Australian Government

endeavour250
Reflecting on Australia's History

Where in the world

How did Cook know where he was in the middle of the ocean? How did mariners measure time, determine current position, Sun/Moon/star positions, and ultimately calculate longitude, before and during Cook's 1770s voyages?

Maths

Year Level: 9–10

EDUCATION RESOURCES

YEAR LEVEL 9–10

SECONDARY

Where in the world

OVERVIEW

This learning sequence challenges students to apply their understanding of trigonometry and the geometry of similar triangles to a real-world context.

Students are introduced to the way different mathematical techniques and tools are used to derive location, are invited to explore one of these technologies in more detail, then continue to make, use and describe this technology.

The overarching idea of technological research being driven by human needs means that the sequence could form part of a cross-curricular learning program that includes elements of the Science curriculum.

LEARNING OUTCOMES

Students can identify some major techniques and tools used for sea (marine) navigation and their relationship to the Earth, Moon, Sun and stars.

Students apply triangulation to a real-world context.

Students gain a historical overview of the interrelationship between human endeavours (drivers of change), mathematics, science, technologies and processes.

Students present their research on a particular form of navigational technology then make a working model, and create instructions for its use.

Students understand the important (often life and death) link between accuracy and safety and how error is handled in practical, real-world situations, and identify areas of risk.

LEARNING AREAS

Maths

DURATION OF LESSONS

4–8 lessons

Australian Curriculum

GENERAL CAPABILITIES

Numeracy

MATHEMATICS – YEAR 9

- Investigate Pythagoras' Theorem and its application to solving simple problems involving right-angled triangles (ACMMG222)
- Use similarity to investigate the constancy of the sine, cosine and tangent ratios for a given angle in right-angled triangles (ACMMG223)
- Apply trigonometry to solve right-angled triangle problems (ACMMG224)

MATHEMATICS – YEAR 10

- Formulate proofs involving congruent triangles and angle properties (ACMMG243)
- Apply logical reasoning, including the use of congruence and similarity, to proofs and numerical exercises involving plane shapes (ACMMG244)
- Solve right-angled triangle problems including those involving direction and angles of elevation and depression (ACMMG245)

Australian Curriculum

SCIENCE – YEAR 9

- Energy transfer through different mediums can be explained using wave and particle models (ACSSU182)
- Advances in scientific understanding often rely on technological advances and are often linked to scientific discoveries (ACSHE158)
- Values and needs of contemporary society can influence the focus of scientific research (ACSHE228)

SCIENCE – YEAR 10

- The motion of objects can be described and predicted using the laws of physics (ACSSU229)
- Advances in scientific understanding often rely on technological advances and are often linked to scientific discoveries (ACSHE158)
- Values and needs of contemporary society can influence the focus of scientific research (ACSHE228)

Engage

Alone in the vastness of the ocean

How on earth did Captain James Cook know where he was – in the middle of the ocean, thousands of kilometres from home, and hundreds of kilometres from the nearest land?

- Lead small group discussions.
- Have students brainstorm ideas, report back to class.
- Consider introducing other navigators from contemporary cultures – for example, Polynesian sailors. Did they use the same principles? (Depending on context, the story of Tupaia could be introduced here.)

Show the Australian National Maritime Museum's video Where on earth are you? A beginners guide to longitude. Discuss with students why it was so important and so difficult to determine longitude.

Explore

Finding your way in the schoolyard

Triangulation: an outdoor activity using estimation, measuring angles and distances, using similar triangles and scale factors. You could use school grounds and a map or take students somewhere unfamiliar and have them triangulate and mark positions on a map.

This linked activity, Topo triangulation, is a good introduction.

Explore 2: Finding your way out of nowhere

It's one thing to know where you are in a familiar place with visible landmarks, but what about on the open ocean? What technologies were used to measure time, current position information, Sun/Moon/star positions – and ultimately calculate longitude at sea – before and during Cook's 1770s voyages?

Split into groups and explore one of the following technologies. Explain to students that what they learn in this activity will be used by the class as they will plan, describe and build some of these instruments in a subsequent lesson. Suggested resources to guide student exploration are included in the Resource list for Explore: Activity 2 – Finding your way out of nowhere.

- Cross staff, Jacob's staff or backstaff
- Astrolabe
- Quadrant, octant, sextant
- Pendulum clock and marine chronometer

Explorations could include the following questions, though students could be encouraged to add their own:

- What was this instrument used to measure? Did it help find an estimated location? How?
- Historical time range – when was it used, how did it relate to the technology of Cook's time?
- How did it work? A brief note of what was measured and how it was used. (More detail on this will come from the next activity.)
- Who used this? Was it a specialist instrument – or did everyone have one, like a ruler?
- Would it have been used at sea? Was it also used on land or for other purposes? If so, was there a nautical version made that was customised for the ship environment, and what were the differences?

