STEM Curriculum Planning Guide

This instructional design guide serves as the template for the design and development of STEM units of instruction at the Dayton Regional STEM Center in Dayton, Ohio. The guide is anchored to the *STEM Education Quality Framework* also developed at the Dayton Regional STEM Center.

STEM Unit Title	**Dig Up the Volume**
Economic Cluster	Sensors
Targeted Grades	Fifth Grade
STEM Disciplines	Technology, Engineering, and Math
Non-STEM Disciplines	English Language Arts

Section I: STEM Unit Overview

Unit Overview

In this unit students will be engineering a systematic strategy for determining the volume of several rectangular prisms without actually being able to see them. Student groups will be given several boxes which contain different sized rectangular prisms. The lids of these boxes will have a coordinate grid which extends into all four quadrants. Each group will be given a set number of sensors for each box which they will use to find to the length, width and height of each prism. Student engineering groups will explain the systematic process they used to find these measurements and volumes, determine how to compile their data and give the coordinates of each of their sensor locations.

Essential Question

How can you use the engineering design process to develop and optimize a procedure to determine the volume of an unseen prism?

Enduring Understanding

Students will be able to record data into a data table, utilize a coordinate grid using all four quadrants, classify three dimensional shapes and engineer a process to solve a math scenario.

Engineering Design Challenge

Students will be given the task of generating and documenting a procedure which enhances the accuracy of estimating the volume of a solid object that is concealed from view. Students will estimate the volume of an object hidden from view by exploring various depths of sensors at pre-determined grid-marked locations. Multiple rectangular prisms of varying dimensions, will be hidden within separate shoe boxes. A grid system with equally spaced bore hole locations will be arranged on the top surface of the shoe box. Students will be responsible for using a limited number of sensors to determine where an object is located and to estimate the approximate dimensions of the hidden artifact in order to calculate its volume. Students will then be asked to complete several tests across different shoe boxes and will compare their results to the actual volume of the hidden prism. The students will then calculate the accuracy of their results (percentage accuracy) versus the actual recorded volume of the object. They will be asked to review their initial results to decide if their findings improved as more tests were completed. Students will then be responsible for determining and documenting their preferred method for increasing the accuracy of their results and shall prepare a procedure proposal report that shall include the placement selection options for the sensors spacing of the sensors used, and the number of pins locations utilized.

Time and Activity Overview

Day	Time Allotment	Actvities
1	60 minutes	pre-test discovery lesson about volume
2	60 minutes	present design challenge mark sensors begin mystery boxes
3	60 minutes	work on mystery boxes find percent accuracy
4	60 minutes	class reports of designed procedure
5	60 minutes	final game post-test

Pre-requisite Knowledge & Skill	Students should have knowledge of three-dimensional shapes and that these shapes have volume measured in cubic units. Students should have knowledge of a number line extending to the left and right of zero. Students will need to know how to create a line graph.

Academic Content Standards

Add Standard	Mathematics
Grade/Conceptual Category	Grade 5
Domain	Geometry
Cluster	Graph Points on the coordinate plane to solve real-world and mathematical problems.
Standards	Use a pair of perpendicular lines, called axes, to define a coordinate system, with the intersection of lines (the origin) arranged to coincide with the 0 on each line and a given point in the plane located by using an ordered pair of numbers, called coordinates. Understand that the first number indicates how far to travel from the origin in the direction of one axis, and the second number indicates how far to travel in the direction of the second axis, with the convention that the names of the two axes and the coordinates correspond (e.g., x-axis and x-coordinate, y-axis, and y-coordinate).

Add Standard	Mathematics
Grade/Conceptual Category	Grade 5
Domain	Geometry
Cluster	Graph points on the coordinate plane to solve real world and mathematical problems.
Standards	Represent real world and mathematical problems by graphing points in the first quadrant of the coordinate plane, and interpret coordinate values of points in the context of the situation.

