major civilizations of the past.

GEOGRAPHY

- A-2:** Develop maps, globes, charts, models, and databases to analyze geographical patterns on the earth.

ECONOMICS

- D-1:** Describe how changes in transportation and communication technologies have affected trade over time.

Visual and Performing Arts

- C-5:** Evaluate work, from their own and other cultures and historical periods, that uses arts elements and principles to persuade and influence.



Activities, Grades 5–8



- **Skills and concepts used in navigation, and learned in this module, are interdisciplinary.** This is true, too, of many career directions; consider what careers use many of the same interdisciplinary skills used in the practice of navigation.
- **Review the instruments used by navigators over the past few hundred years** and suggest spin-offs that occurred, resulting in technological developments not necessarily related to navigation. One surprising spin-off was the microwave oven from the development of radar.
- **Read Latham's *Carry On, Mr. Bowditch*, to see an historical fictional account** of one of this country's most important mathematicians. Discuss what parts of the book might be fictional and what parts might be fact. Was the ability to navigate ships an important skill two hundred years ago? Is it important today?
- **Use a globe, a bright light, and other balls to model the solar system.** Alternatively, use students to act as different bodies in the solar system to show the changing relationships between these bodies and to show how knowing their motion can help navigation at sea. Note how eclipses occur. Learn about the constellations and the bright stars that help navigators, making drawings of the constellations. Show how the tilt of the earth results in seasons, long days, short days, and where the sun rises and sets. Express size and distance information of stars and planets in tabular or graphic form for different parts of the earth.
- **Describe an ellipse and how it is similar to a circle.** Discuss the elliptical orbit of the earth around the sun and how that affects the length of a solar day (equation of time). Compare the distances between the sun and earth, earth and moon, earth and other planets, and earth and the nearest stars and galaxies. Determine the speed of the earth around the sun, the moon around the earth, and the speed of rotation of the earth at the equator. Discuss how these might affect navigation.
- **For centuries, people thought the earth was at the center of the universe,** and that the sun went around the earth. How did people come to that conclusion? Describe the motions of the sun, moon, and planets that made astronomers like Copernicus think the sun, instead, was at the center of the universe (or at least of our solar system). Study the advantages and difficulties with Copernicus' hypothesis, and how the research of Kepler and Newton improved Copernicus' hypothesis. How is this knowledge important in navigation?
- **Research the history of determining one's longitude accurately.** Because so many ships were lost with incomplete navigational tools up to the eighteenth century, there were international competitions to invent better ways to determine longitude. How did different countries approach this challenge? Note how technological inventions, such as the chronometer, were originally built with great artistry.
- **Compare the routes used by Columbus crossing the Atlantic** with those of nineteenth-century sailing ships and modern powered ships, plotting the courses on a map or globe. Why were they different? How have technological developments in navigation impacted transportation and communications history?



Learning Results, Grades 9-12

Career Preparation

- A-2:** Analyze skills and abilities required in a variety of career options and relate them to their own skills and abilities.
- A-3:** Demonstrate an understanding of the relationship between the changing nature of work and educational requirements.

English Language Arts

- A-9:** Identify the philosophical assumptions and basic beliefs underlying a particular text.
- H-5:** Use government publications, in-depth field studies, and almanacs for research.

Mathematics

- E-3:** Apply trigonometry to problem situations involving triangles and periodic phenomena.
- F-1:** Use measurement tools and units appropriately and recognize limitations in the precision of the measurement tools.
- G-3:** Model phenomena using a variety of functions (linear, quadratic, exponential, trigonometric, etc.).
- K-2:** Read mathematical presentations of topics within the Learning Results with understanding.

Science and Technology

- G-1:** Describe how scientists gather data about the universe.
- G-3:** Explain how astronomers measure interstellar distances.
- H-2:** Examine and describe how light is reflected and refracted (deflected) by mirrors and lenses.
- J-1:** Make accurate observations using appropriate tools and units of measure.
- J-3:** Demonstrate the ability to use scientific inquiry and technological method with short term and long term investigations, recognizing that there is more than one way to solve a problem. Demonstrate knowledge of when to try different strategies.
- K-1:** Judge the accuracy of alternative explanations by identifying the evidence necessary to support them. Explain why agreement among people does not make an argument valid.
- K-6:** Analyze situations where more than one logical conclusion can be drawn.
- L-3:** Make and use appropriate symbols, pictures, diagrams, scale drawings, and models to represent and simplify real-life situations and to solve problems.
- L-4:** Employ graphs, tables, and maps in making arguments and drawing conclusions.
- L-5:** Critique models, stating how they do and do not effectively represent the real phenomenon.

