Submarine Force Museum Lesson Plan

Developed by 2015 Submarine Force Library and Museum STEM –H Teacher Fellow
Robert Mayne, Math Teacher, Chariho Regional High School, Wood River Jct., RI

Lesson Name: Submarine Atmosphere Monitoring-Engineering **Number of minutes in the Lesson:** 135

Intended Audience: High school students in statistics or engineering

Content Standards:

CSS.ELA-Literacy.RST.11-12.7 Integrate and evaluate multiple sources of information presented in diverse formats and media (e.g., quantitative data, video, multimedia) in order to address a question or solve a problem.
CCSS.ELA-LITERACY.WHST.11-12.1. Write arguments focused on *discipline-specific content*.
CCSS.ELA-LITERACY.WHST.11-12.2. Write informative/explanatory texts, including the narration of historical events, scientific procedures/experiments, or technical processes.
CCSS.ELA-LITERACY.WHST.11-12.7
Conduct short as well as more sustained research projects to answer a question (including a self-generated question) or solve a problem; narrow or broaden the inquiry when appropriate; synthesize multiple sources on the subject, demonstrating understanding of the subject under investigation.
CCSS.MATH.CONTENT.HSS.ID.A.1
Represent data with plots on the real number line (dot plots, histograms, and box plots).
CCSS.MATH.CONTENT.HSS.ID.A.2
Use statistics appropriate to the shape of the data distribution to compare center (median, mean) and spread (interquartile range, standard deviation) of two or more different data sets.
CCSS.MATH.CONTENT.HSS.ID.A.3
Interpret differences in shape, center, and spread in the context of the data sets, accounting for possible effects of extreme data points (outliers).
CCSS.MATH.CONTENT.HSS.ID.A.4
Use the mean and standard deviation of a data set to fit it to a normal distribution and to estimate population percentages. Recognize that there are data sets for which such a procedure is not appropriate. Use calculators, spreadsheets, and tables to estimate areas under the normal curve.
CCSS.MATH.CONTENT.HSS.IC.A.1
Understand statistics as a process for making inferences about population parameters based on a random sample from that population.
CCSS.MATH.CONTENT.HSS.IC.A.2
Decide if a specified model is consistent with results from a given data-generating process, e.g., using simulation. *For example, a model says a spinning coin falls heads up with probability 0.5. Would a result of 5 tails in a row cause you to question the model*?
CCSS.MATH.CONTENT.HSS.IC.B.3
Recognize the purposes of and differences among sample surveys, experiments, and observational studies; explain how randomization relates to each.
CCSS.MATH.CONTENT.HSS.IC.B.4
Use data from a sample survey to estimate a population mean or proportion; develop a margin of error through the use of simulation models for random sampling.
CCSS.MATH.CONTENT.HSS.MD.B.7
(+) Analyze decisions and strategies using probability concepts (e.g., product testing, medical testing, pulling a hockey goalie at the end of a game).

CCSS.MATH.PRACTICE.MP1 Make sense of problems and persevere in solving them.
CCSS.MATH.PRACTICE.MP2
Reason abstractly and quantitatively.
CCSS.MATH.PRACTICE.MP3
Construct viable arguments and critique the reasoning of others.
CCSS.MATH.PRACTICE.MP4
Model with mathematics.
CCSS.MATH.PRACTICE.MP6
Attend to precision.
ISTE Student Standards 1.a. Apply existing knowledge to generate new ideas, products, or processes.
ISTE Student Standards 3.a. Plan strategies to guide inquiry.
ISTE Student Standards 3.b. Locate, organize, analyze, evaluate, synthesize, and ethically use information from a variety of sources and media.
ISTE Student Standards 3.c. Evaluate and select information sources and digital tools based on the appropriateness to specific tasks.
ISTE Student Standards 4.c. Use multiple processes and diverse perspectives to explore alternative solutions.

Pre-Visit Materials/Activities:

Students will read the attached summary on pages 4-6 about submarine atmosphere monitoring systems and how submarines provide a healthy atmosphere for the crew.

Set up Before the Lesson Begins: None

Content Objective(s):

Statistics*

1. Students will be able to create histograms and boxplots of quantitative data from a sample.
2. Students will be able to describe the distribution of sample data.
3. Students will be able to calculate the summary statistics of sample data and determine which measure is most appropriate.
4. Students will be able to distinguish between designed experiments and observational studies.
5. Students will be able to sample from a population to create a sampling distribution of sample means.
6. Students will be able to create a Normal model from sample data.
7. Students will be able to create a confidence interval for the mean.
8. Students will be able to make decisions using inference for means.