Add Standard	Mathematics
Grade/Conceptual Category	Grade 5
Domain	Measurement and Data
Cluster	Geometric measurement: understand concepts of volume and relate volume to multiplication and to addition.
Standards	Recognize volume as an attribute of solid figures and understand concepts of volume measurement. a. A cube with side length 1 unit, called "unit cube," of volume, and can be used to measure volume. b. A solid figure which can be packed without gaps or overlaps using n unit cubes is said to have volume of n cubic units.

Add Standard	Mathematics
Grade/Conceptual Category	Grade 5
Domain	Measurement and Data
Cluster	Geometric measurement: understand concepts of volume and relate volume to multiplication and to addition.
Standards	Measure volume by counting unit cubes, using cubic cm, cubic in, cubic ft, and improvised units.

Add Standard	Mathematics
Grade/Conceptual Category	Grade 5
Domain	Measurement and Data
Cluster	Geometric measurement: understand concepts of volume and relate volume to multiplication and to addition.
Standards	Relate volume to the operations of multiplication and addition and solve real world and mathematical problems involving volume. a. Find the volume of a right rectangular prism with whole-number side lengths by packing it with unit cubes, and show that the volume is the same as would be found by multiplying the edge lengths, equivalently by multiplying the height, by the area of the base. Represent threefold whole-number products as volumes, e.g., to represent the associative property of multiplication. b. Apply the formulas V= l x w x h and V = B x h for rectangular prisms to find the volumes of right rectangular prisms with whole-number edge lengths in the context of solving real world and mathematical problems. c. Recognize volume as additive. Find volumes of solid figures composed of two non-overlapping right rectangular prisms by adding the volumes of the non-overlapping parts, applying this technique to solve real world problems.

Add Standard	English Language Arts
Grade	Grade 5
Strand	Speaking and Listening
Topic	Comprehension and Collaboration
Standard	Engage effectively in a range of collaborative discussions (one-on-one, in groups, and teacher-led) with diverse partners on grade 5 topics and texts, building on others' ideas and expressing their own clearly. a. Come to discussions prepared, having read or studied required material, explicitly draw on that preparation and other information known about the topic to explore ideas under discussion. b. Follow agreed-upon rules for discussions and carry out assigned roles. c. Pose and respond to specific questions by making comments that contribute to the discussion and elaborate on the remarks of others. d. Review the key ideas expressed and draw conclusions in light of information and knowledge gained from the discussions.

Add Standard	English Language Arts
Grade	Grade 5
Strand	Speaking and Listening
Topic	Presentation of Knowledge and Ideas
Standard	Include multimedia components (e.g., graphics, sound) and visual displays in presentations when appropriate to enhance the development of main ideas or themes.

Add Standard	English Language Arts
Grade	Grade 5
Strand	Speaking and Listening
Topic	Presentation of Knowledge and Ideas
Standard	Report on a topic or text or present an opinion, sequencing ideas logically and using appropriate facts and relevant, descriptive details to support main ideas or themes; speak clearly at an understandable pace.

Add Standard	Social Studies
Grade	
Theme	
Strand (pk-8 only)	
Topic	
Content Standard	

Add Standard	Science	Ohio
Grade		
Theme		
Topic		
Content Standard		

Add Standard	Science	Ohio
Strand		
Course Content		
Content Elaboration		

Add Standard	Fine Arts	Ohio
Grade		
Subject		
Standard		
Benchmark		
Indicator		

Add Standard	Technology
Grade	Grade 5
Standard	Nature of Technology
Benchmark	Compare and discuss the characteristics of technology in our community.
Indicator	Use tools, materials, and processes to produce products and carry out tasks efficiently and effectively.

Add Standard	Technology
Grade	Grade 5
Standard	Nature of Technology
Benchmark	Identify, describe, and discuss the core concepts of technology.
Indicator	Demonstrate how tools and machines extend human capabilities.

Add Standard	Technology
Grade	Grade 5
Standard	Nature of Technology
Benchmark	Identify, describe, and discuss the core concepts of technology.
Indicator	Recognize that requirements are the limits to designing or making a product or system.