- L-7:** Use computers to organize data, generate models, and do research for problem solving.

- M-4:** Analyze the impacts of various scientific and technological developments.

- M-5:** Examine the historical relationships between prevailing cultural beliefs and breakthroughs in science and technology.

Social Studies

HISTORY

- A-1:** Identify and analyze major events and people that characterize each of the significant eras in the United States and world history.

- B-2:** Demonstrate an understanding of selected major events in ancient and modern world history and their connection to United States history.

- B-3:** Demonstrate an understanding of the lives of selected individuals who have had a major influence on history.

- B-5:** Explain how different ways of knowing and believing have influenced human history and culture.

GEOGRAPHY

- A-1:** Use mapping to answer complex geographic and environmental problems.





Activities, Grades 9-12

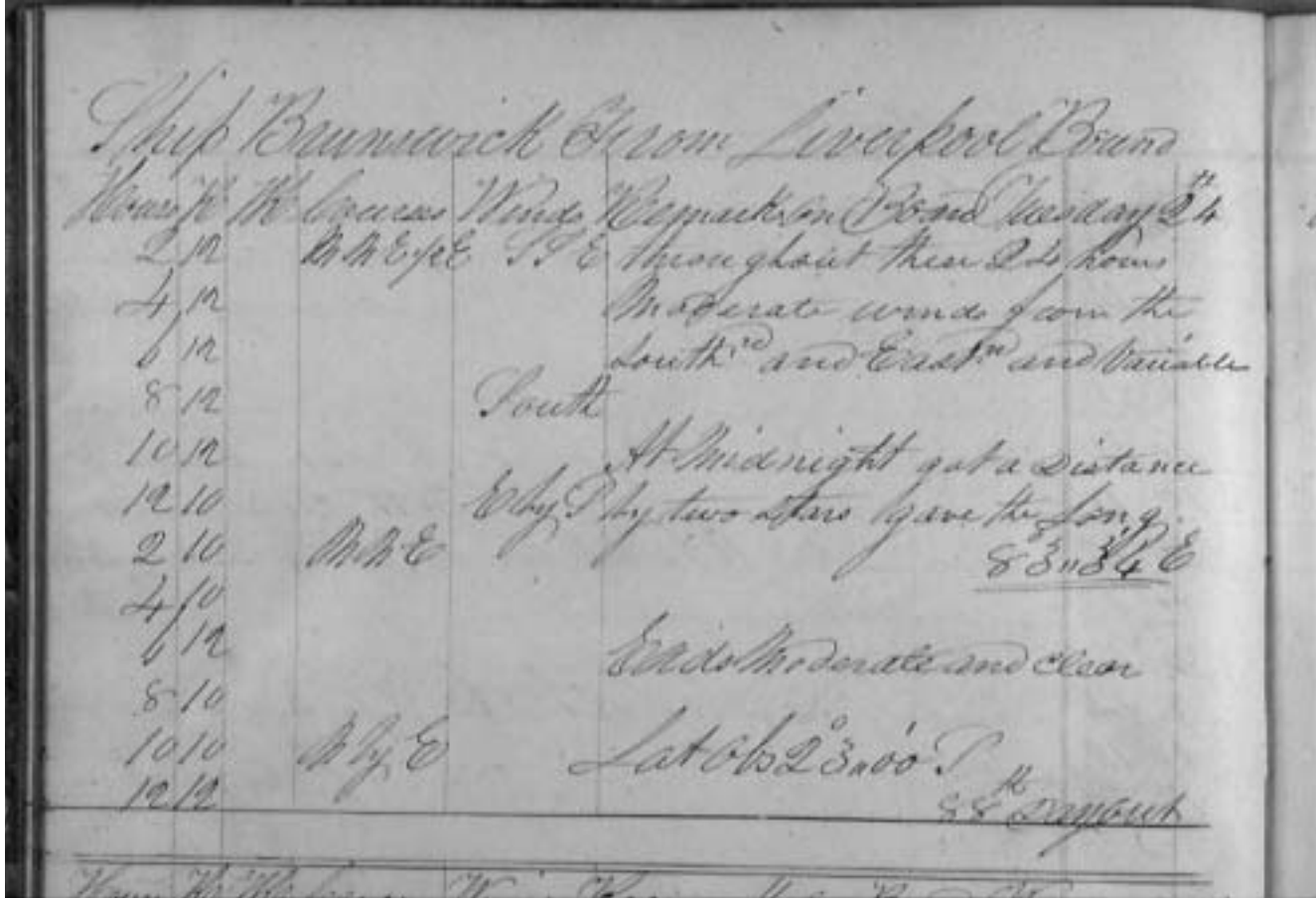
- **The work of navigating a ship, or, for that matter, an airplane,** has changed significantly, just in the last two decades. The skills that were so important a few years ago have been replaced with others. Discuss how this is true in many career paths and how educational requirements often change, even with multi-disciplinary skills like navigation. Discuss how to prepare for changes.
- **Research some aspect of navigation and its history,** using sources listed in the Resource List and others. Look at how the subject is covered in Bowditch's *American Practical Navigator* and in other modern navigation texts. If appropriate, try to review the types of information available in such modern almanacs as the *Nautical Almanac*, *Eldridge Tide and Pilot Book*, and other tide tables (almanac information available at some local bookstores or on the internet—see Resource List). Compare types of information and technology available to navigators today with information and tools available one hundred fifty years ago or more.
- **Study the sextant and its predecessors as measuring tools.** How accurately can a sextant measure angles? How accurate does it need to be in order to find one's position on the earth within a mile? Consider, in general, the history of the development of navigational tools and how the pursuit of accuracy continues to drive innovation and technological developments.
