A New Wrinkle in the "Golf Ball Float" Ingenuity Challenge

Aaron M. Gray

Maryland's emphasis on raising the achievement levels of students in mathematics is cause to reexamine the way we are teaching students about technology. By making some minor additions to a long-established Ingenuity Challenge, students are required to demonstrate knowledge and skills identified in our State's Core Learning Goals.

The Ingenuity Challenge teaching/learning strategy provides a way for students to: 1) learn and practice systematic problem solving; 2) develop and apply their ingenuity and creativity; and 3) make concrete applications of concepts and skills learned in mathematics, science, and language arts.

The *Golf Ball Float* is a short-term Ingenuity Challenge in which students design and fabricate an aluminum boat (vessel) that will hold as many golf balls as possible before sinking. The specifications for the challenge include the statement of the problem, rules for the challenge, the resources available, and how solutions will be evaluated.

The new element being suggested here is to have students collect and analyze data that will guide them in their design process. By making predictions about a design's effectiveness and then constructing and testing a series of sample designs, students learn the relationship between a vessel's volume and its ability to support a load.

In the process of obtaining valuable data; students develop measuring skills, fabrication skills, and skill in loading the vessels. They also develop an understanding of the science concepts related to the activity including: force, gravity, buoyancy, displacement, density, balance, center of gravity, mass, and volume. In the process of making predictions about a vessel's capacity, they are required to perform several mathematical calculations.

Armed with the results from this preliminary activity, students are ready to tackle the *Golf Ball Challenge.*

Ingenuity Challenge: Problem Assignment Specifications For "Golf Ball Float"

Challenge Problem:

Design and fabricate an aluminum boat which will hold as many golf balls as possible before sinking.

Rules:

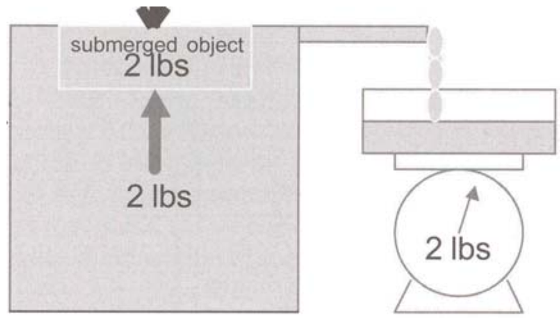
1. *Each student is to fabricate an aluminum boat from a twelve-inch square piece of aluminum foil.*
2. *Each student will build and test his/her own boat.*

Resources:

People:	*Students working individually*
Information:	*Facts and knowledge the individual possesses or obtains.* *Instruction from teacher*
Materials:	*Aluminum foil, 30 cm x 30 cm* (12" *x* 12")
Tools:	*Ruler*
Time:	*90 Minutes*
Energy	*Human muscle power:*
Capital:	*Provided by teacher*

Evaluation: *The boat that floats while holding the greatest number of golf balls will be the winner.*

In the *Ingenuity Challenge* Teaching Learning Strategy, the teacher provides instruction on science, mathematics, and technology concepts related to the problem. For this challenge, students are introduced to Archimedes' Principle which states that the buoyancy of a submerged or partially submerged object is equal to the weight of the fluid the object displaces. The setup below demonstrates the principle.



For the floating object, the gravitational force must be equal to the buoyant force, otherwise, the object would rise or sink due to the net force. For example, a 10 pound log is floating in a bucket of water that is filled to the very top. If we caught all of the water that spilled out when the log was placed into the water and then weighed it, we would find that the displaced water weighed exactly 10 pounds. According to Archimedes, this 10 pounds is equal to the buoyant force. Since the log is floating, we know the buoyant force must be 10 pounds.

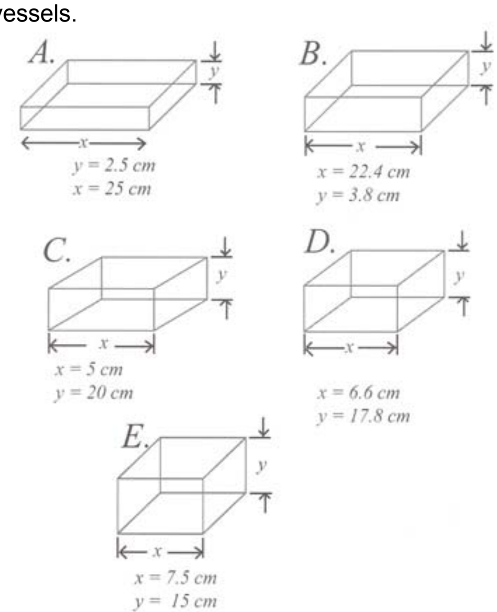
To float a cargo we need to create a vessel that has good stability, strength, and capacity. Stability will keep the vessel from tipping over. Strength will keep it from breaking or changing shape. Capacity will determine how much cargo it can support.

There must be enough room on board the vessel to store the cargo. The vessel must also be shaped in a way to displace as much water as possible resulting in as much buoyant force as possible. The more water displaced the better.

With this information and some instruction on shaping the material, students begin the problem solving process. They may "design-on-the-fly," creating a vessel by shaping the material into a boat that they think will hold a number of golf balls. Before preliminary testing, it is desirable to have the students record their prediction of the number of balls their vessel will hold.

After preliminary testing students will have recorded their predicted and actual results and will have acquired considerable knowledge regarding subtle aspects of the problem such as the importance of carefully loading the vessel to avoid sinking the vessel before its maximum capacity is reached.

At this point some more formal data collection is needed before more designing. Assign teams of two students to construct the following shaped vessels.



Before testing, students will calculate the volume of their vessel and determine the buoyant force created by submerging the vessel. The following table will guide students through the process.