Add Standard	Technology
Grade	Grade 5
Standard	Technology and Society Interaction
Benchmark	Define responsible citizenship relative to technology.
Indicator	Identify and show cooperative and collaborative strategies to work with others when using technology systems.

Assessment Plan

What evidence will show that students have acquired the enduring understandings for this STEM unit?

Performance Task, Projects	Engineering Design Challenge Volume calculations in Discovery Lesson
Quizzes, Tests, Academic Prompts	Pre-test Post-test
Other Evidence (e.g. observations, work samples, student artifacts, etc.)	Percent accuracy of each hidden object's volume engineering team procedure reports rubric
Student Self- Assessment	Percent accuracy of each hidden object's volume rubric

Technology Integration

ADISC Technology Integration Model*

	Type of Integration	Application(s) in this STEM Unit
A	Technology tools and resources that support students and teachers in ***adjusting, adapting, or augmenting*** teaching and learning to meet the needs of individual learners or groups of learners.	calculator
D	Technology tools and resources that support students and teachers in ***dealing effectively with data***, including data management, manipulation, and display.	excel (extension) fathom
I	Technology tools and resources that support students and teachers in conducting ***inquiry***, including the effective use of Internet research methods.	sensors
S	Technology tools and resources that support students and teachers in ***simulating*** real world phenomena including the modeling of physical, social, economic, and mathematical relationships.	
C	Technology tools and resources that support students and teachers in ***communicating and collaborating*** including the effective use of multimedia tools and online collaboration.	power point overhead document camera SmartBoard
	**The ADISC Model was developed by James Rowley PhD, Executive Director of the Institute for Technology-Enhanced Learning at the University of Dayton*	

Career Connections

Career Description

This lesson uses sensors to determine the location, size and shape of an object that this not visible with the naked eye. There are many science fields that design and use these types of measurement devices in their daily work. These sensing devices use a variety of methods to measure location, size and shape, including: satellite imaging, lasers, sonar, radar, and magnetic fields. Related careers include:

Archeologists study past human culture and behavior by examining fossils (preserved bones) of humans, food remains, the ruins of buildings, and human artifacts—items such as tools, pottery, and jewelry to reconstruct past ways of life.

If you are going to build a building or bridge, you need to know what you are digging into. Civil engineers, including structural and geotechnical engineers, plan, design, construct, operate, and maintain buildings, dams, bridges, harbors, power facilities, pollution control facilities, water supply, and their foundations where earth and rock are engineering materials.

Petroleum engineers, surveyors and geologists study surface features, satellite maps, and check soil and rock samples to locate and produce oil and natural gas.
This lesson also focuses on developing and improving a sensing process. Process design, development and optimization of many different types of processes is the focus of multiple engineering careers, including:

Process engineers design and develop the way a product is manufactured. They analyze the operation sequences that the product would follow, assembly processes, whether automation can be considered, and what kind of interface the operator would have with the process.

Manufacturing engineers make manufacturing processes better, faster, and cheaper.

Industrial Engineers improve quality and productivity in manufacturing processes and in service industries such as entertainment industries, shipping and logistics businesses, and health care organizations. They work to eliminate waste of time, money, materials, energy, and other commodities using techniques such as lean manufacturing and Six Sigma.

Section II: STEM Lesson Plan

Title of Lesson

Day 1

Time Required

60 minutes

Materials

Pre-Test (Appendix A) - copies for all students
Volume Discovery Activity (Appendix C) - copies for all students
Rectangular prism for each student. It would be helpful for students to bring in their own cereal, shoe, or other box for the activity.
rulers - 1 per student
centimeter cubes - class set

Objectives

Students will discover the formula for calculating the volume of a rectangular prism.

Instructional Process

1. Administer pre-test.
2. Complete the Volume Discovery Activity Appendix C. Have students take their rectangular prism and a copy of the worksheet, then measure their box's dimensions and calculate its volume.
3. After they calculate their volume students have meet with another student that has a similar volume and compare the dimensions of their boxes.
4. Facilitate a class discussion on their findings.