- **Discuss the relationship between the tides and the location of the moon and sun.** Determine an approximate trigonometric function that describes tide rise and fall in different parts of the globe.
- **Research how the prevailing and trade winds are caused** and how they relate to ocean currents such as the Gulf Stream. Discuss the relationship between ocean currents and weather. How is weather considered to be an important part of navigation?
- **Describe an ellipse and how it is similar to a circle.** Discuss the elliptical orbit of the earth around the sun and how that affects the length of a solar day (equation of time). Compare the distances between the sun and earth, earth and moon, earth and other planets, and earth and the nearest stars and galaxies. Determine the speed of the earth around the sun, the moon around the earth, and the speed of rotation of the earth at the equator. Discuss how these might affect navigation.
- **Research the work of scientists, mathematicians, and inventors** who prepared the way for safe navigation of the oceans. How did they collect data, process the data, and develop hypotheses about new understandings of the universe or develop ideas that resulted in valuable inventions? What other ways did their work impact society? Research can include exploration voyages of the eighteenth and nineteenth centuries to find the size and shape of the earth, accurately chart the oceans and lands, and learn about wind and ocean current patterns. Consider, for example, the environment and situation in which Charles Darwin made his observations.
- **Research how different cultures have solved navigational problems,** including Babylonians, Polynesians, Vikings, Chinese, and Europeans.
- **Apply trigonometry to the angular measurement of the earth, sun, moon, planets, and stars.** Make estimates of the diameter of the sun and moon, based on angular measurements. Draw relationships between distances and angle, when measuring between two places on the globe. Use trigonometry to determine the distance between two points of the same latitude, knowing the longitude difference. Note how the "great circle" route is the shortest between two points on the globe and explain why.