	Vessel Size(cm)	Volume (cu cm)	Predicted Cavacity	Actual Capacity *
Vessel		* Calculations	to be done	by students
A.	25 x 25 x 2.5	1563*	31*	_______
B.	22.4 x 22.4 x 3.8	1907*	40*	_______
C.	20 x 20 x 5	2000*	40*	_______
D.	18x18x6.4	2074*	41*	_______
E.	7.6x7.6x15	1710*	34*	_______

It may be useful to use the following teaching aid to help students calculate the volume of the vessels.

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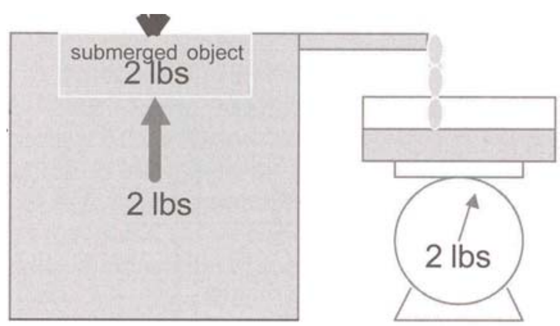

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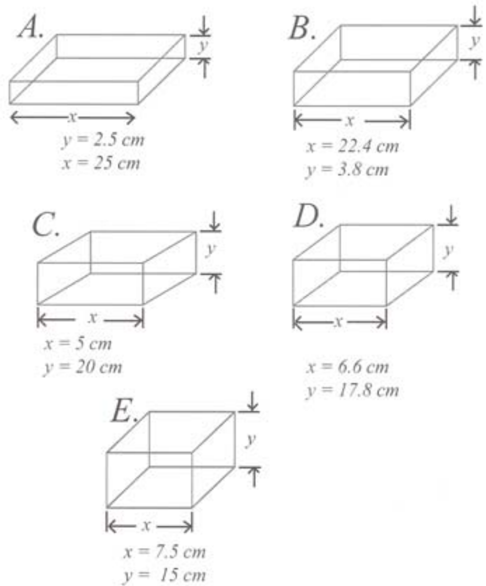

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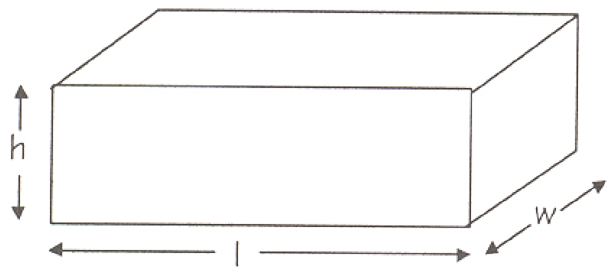
It may be useful to use the following teaching aid to help students calculate the volume of the vessels.

Finding Volume of a
Rectangular Object

V=l x w x h
where
V = volume
l = length
w = width
h = height



For example, what is the volume of a 18 cm x 8 cm x 5 cm rectangular solid.
V=l x w x h
V = 18 cm x 8 cm x 5 cm
V = 720 cu. cm.

Once students know the volume of the vessel, they will calculate the buoyant force developed when it is submerged. At this point we utilize Archimedes' Principal to make a prediction of the capacity of the vessel. The buoyant force is equal to the weight of the fluid displaced. One cubic centimeter of water weighs one gram so the buoyant force is equals:

Buoyant Force = V(cm^3) x Weight of Water (g/cm^3)

For the example above, the buoyant force is:

$$720\ cm^3 \times 1\ g/cm = 720\ g$$

The capacity of *the vessel is determined by dividing the weight* of a *golf ball into the vessel's capacity.*

$$\frac{720\ g}{46\ g\ /\ golf\ ball} = 15.6\ golf\ balls$$

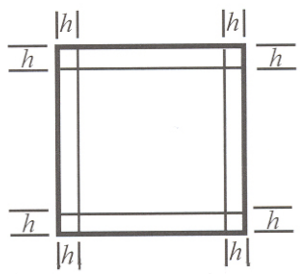
The predicted capacity of the vessel is 15 golf balls. Students will use this process to calculate the capacity of the test vessels and fill in the third column of the table.

The next step is to test the vessels' capacity by loading it until it sinks. They will record the number of golf balls held in the last column of the table. If the predicted results do not match the actual results, a good followup activity is for the students to speculate on why their prediction was not accurate.

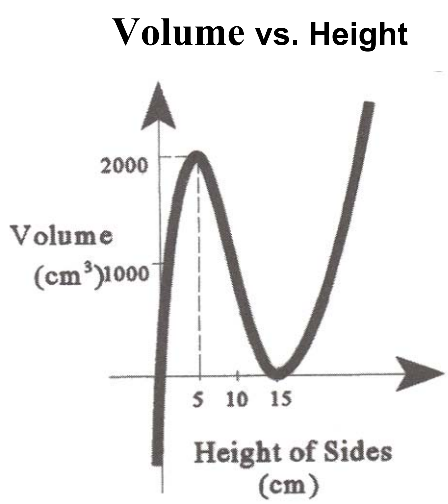
Another interesting mathematics application related to this problem is to have the students calculate the maximum volume that can be attained from the material. Determining the maximum volume box that can be made from a sheet of material can be determined using the following formula:

$$v = h\,(\text{length} - 2h)\,(\text{width} - 2h)$$

"V" is the volume and "h" is the height of the resulting box.



The graph below indicates a definite value for "h" that will provide the maximum volume.



With this experience, students are prepared to tackle the challenge again using their own designs. They may decide to use shapes other than rectangular solids but their knowledge and skills base has been enhanced to a point where they can make a very efficient vessel.

Aaron M. Gray is the Technology Education teacher at Burleigh Manor Middle School in Howard County, Maryland.