Engineering

1. Students will be able to interpret the impact of this technology in society, culture, economics, politics, the military and the environment.
2. Students will be able to relate the mathematics and science to previously learned mathematics and science concepts.

*The overall lesson for statistics covers much material. It is designed in such a manner to be broken into many different lessons or used as one final assessment of learning.

Language Objective(s): Distinguish between receptive skills (**listening and reading**) and productive skills (**speaking and writing**). Please **include how you would use them all where appropriate**: Listening, reading, speaking and writing.

Differentiation: Think about: Educators will make decisions about differentiation based on the needs knowledge of their students.

Students with special needs How will you differentiate this lesson for special education students?

Gifted students-

Regular education students: Think about how you would differentiate the lesson for all students on all levels:

High-

Middle-

Low-

Sheltered Instruction Observation Protocol (SIOP) Strategies for ELL and regular Ed Students:

Identify the S.I.O.P features that support English Learners and all learners including thorough and accurate explanations on how they will assist English Learners. Identify Sheltered Instruction strategies throughout the lesson.

- Preparation
- Building Background
- Comprehensible Input
- Strategies
- Interaction
- Practice/Application
- Lesson Delivery
- Review/Assessment
- The overall lesson for statistics covers much material. It is designed in such a manner to be broken into many different lessons or used as one final assessment of learning.

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Submarine Atmosphere Monitoring

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Introduction

Imagine being inside a WW2 Gato class diesel powered submarine patrolling the Pacific Ocean just months following the Japanese attack on Pearl Harbor, December 7, 1941. While running on the surface your boat is spotted by a Japanese patrol plane surveying the area. The siren sounds to dive the boat. As fast as possible the boat submerges below the waves. In the distance the SONAR operator has identified a ship heading your way at high speeds. Everyone on your boat is calm and focused as you try to evade enemy detection. After hours submerged, the captain tries lighting a cigarette but to no avail. His difficulty is a sign of the decreased level of oxygen in the atmosphere. The SONAR operator reports no more contacts. The boat is brought to periscope depth. By now night has fallen over the Pacific and the captain decides to surface the boat. You are relieved, fresh air at last. (Picture of USS Gato SS-212 in Groton, CT 1941)

While on the surface the diesel engines brought fresh outside air into the boat. While submerged the boat propelled itself through the water using electric motors powered by electricity stored in banks of batteries. The boat no longer has access to the fresh air. The longer the boat stays submerged the lower the air quality becomes. Oxygen is replaced with carbon dioxide, leading to diminished cognitive ability of the crew.

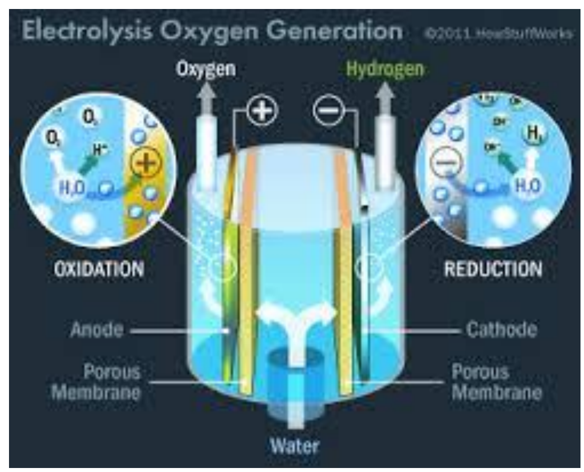
With the advent of nuclear power for submarines, the mission and designs for submarines changed. No longer was a submarine a surface vessel that submerged when necessary. Nuclear powered submarines, now designed with a teardrop shape, cruise submerged and surface only when absolutely necessary. (Picture of USS Greenville SSN-772 in dry dock in Pearl Harbor, HI 2001)

Submarine Atmosphere Characteristics

The submarine's atmospheric control system must be efficient and reliable to insure the health and safety of all crew. In order to do this, the atmospheric control system maintains air in the submerged submarine comparable in composition to the clean, fresh air. According to the US Navy, clean dry air should resemble the percentages in the table to the right. In order to maintain these levels, submarines have oxygen supply systems, carbon dioxide removal systems and air purification systems.

In 1975, the Naval Research Laboratory developed the Central Atmosphere Monitoring System (CAMS), allowing crews to reliably monitor the air aboard their boats. CAMS is a combination carbon dioxide detector and fixed-collector mass spectrometer that monitors hydrogen, water, nitrogen, carbon monoxide, oxygen, carbon dioxide and refrigerant gasses. NASA uses a variant of the same system for manned space vehicles.