Differentiation

Use calculators to determine volume.
Vary measurement precision levels for different abilities (nearest cm, mm).
Have students convert measurements.

Assessments

Pre-test
Volume Discovery worksheet

Section II: STEM Lesson Plan

Title of Lesson — **Day 2**

Time Required — 60 minutes

Materials

Engineering Design Challenge (Appendix D) - one per student
Bamboo skewers - 15 per group
fine tip markers to mark measurements on skewers - one per student
mystery boxes - one per group
Rulers or measuring tapes - one per group
graph paper - 6 sheets per group
examples of data tables (Appendix E)
safety goggles - one per "Sensor Operator"

Objectives

Students will draw the centimeter and half centimeter increments on their sensors for the challenge and begin setting up their data table for the challenge.

Instructional Process

Teacher's Note:
Mystery Box Construction - secure a rectangular prism on the inside bottom of a box using masking tape. The rectangular prisms should have different volumes and/or dimensions and be placed in different locations in each box. Precalculate the volume of each rectangular prism prior to closing the box. Create multiple lids (number of groups times the number of boxes) with a coordinate grid (copied on paper that will cover the opening of the box) that extends into all four quadrants on the top. (You can also choose to use the same lid for each group.) The coordinate grid should be mounted on thin cardboard, card-stock, or poster-board for support. Attach coordinate to cardboard lid. Students will use the coordinate grid and the sensors (skewers) for the activity. Label or number the boxes. Example of prisms include: single serving cereal boxes, Jell-o, deck of cards, marker box, crayon box, kool-aid, or raisin.

1. Present the Engineering Design Challenge (Appendix D).
2. Place the students into engineering teams and assign roles. Students will choose their initial role but they will rotate responsibilities with each box.
3. Give each group fifteen sensors (skewers). Explain to the students that they will use their sensors to measure the depth of each probe. Instruct them to use a different color with each box to avoid confusion.
4. Review an example data table (Appendix E) and how to find percent accuracy. Use practice page (Appendix F) if needed.
5. Each group will receive their first mystery box. They will need fifteen sensors to determine the length, width, and height of the rectangular prism inside the box. Inform the students their sensors will be reduced by one with each new box.
6. Students will record data on self-created data tables (use graph paper). After finding these measurements, they will calculate the volume of the rectangular prism inside the box.
7. Once they have calculated the volume they will get the actual volume from the teacher and calculate their percent accuracy. They will graph the percent on a line graph.

Differentiation

calculators to find percent accuracy
pre-made data table
graph time efficiency

Assessments

percent accuracy practice page
data table
line graph

Section II: STEM Lesson Plan

Title of Lesson	**Day 3**
Time Required	60 minutes
Materials	Mystery Boxes - one per group (same set from Day #2) student created data tables and graphs sensors (skewers from Day #2) safety goggles - one per "Sensor Operator"
Objectives	Students will use their sensors to find the dimensions and volume of the hidden rectangular prisms and identify the coordinate of each sensor.
Instructional Process	1. Students will continue to follow the steps from Day #2 to find the dimensions and volume for each mystery prism They will record all their information in their data tables and graph each percent accuracy on their line graph. 2. Each time they move to a new box the number of sensors should be reduced by one. The students are reassessing their accuracy and changing their plan for finding the object's volume. They should be questioning every sensor's position. 3. Students should complete the process for at least 4 boxes total. Engineering teams will have twenty minutes with each box to determine dimensions, record data, find volume, and calculate percent accuracy.
Differentiation	calculators for percent accuracy do not reduce the number of sensors reduce by two sensors
Assessments	percent accuracy data table line graph