Resources

CHILDREN'S BOOKS

- Aust, Siegfried. *Ships! Come Aboard*. Minneapolis: Lerner, 1993. Navigation, pirates, the age of exploration, and other historical information about ships. Good illustrations. Ages 5-10.
- Borden, Louise. *Sea Clocks: The Story of Longitude*. New York: Margaret K. McElderry Books, 2004. Elementary level.
- Clough, Fred. *Sal T. Dog: One Stormy Night at Pickle Light*. Camden, ME: Down East Books, 1990. A story in rhyme about a lighthouse keeper and his wife. Ages 4-8.
- Eyewitness Visual Dictionaries. *The Visual Dictionary of Ships and Sailing*. New York: Dorling Kindersley, 1991. Good illustrations of shipbuilding, rigging, and navigation instruments. Ages 8-12.
- Fleming, Candace. *Women of the Lights*. Morton Grove, IL: A. Whitman, 1996. True stories of women who lived and worked in lighthouses, including Abbie Burgess of Matinicus Rock, Maine. Contains many historic photographs. Upper elementary grades through middle school.
- Gibbons, Gail. *Beacons of Light: Lighthouses*. New York: Morrow Junior Books, 1990. Ages 4-8.
- Latham, Jean Lee. *Carry on, Mr. Bowditch*. Boston: Houghton Mifflin Co., 1955. Biography of the young man who became a mathematician and navigator and authored *The American Practical Navigator*—known as the “sailor’s bible.” Ages 9-14.
- Morrison, Taylor. *The Coast Mappers*. Boston: Houghton Mifflin Co., 2004. The story of George Morrison, who mapped the Pacific coast in 1850, when merchant ships from Maine were carrying passengers to the Gold Rush. Information on charts and navigation. Very good illustrations. Ages 9-12.
- Scarpino, Jane. *Nellie the Lighthouse Dog*. Mt. Desert, ME: Windswept House, 1993. Ages 4-8.
- Smith, A.G. *Where am I? The Story of Maps and Navigation*. Toronto, ON: Canada: Stoddart Kids, 1997. Thorough history of navigation going back to ancient times, readable and clear for ages 9-12.





HIGH SCHOOL/ADULT BOOKS

- Bowditch, Nathaniel. *The American Practical Navigator: An Epitome of Navigation*. Washington, DC: U.S. G.P.O., 2002. Published since 1802, since 1867 as a U.S. government document. This is considered to be the “sailor’s bible” for navigation. Good history of navigation overview in the first chapter.
- Calder, Nigel. *How to Read a Nautical Chart. Interpreting the Symbols on a Nautical Chart*. Camden, ME: International Marine, McGraw-Hill, 2003. Many illustrations.
- Clifford, J. Candace and Mary Louise Clifford. *Maine Lighthouses: Documentation of Their Past*. Alexandria, VA: Cypress Communications, 2005.
- Cutler, Thomas J. *Dutton’s Nautical Navigation*, 15th ed. Annapolis, MD: Naval Institute Press, 2004. Thorough coverage of all aspects of navigation.
- De Wire, Eleanor. *Guardians of the Lights: The Men and Women of the U.S. Lighthouse Service*. Sarasota, FL: Pineapple Press, 1995. Includes stories of Maine lighthouse keepers.
- Fisher, Dennis. *Latitude Hooks and Azimuth Rings: How to Build and Use 18 Traditional Navigational Tools*. Camden, ME: International Marine, 1995. Instructions on building working models of navigational instruments.
- Ifland, Peter. *Taking the Stars: Celestial Navigation from Argonauts to Astronauts*. Newport News, VA: Mariners’ Museum, 1998.
- Marcus, Jon. *Lighthouses of New England*. Stillwater, MN: Voyageur Press, 2001. The history of the US Lighthouse Service.
- Rogers, Cedric. *Sailing Ships*. London: Camden House Books, 1984. Historic photographs, including navigational instruments.
- Sobel, Dava, and William J.H. Andrews. *The Illustrated Longitude*. New York: Walker, 2003, 1998. This book was the subject of a documentary. It describes the prize offered in Britain to the person who could solve the problem of accurate identification of longitude at sea.
- Waters, David W. *The Art of Navigation in England in Elizabethan and Early Stuart Times*. New Haven: Yale University Press, 1958.
- Williams, J.E.D. *From Sails to Satellites. A History of Navigation*. Oxford, NY: Oxford University Press, 1992.

WEB PAGES

- Celestial Navigation website:
<http://www.celestialnavigation.net/>. Has history information and other links.
- Celestial Navigation website:
<http://www.math.nus.edu.sg/aslaksen/gem-projects/hm/0203-1-10-instruments/home.htm>. Originates from math department of the National University of Singapore. Includes information on instruments, with links to other sites.
- Nautical Almanac On-Line:
<http://www.tecepe.com.br/scripts/AlmanacPagesISAPI.is>. Includes many years of nautical almanacs and provides a star finder.
- Navigation in the days of John Cabot:
<http://www.heritage.nf.ca/exploration/navigate.html>. Shows navigational instruments of the sixteenth century, as used in voyages to Newfoundland by John Cabot.
- Instructions to make a Chinese Compass:
www.historyforkids.org/crafts/china/compass.htm. Nice project for children, can be adapted with other floats.