Oxygen Supply Systems



Electrolytic Oxygen Generators: The production of oxygen is accomplished though electrolysis of water. A sufficiently strong electrical current is passed through seawater, decomposing water into oxygen and hydrogen gas. Modern nuclear submarines produce ample amounts of electrical power for producing oxygen through electrolysis and the amount of seawater available is limitless. The system has the ability to pump oxygen directly into the boat and store excess oxygen into pressurized tanks. Excess hydrogen is safely disposed overboard.

Carbon Dioxide Removal

CO_2 Scrubbers: The "scrubbers" are systems, which utilize a liquid solution of monoethanolamine (MEA) to absorb excess CO_2 from the submarine atmosphere. The air to be treated enters an exchange tower, is blown through woven stainless steel packing over which the MEA solution is flowing. Between 70 and 90% of the CO_2 is removed with one pass through. The air then passes through a filter to trap droplets of the MEA solution and the air returns to the submarine atmosphere. The CO_2 is cooled, compressed and safely discharged overboard.

Component	Symbol	Volume %
Nitrogen	N_2	78.09
Oxygen	O_2	20.95
Argon	Ar	0.93
Carbon Dioxide	CO_2	0.03

LiOH Absorbers: A gas stream is passed through these one-time use canisters containing lithium hydroxide (LiOH). They are designed to atmospheric CO_2 below 1% and do not require a power for operation.

Air Purification

CO-H_2 Burner: This is used to remove carbon monoxide, hydrogen, hydrocarbons and other contaminants by oxidizing them into carbon dioxide and water. Air passes through a filter and heat exchanger to a catalyst bed at 600^{o}F that contains a mixture of copper oxide and manganese dioxide. From the catalyst bed, air flows through a heat exchanger where it is cooled and passed through a final filter to remove any acidic gases from the air. In the final stage the air is passed through activated charcoal, which acts to absorb any remaining chemicals in the air.

Activated Carbon: Charcoal is activated by the use of controlled heating. The behavior of activated carbon in removing contaminant gases is rather complex. Activated carbon is commonly used for removal of odor throughout spaces such as the washroom and sanitary tanks as well as the galley.

Creating a Histogram

Below is a list of 50 samples of the percent of carbon dioxide in the atmosphere of a nuclear powered US submarine.

Create a histogram of these data and describe the distribution.

Determine the following summary statistics for the above data set.

Maximum: ________________________ Mean: ________________________

Q3: ________________________ Standard Deviation: ________________________

Median: ________________________

Q1: ________________________

Minimum: ________________________

Interquartile Range: ________________________

Draw a boxplot to represent the distribution of these data.

Based on your distribution of these data, would the mean or the median be the best measure of center? Explain.

<u>Experiments or Observational Study</u>

The atmosphere of a submarine must be constantly monitored to maintain a healthy air supply aboard. Increased exposure to carbon dioxide can produce symptoms such as impaired night vision, heavy breathing, impaired judgment, dizziness, slow thinking, impaired muscular coordination, unconsciousness and death. Submarines are randomly chosen where crews wear passive assessment badges to gather information with respect to carbon dioxide (and other gas) exposure. This information is given to the Naval Submarine Medical Research Laboratory for analysis.

Would this be an example of a designed experiment or an observational study? Explain.

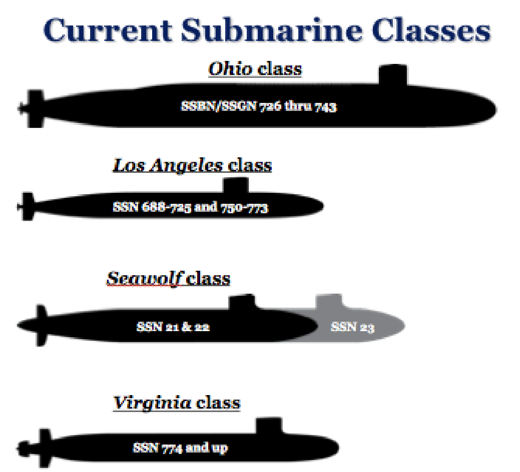
<u>Sampling Techniques</u>

The US Navy has provided you with thousands of data points for the percent carbon dioxide present in the atmosphere of a submarine at any given time. They are in no particular order. Determine a method of sampling that could be used to gather a sample of fifty data points from the list they provided and how would you attain your sample using this method.