Section II: STEM Lesson Plan

Title of Lesson | **Day 4**

Title of Lesson	**Day 4**
Time Required	60 minutes
Materials	Mystery Boxes from previous days student created data tables and graphs sensors (skewers from Day #2) safety goggles - one per "Sensor Operator"
Objectives	Students will analyze their data and communicate the strategy that was most successful for determining the hidden object's volume.
Instructional Process	1. Write the following speaking points that the engineering teams need to share in their informal presentation on the board. a. What worked well? b. What didn't work? c. Share data recorded in table d. Share line graph trend e. If you were to do this again, what would you do the same and what would you change? 2. Give engineering teams 20 minutes to prepare their presentations. 3. Each team will present their information to the class.
Differentiation	Use presentation software
Assessments	presentation of strategy data tables line graphs

Section II: STEM Lesson Plan

Title of Lesson	**Day 5**
Time Required	60 minutes
Materials	Post-test (Appendix A) a new mystery box - one per group (not one they have completed) student created data tables and graphs sensors (skewers from Day #2) safety goggles - one per "Sensor Operator"
Objectives	Student engineering teams will demonstrate and apply their most accurate strategy to determine the volume of the hidden prism.
Instructional Process	1. The student groups will complete one final "dig". They will be given a new box. They will find the length, width, and height. They will then calculate the volume of their mystery rectangular prism. Students may use up to15 sensors, however the fewer sensors they use the lower their score will be. 2. After finding the volume they will calculate the percent accuracy. 3. Using the following formula to determine the winning engineering team: percent accuracy score (ignore negative sign if present) + the number of sensors used. The team with the lowest score will win. 4. Administer post-test (Appendix A).
Differentiation	Have student teams decide the maximum number of sensors they will use before beginning the activity. Teams will earn a reduction of their score (example by two points) for choosing this option. For example, a group may decide they will only use 10 sensors and if they do they can subtract points. If not, they would have penalty points added.
Assessments	post-test game score

Section III: Unit Resources

Materials and Resource Master List

shoe boxes (or other small boxes) - # of groups times two
copies of needed appendices
rectangular prisms - one per box
tape
ruler - one per student
measuring tapes - one per group
graph paper (6 copies for each group)
paper
pencils
safety goggles - one per group
coordinate grids - one per box
various rectangular prisms - one per box
skewers - 15 per group
masking tape
timer - one per group
card-stock, poster-board or cardboard - enough to support each lid

Key Vocabulary

3-dimensional - a shape with three dimensions; length, width and height.

Accurate - the condition or quality of being true, correct or exact.

Area - the amount of surface inside a closed boundary. Area is measured in square units, such as square inches or square centimeters.

Base or a prism or cylinder - either of the two parallel and congruent faces that define the shape of a prism or cylinder.

Bisect - to divide a segment, an angle, or another figure into two equal parts.

Coordinate grid - a device for locating points in a plane using ordered number pairs, or coordinates. A coordinate grid is formed by two number lines that intersect at their zero points and form right angles.

Data table - facts or information displayed in rows and columns

Depth - dimension that is downward

Edge - a line segment or curve where two surfaces meet.

Efficient - performing or functioning in the best possible manner with the least amount of waste in time and effort.

Engineering Design Process - is a series of steps that engineers use to guide them as they solve problems.

Height - the length of the shortest line segment between the vertex of a pyramid of a cone and the plane containing its base.

Length - the longest dimension when measured from end to end.

Optimize - to make as effective, perfect or useful as possible.

Percent accuracy - the ratio or comparison of how correct a measurement is compared to the actual measurement.

Prism - a solid figure with two faces called bases bounded by polygons that are Parallel and congruent.

Quadrant - one fourth of a coordinate grid

Volume - a measure of how much space a solid object takes up. Volume is measured in cubic units, such as cubic inches or cubic centimeters. The volume or capacity of a container is a measure of how much the container will hold.

Width - the measurement of something from side to side

X - axis - the horizontal number line in a coordinate grid

Y - axis - the vertical number line in a coordinate grid

Technical Brief

In a real sense, scientists and engineers often are searching for buried treasure. The treasure could be a vein of gold, but the buried treasures are more likely underground oil reserves, underground water basins, or artifacts such as buried gas lines. Exactly where is the item of interest? How large is it: length, breadth, depth? The location and measurement tasks have one thing in common: the presumed targets are neither within sight nor easily reached.