Results of research could be presented in several ways:

- using interactive presentation software like Prezi, or PowerPoint
- as a short documentary video
- as a briefing to a newspaper or scientific journal in the 1700s
- as an instructional booklet from a sailor to his/her children.

Explore further (optional): Charting

The maths and science of charting a voyage: an investigation into how charts were made and positions recorded. Examples of questions to guide such an investigation:

- Once position at sea was determined, how was it recorded?
- What other data was collected other than position (eg ocean depths, wind directions)?
- How was the information collected?
    - What technology and mathematical techniques were used?
    - What systems of measurement were used?
    - How were coastlines and other features such as shoals and reefs recorded?

Explain

Make or break

A hands-on activity with accompanying diagrams and notes. Students are to make working models, including diagrams, and write detailed instructions that explain the mathematics and science behind one of the technologies listed below.

- Jacob's staff, backstaff or cross staff (Note that a cross staff would be the simplest of these, so students who are beginning understanding may want to start here)
- Astrolabe
  - Simple astrolabe – includes printouts, instructions for how to make astrolabe, suggestions for what to measure
  - Complex astrolabe – note separate instructions for generating astrolabe printouts for your own latitude
- Quadrant, sextant or octant

Instructions should include what the device measured, how it was used, and the mathematics behind the way it worked. Diagrams should identify the relevant mathematics – similar triangles, angles of inclination – and indicate what trigonometric ratios are used and in what measurements.

Resources for students are included in the 'Student resource sheet for Explain activity – Make or break.'

Groups for this activity could be the same as in the previous activity, or different. The task could also be conducted as a jigsaw activity, depending upon the class context. Small groups would make constructing and using the astrolabe easier to manage.

Extending further: Lunar distance (optional)

This is a small-group activity for students with a firm understanding of trigonometry who wish to extend their understanding. The full technique of using lunar distance involves spherical trigonometry, which is well outside the scope of the curriculum, but the basic concepts would interest students who are looking for a challenge.

Provide students with 'Student worksheet: Lunar distance' (contents provided below).

Introductory questions to consider:

- How accurate was the method of lunar distance?
- How long was this technique used?
- Was it used by Cook on his voyages?

For your reference: Contents of student worksheet

Cook used a navigation technique on his early voyages that involved the distance between the Moon and other celestial bodies (particular stars or the Sun) called 'lunar distances'.

Introductory information

- National Museum Australia – The lunar distance method
- Wikipedia – Lunar distance (navigation)

Detailed information

- Longitude by lunars
- GMT and longitude by lunar distance
- Navigation by lunar distance (includes some nice trigonometry)

Instructions

Construct a labelled diagram showing how lunar distances were measured. Explain how knowing these distances and using nautical almanacs allowed you to calculate the time.

Elaborate

Accuracy or perish? When accuracy is life or death: the Scilly naval disaster of 1707

View a Royal Museums Greenwich blog post about this disaster. Two more sources containing relevant information are How did the sinking of a ship in 1707 lead to the invention of the Marine Chronometer? and Scilly naval disaster of 1707.

Have students suggest what navigation methods, instruments and technologies would have been used on the naval ships in 1707. Ask:

- Were the same technologies and techniques in use during Cook's voyages?
- What were some of the possible sources of error contributing to the Scilly disaster?

The Scilly naval disaster and other losses at sea led the British government to set up the Longitude Act of 1714, which enact a board of Longitude and offered a series of cash prizes for an accurate way to calculate longitude. (For further information see The Longitude Act.)

The maritime chronometer was developed by John Harrison, as one of series of technological inventions aimed at winning prizes under the Act.

Introduce the chronometer and discuss the problem of telling the time at sea (refer to Australian National Maritime Museum video from the Engage phase).

Ask students to consider how the chronometer changed all of this. How was this more accurate? Why is this so important?

Evaluate

Let the captain know what needs to be done

For students

- Look again at the navigation technology you investigated in the Explain phase and identify points where errors are likely to occur. For example: what effect would movement on the ship have on taking measurements? How clear and accurate are the markings on the scales? How easy is it to sight horizons and estimate angles for objects in the sky?
- Write a status report for a ship's captain that explains these points of error. Make recommendations for how these could be overcome. Include diagrams showing measurements and explaining the mathematics of your instructions.

(Students' suggestions could include repeating measurements; more expensive or more modern equipment; use of other technology/tools to supplement; changing measuring methods; cross-checking with other methods/technology.)

Extend

Position and location in today's technology

Further investigation 1: Positioning services

- How do location services work on your phone?
- What are the differences and similarities to the way Cook found his location?
- What are the sources for error in modern location services?