Sampling Distributions of Sample Means

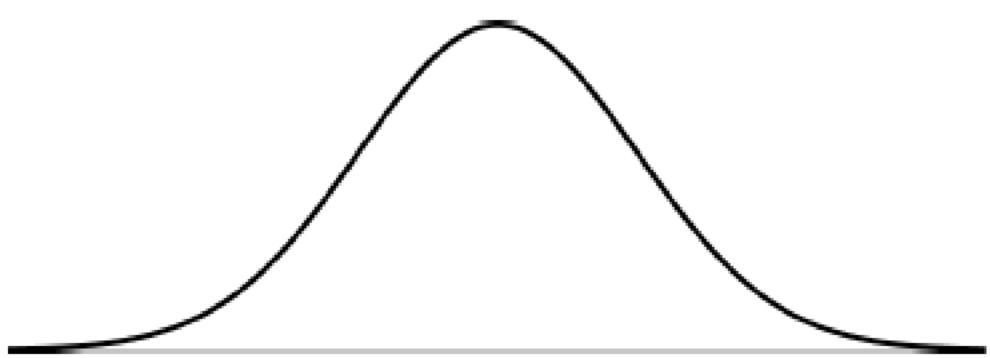
To the teacher: Have students create a sample of fifty data points from the data set provided in the Excel sheet. Ask students to create a histogram and calculate the mean and standard deviation of their sample. Create a sampling distribution of the sample means using the means provided from the students. Compare the histogram of the sampling distribution with the histograms of the sample data students attained. Calculate the mean and ask students whether they think the standard deviations of the samples would be larger or smaller than the standard deviation of the sample means. What if the sample sizes were 100 or 1,000? How would this affect the mean and standard deviation? This could be a good "hands-on" introduction to sampling distributions. Have the students perform the actual comparisons using the attached data set.

Central Limit Theorem



Based on tens of thousands of samples from US Navy submarines, it is estimated that the mean percent of CO_2 in the atmosphere of nuclear submarines is ______ with a standard deviation of ______. This result was based on a very large sample of percent of CO_2 in various sections of submarines on all classes of U.S. nuclear submarines while underway. Therefore, let's assume that these summaries are the population parameters and the distribution of percent CO_2 in the atmosphere of submarines is roughly unimodal and reasonably symmetric.

What does the Central Limit Theorem predict about the percent CO_2 in the atmosphere of submarines in random samples of 50 atmospheres?



Confidence Intervals for Means

While underway, the boats are subject to various pressures and stresses leading to potential failure of equipment. If the CO_2 scrubbers failed while underway, the main method of removing excess CO_2 from the submarine atmosphere would need to be fixed while underway. Technicians fix the scrubbers so they operate but are not sure if they are operating correctly. Below is a list of 50 samples of the percent of carbon dioxide in the atmosphere of various compartments on this fictional submarine.

What assumptions must you make in order to use these data for inference?

Write a 95% confidence interval for the mean percent of carbon dioxide in the atmosphere of various compartments on this fictional submarine.

Interpret the confidence interval in context.

Explain what “95% confidence” means in this context.

Inferences About Means

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The mean percent of CO_2 in the atmosphere of nuclear submarines is ______.

Are the CO_2 scrubbers functioning properly?

Hypotheses: (State your hypotheses.)

Model: (Think about the assumptions and check your hypotheses.)

Mechanics: (Make a picture. Sketch the model. Show all your calculations.)

Conclusion: (Interpret your result in proper context. Be careful to relate to the original question.)

Lesson Plan Resources: "Submarine Atmosphere Monitoring"

Instructional Goals

This lesson is designed to span the high school statistics and probability standards of the Common Core State Standards and the curriculum for AP Statistics. Students will be able to use and apply the concepts of random sampling, designed experiments, observational studies and statistical inference.

Common Core State Mathematic/Literacy Standards:

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Understand statistics as a process for making inferences about population parameters based on a random sample from that population.

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Construct viable arguments and critique the reasoning of others.

CCSS.MATH.PRACTICE.MP4
Model with mathematics.

CCSS.MATH.PRACTICE.MP6
Attend to precision.

Related Documents & Resources

http://www.med.navy.mil/sites/nsmrl/Pages/team01.aspx - Naval Submarine Medical Research Laboratory – Research – Submarine Medicine
http://web.mit.edu/12.000/www/m2005/a2/8/pdf1.pdf - Submarine Air Treatment
http://www.maritime.org/doc/submed/chap22.htm - Medical Problems of Future Submarines
http://www.nrl.navy.mil/accomplishments/materials/atmosphere-monitoring/ - Central Atmosphere Monitoring System
http://www.afcea.org/content/?q=Blog-us-navy-awards-submarine-atmospheric-monitoring-contract - Blog: U.S. Navy Awards Submarine Atmospheric Monitoring Contract