The scientists and engineers must use some sensor that can reach the target and enable a distance to be measured. The sensors could be physical rods, but they can also be radio or sonar waves which can reflect off of objects. We are familiar with radars that can report on the location and distance of airplanes and weather clouds. But there are also ground-penetrating radars that can find buried items such as rivers of molten lava. In a more general sense, the objects of interest can be as close as within our own bodies. Think dental X-rays and the search for cavities. Think of brain tomography which can find tumors or blood clots. Or the objects can be quite distant such as a galaxy far far away.

But the scientists and engineers cannot just randomly run around pointing their sensors any old place and until they find something. They usually are limited in both time and money. For example, drilling exploratory oil wells is both time-consuming and expensive. Hence, the explorers must have a plan and a strategy for where and how they will test for the presence of an object of interest. They also must have a criterion and plan for when to move on to a new search site whether or not they found something in a previous site. Think of the game Battleship. They must also know when to give up a fruitless search. Remember, the presence of a coal deposit or old abandoned pipeline is only suspected or hypothesized. There is no guarantee that any object exists at all in the general area.

Measurement is a key scientific and engineering activity. Not only do scientists and engineers use a variety of sensors, they spend considerable effort on designing and building new sensors. Think tools to explore nanoscale molecules, replacements for X-rays for safer medical exams, and deep-space radio-telescopes. A single inventor might work entirely in their garage, but teams which build huge machines to explore tiny sub-atomic particles can employ hundreds of scientists and engineer from many specialties.

Let's not neglect the problem of determining efficient search strategies and knowing when to stop and declare a success or a failure. This is in the domain of a little-know area of applied mathematics known as operations research.

Safety and Disposal

The boxes can be saved for future lessons by simply moving hidden prism to a new location.
Use safety goggles if students use sharp objects as sensors.

References

Everyday Mathematics Student Reference Book (Grade 6). 2007. Wright Group/McGraw-Hill. Chicago, IL. 2010.

Progress in Mathematics. Sadler-Oxford. New York, NY. 2006.

http://www.mos.org/eie/engineering_design.php (5/9/12)

Archeology (2003). The International History Project. Retrieved April 8, 2012, from http://history-world.org/archeology.htm

Civil Engineering. NC State University: What can I do with a Major in… Retrieved April 8, 2012, from http://www.ncsu.edu/majors-careers/do_with_major_in/showmajor.php?id=49

The Relevance of Geology - Union College Geosciences (C03). UnionGeosciences on YouTube. Retrieved April 8, 2012, from http://www.youtube.com/watch?v=VJaUzJUAvJI
What is Geology? - What does a Geologist do? Geology.com. Retrieved April 8, 2012, from http://geology.com/articles/what-is-geology.shtml

How Offshore Drilling Works. How Stuff Works. Retrieved April 8, 2012, from http://science.howstuffworks.com/environmental/energy/offshore-drilling1.htm

How Oil Drilling Works. How Stuff Works. Retrieved April 8, 2012, from http://science.howstuffworks.com/environmental/energy/oil-drilling2.htm

Career Details: Manufacturing Engineer. Career Me: Your Career in Advanced Manufacturing. Retrieve May 20, 2012, from http://www.careerme.org/career_details.php?id=2

Career Details: Industrial Engineer. Career Me: Your Career in Advanced Manufacturing. Retrieve May 20, 2012, from http://www.careerme.org/career_details.php?id=1

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Section IV: Appendices

Appendix A - Pre/Post Test
Appendix B - Pre/Post Test Answer Key
Appendix C - Volume Discovery Activity
Appendix D - Engineering Design Challenge
Appendix E - Sample Data Table
Appendix F - Percent Accuracy Practice Page
Appendix G - Rubric