Further investigation 2: Dead reckoning

Dead reckoning is used in online games to estimate where a player is right now, by using their last known speed, direction and position. The home computer communicates with the server periodically to try to synchronise where the player thinks they should be with where the server thinks they should be. If there is a break in network communication for some reason, this information can be quite different between the two.

- What happens? Why?
- How is the difference in positions resolved?

Dead reckoning uses current estimations of velocity and past positions to calculate an estimate for current positions. This technique was used at sea as one way to estimate position, but it suffers errors that become more significant with the passage of time over greater distances. Explore how dead reckoning was used at sea during Cook's time and how it is used today in inertial navigation devices.

Lunar distance

Instructions

Construct a labelled diagram showing how lunar distances were measured. Explain how knowing these distances and using nautical almanacs allowed people to calculate the time.

Cook used a navigation technique on his early voyages that involved the distance between the Moon and other celestial bodies (particular stars or the Sun). The technique was called 'lunar distances'.

Introductory information

- National Museum Australia – The lunar distance method
- Wikipedia – Lunar distance (navigation)

Detailed information

- Longitude by lunars
- GMT and longitude by lunar distance
- Navigation by lunar distance (includes some nice trigonometry):

Construct a labelled diagram

Resource sheet

Explore: Activity 2 – Finding your way out of nowhere

Cross staff/Jacob's staff/backstaff

- Wikipedia, includes variations
- Useful images at the Royal Museums Greenwich
- The Mariners' Museum and Park on YouTube
  - YouTube 'Navigational Instruments', Segment 4 Back-staff **Alternatively**, see the website Back-staff information page
  - YouTube 'Navigational Instruments', Segment 3 Cross-staff **Alternatively,** see the website's Cross-staff information page and select 'Videos' at the bottom of the page
- From an astronomy page hosted at Swinburne; has good diagrams and a brief note about the trigonometry involved

Astrolabe

- The Mariners' Museum and Park on YouTube 'Navigational Instruments', Segment 2 Astrolabe
- BBC Video on YouTube 'How to use an astrolabe, Curator's Corner season 3 episode1'
- Muslim heritage history, uses and types of astrolabes
- Wikipedia

Octant/sextant/quadrant (all similar instruments used during different time periods. You may wish to choose one or give an overview of all three)

- Wikipedia (and compare with the octant)
- PBS, How a sextant works
- The Mariners' Museum and Park on YouTube 'Navigational Instruments, Segment 1 Quadrant' Alternatively, see the museum's website and select 'Videos'
- Museum of the History of Science, 'Animate it: Octant' includes a short video showing an octant in use

Pendulum clock/ marine chronometer

- Wikipedia
- National Maritime Museum, Ships, clocks and stars
- Timelines documentary on YouTube. Relevant section begins at 25:02
- National Museum of Australia: Harrion's four chronometers (see other links in the sidebar for more details)

Explain activity – Make or break

A cross staff

- Phy6.org. Uses imperial units as approximate measurements, but can be easily interpreted by students

An astrolabe

- Simple astrolabe – includes printouts, instructions for how to make, suggestions for what to measure
- Complex astrolabe – note separate instructions for generating astrolabe printouts for your own latitude
- San Francisco High School on YouTube, 'How to use an astrolabe' using a modern reproduction

A sextant or octant

- Making a sextant
- Making an octant (requires more materials and time)
- Canadian War Museum, Make your own simple sextant

Optional extension activity – Lunar distance

- National Museum Australia – The lunar distance method
- Wikipedia – Lunar distance (navigation)
- Longitude by lunars
- GMT and longitude by lunar distance
- Navigation by lunar distance (includes some nice trigonometry)

Elaborate: Accuracy or perish?

Scilly naval disaster of 1707 and its effects

- Royal Museums Greenwich blog post
- How did the sinking of a ship in 1707 lead to the invention of the Marine Chronometer?
- Scilly naval disaster of 1707
- Longitude Act of 1714

Other useful resources

- Captain Cook's navigational instruments
- The ocean shows us the way
- EagleCat: Bearings (only available through Scootle)

Australian National Maritime Museum

- A beginners guide to longitude
- Latitude and longitude (from the Finding our way: navigation page)
- Ships, clocks and stars: Assembling the H3 replica (clock)

National Library of Australia

- Cook's Endeavour log
- Cook's charting of part of NSW coast
- Variations of the compass on board Endeavour

National Museum of Australia

- Lunar distances

Other museums

- The Royal Museums Greenwich has a useful collection of images and documents about navigation and associated instruments
- The Smithsonian National Museum has an extensive collection of navigation instruments, which can be browsed here.

Australian Government

Department of Education, Skills and Employment

Department of Infrastructure, Transport, Regional Development and Communications

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