NAVAL HISTORY STEM-H LESSON PLAN

TEACHER HELP GUIDE

LESSON PLAN: Sailing Blind – the Challenges of a Submarine's Navigator
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2012 Naval Historical Foundation STEM-H Teacher Fellowship

INSTRUCTIONAL GOAL:

How does a submariner navigate when submerged? Let your students find out as they explore the concept of vector addition as used in the Navy to combine dead reckoning calculations and inertial navigation data to determine the ships position after many hours under the sea. Can the students navigate through the Strait of Gibraltar to reach a safe port?

Students will complete activities applying the concept of vector addition to a real world application – a submariner calculating the ship's position in the water while submerged.

BACKGROUND:

In the early days of sailing, navigating by the stars or celestial navigation kept ships on course. A tool called a sextant allowed a sailor to calculate the ship's position with a fair degree of accuracy. A sextant allowed the navigator to determine the angle between a selected star and the horizon. The sextant measured the angle from the horizon up to the star. Using simple trigonometry a possible range of positions could be determined. By determining the angle to other stars, an accurate position can be found.

When sailing under the water getting a star fix is difficult as submarines have no windows and when it surfaces it is highly vulnerable to detection. Avoiding detection remains a submarine's greatest protection. Still, a submarine navigator must have a good sense of where the ship is even when underwater and underway.

With advances in technology it has become easier for a submarine to know its current location with high precision. Often, only putting up the periscope a few feet above the water line is enough to get a location "fix" in today's world. Ironically, while the math is automated and the data transfer lighting fast, the concept of today's state of the art GPS tracking is still based on the same "triangulation" principles used with the sextant.

So how do you navigate a submarine underwater? The answer is a combination of two systems that can calculate a ship's position – dead reckoning and inertial navigation. Dead reckoning uses a fixed starting point and then adds the speed and direction of ship to determine the current position. However going in a straight line in the ocean is difficult in comparison to dry land. Currents and tides in the water are also moving the ship around while it sails along and if these factors are not accounted for it is very likely that the navigator is not where he thinks he is.

To account for the factors of current, tides, and not steering straight, the navigator uses additional information collected from the inertial guidance system which collects data on forces acting on the ship. If a current is pushing the ship, or there is a change in speed, or there are small course changes, the inertial guidance system will collect that data for the navigator to use in adjusting the position calculation predicted by dead reckoning. The inertial guidance system uses gyroscopes and accelerometers to detect a ships movement. In a sense, the two devises sit in the middle of the ship and the ship moves around it.

RESOURCES:

Inertial Navigation systems – how they work:
http://usnavymuseum.org/Ex2_Navigation.asp

http://en.wikipedia.org/wiki/Inertial_navigation_system

Gyroscopes explained:
http://en.wikipedia.org/wiki/Gyroscopes

Accelerometers explained:
http://en.wikipedia.org/wiki/Accelerometer

Navy Satellite Navigation Video:
http://www.youtube.com/watch?v=FfJILjNak0U

Background on Celestial Navigation:
http://en.wikipedia.org/wiki/Celestial_navigation

Reading Navy Charts:
http://www.youtube.com/watch?v=TEsQF-uk5qU

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STANDARDS:

Florida Science Standards:

SC.912.P.12.1: Distinguish between scalar and vector quantities and assess which should be used to describe an event.

SC.912.P.12.2: Analyze the motion of an object in terms of its position, velocity, and acceleration

SC.912.P.12.3: Interpret and apply Newton's three laws of motion.

SC.912.N.1.6: Describe how scientific inferences are drawn from scientific observations and provide examples from the content being studied.

SC.912.N.1.7: Recognize the role of creativity in constructing scientific questions, methods and explanations.

INSTRUCTIONAL PROCEDURES FOR LESSON & ACTIVITY:

For the basic problem, the solution requires knowledge of east/west, north/south directions. The motions involved move only on those four "cardinal headings". To solve for the new "angle" or course to reach the entrance to the Strait of Gibraltar from the end point (estimated position) can be done with a compass or protractor. The solution provided gives a more exact angle using trigonometry. If no course change is done, the submarine will run aground on the coast of Africa.

For the more advanced problem, to solve for the motion, trigonometry is required to determine how far north/south the motion is changed by the factors of current and course change:

Distance north/south = speed x sin (angle of motion).

Then the vectors can be added as before and either a compass or trigonometry used to find the new course from the end point (estimated position) to the entrance to the Strait of Gibraltar. Again, if no course change is done, the submarine will probably run aground near the strait, possibly even at the "rock of Gibraltar".

For both problems, nautical miles (NM) are used. One NM = 2000 yards (a statute mile is 1760 yards).

One knot is one nautical mile per hour: kt = nm/hr.

An accompanying video on Navy navigation and charts is provided:
Reading Navy Charts:
http://www.youtube.com/watch?v=TEsQF-uk5qU