Lesson Plans on Density for Middle School Teachers

bu Cory Patterson, Teresa Kennedy and Tiffany Miller

Manifest Density

Expanding science and engineering to new horizons

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Meet the Teachers

- **Cory Patterson is a teacher at Monaco Middle School in Las Vegas. He teaches 7th grade Earth Science. He will be teaching in Cairo, Egypt for the 2004-2006 school years.**

- **Teresa Kennedy is a teacher at Our Lady of the Snows Catholic School in Reno, Nevada. She teaches 6th, 7th and 8th grade science. She is also a geologist and enjoys studying earth science in her free time!**

- **Tiffany Miller teaches 7th and 8th grade science at O'Brien Middle School in Reno, Nevada.**

Module Overview

Topic: Manifest *Density*

As a result of this unit, students will understand:

- Density is defined by the ratio of the mass of a substance to its volume.
- For an object to float, relative to its surroundings, it must be less dense than its surroundings.
- Density is a principle that is found in many of Earth's processes, including the water cycle.
- Density affects the workings of hot air balloons.

Essential Questions that focus this unit are:

- What is density?
- What is mass?
- What is volume?
- Can density be measured?
- Why do some objects float or sink relative to other objects?
- What role does density play in the water cycle?
- Can we make a balloon that floats in air?

Assessment

Performance Tasks:
- Students will create a miniature hot-air balloon that floats using their knowledge of density, volume and mass.
- Students will design a replicable model showing density at work in the water cycle

Quizzes, Tests, Academic Prompts
- Students will be quizzed on their understanding of volume using a PowerPoint presentation
- Students will use their knowledge of mass and volume to write a letter to a company explaining these scientific concepts.

Other Evidence
- Students will record data and fill in lab sheets on day 1 and day 2.
- Student will complete a flow chart to show their testing data from a computer simulation.

Student Self-Assessment
- Students will write a review of their balloon building experience and describe how mass, density and volume affected their models. They will evaluate their own learning and progress throughout the unit.

Key elements students will need to know:

- Definitions of density, mass and volume.
- SI Units.
- Variable management.
- Density is measurable.
- Real-world examples of density working all around us.
- A working knowledge of density in order to meet the challenge of constructing a working hot air balloon for their culminating task/project.

Key skills students will need to be able to do:

- Take measurements (mass and volume) in determining the density of selected objects.
- Comfortably use density-related terminology.
- Scientific reasoning and problem solving.
- Describe scientific concepts in writing.
- Calculate the densities of objects.
- Construct and use graphs in presenting data.
- Use higher-order thinking skills such as analysis, synthesis and evaluation.
- Working cooperatively.
- Manipulate variables toward desired outcomes.
- Successfully navigate applet program.
- Apply the knowledge and skills learned from the density unit in creating working hot air balloon.

Teaching and Learning Experiences Mapped to State Standards:

Lesson One – Into to Mass and Volume	Science	1.6.4 Investigate and describe the relationship between the mass and the volume of various objects. 22.8.2 Organize information in tables and graphs and describe the relationships they reveal. 23.8.1 Explain that quantities can vary in proportion to one another. (e.g., the ratio of mass to volume in the calculation of density). 23.8.4 Select and use the appropriate SI unit for a particular measurement (e.g., meters for length, seconds for time, and kilograms for mass). 23.8.5 Make predictions based on all known data from similar conditions. 24.8.1 Use instruments and laboratory safety equipment properly. 24.8.4 Use appropriate technology in laboratory procedures for measuring, recording, and analyzing data (e.g., computers, graphing calculators and probes). 24.8.6 Design a controlled experiment. 24.8.8 Keep an organized record of scientific investigations.
	Math	3.7.1 Estimate and convert, units of measure for mass, and volume within the same measurement system; compare corresponding units of the two systems.

Lesson Two – The Nitty gritty of density	Science	1.7.4 Investigate and describe the density of solids, liquids, and gases. 23.8.1 Explain that quantities can vary in proportion to one another. (e.g., the ratio of mass to volume in the calculation of density). 22.8.3 Organize information in tables and graphs and describe the relationships they reveal. 23.8.6 Make predictions based on all known data from similar conditions. 24.8.1 Use instruments and laboratory safety equipment properly. 24.8.4 Use appropriate technology in laboratory procedures for measuring, recording, and analyzing data (e.g., computers, graphing calculators, and probes). 24.8.5 Keep an organized record of scientific investigations. 24.8.6 Design a controlled experiment.
Lesson Three- Wet comes up, must come down	Science	1.6.4 Investigate and describe the relationship between the mass and the volume of various objects. 1.7.4 Investigate and describe the density of solids, liquids, and gases. 20.8.3 Identify and illustrate natural cycles within systems (e.g., water, planetary motion, climate, geological changes). 23.8.1 Explain that quantities can vary in proportion to one another. (e.g., the ratio of mass to volume in the calculation of density).

		23.8.7 Make predictions based on all known data from similar conditions. 24.8.1 Use instruments and laboratory safety equipment properly. 24.8.5 Keep an organized record of scientific investigations. 24.8.6 Design a controlled experiment. 24.8.8 Use appropriate technology in laboratory procedures for measuring, recording, and analyzing data (e.g., computers, graphing calculators, and probes).
Lesson Four – Density is in the air	Science	1.6.4 Investigate and describe the relationship between the mass and the volume of various objects. 1.7.5 Investigate and describe the density of solids, liquids, and gases. 23.8.1 Explain that quantities can vary in proportion to one another. (e.g., the ratio of mass to volume in the calculation of density). 23.8.2 Investigate and describe the relationship between the mass and the volume of various objects. 23.8.8 Select and use the appropriate SI unit for a particular measurement (e.g., meters for length, seconds for time, and kilograms for mass). 23.8.9 Make predictions based on all known data from similar conditions. 22.8.4 Organize information in tables and graphs and describe the relationships they reveal.

		24.8.5 Keep an organized record of scientific investigations. 24.8.6 Design a controlled experiment. 24.8.8 Use appropriate technology in laboratory procedures for measuring, recording, and analyzing data (e.g., computers, graphing calculators, and probes). 24.8.9 Use instruments and laboratory safety equipment properly.
	Math	3.7.1 Estimate and convert units of measure for mass, and volume within the same measurement system; compare corresponding units of the two systems. . 3.7.2 Estimate, measure to the required degree of accuracy, derive, and apply standard formulas to find the volume and surface area of solid figures (e.g., cylinders, triangular solids). 3.8.3 Select and apply appropriate formulas to solve problems; identify the relationship between changes in area and volume and changes in linear measures of figures.

Manifest Density – Lesson Plans

Lesson 1: Intro to Mass and Volume

Lesson Goal: The purpose of this lesson series is to introduce students to the concepts of density, mass and volume and prepare them to complete a performance task in which they must use their knowledge of these concepts.

Concepts to be developed:
1. Density is the measurement of the compactness of an object.
2. Density is a property that is determined by the ratio of a substance's mass to its volume.
3. Mass is how much matter is inside of an object.
4. Volume is how much space something takes up.

Skills to be developed:
1. Students will use a balance to measure mass.
2. Students will describe a scientific concept in writing using their own words.
3. Students will use logic and scientific guessing to find objects of the same mass.

Objectives:
1. Students will describe the concepts of mass and volume in a letter.
2. Students will calculate the mass of objects using a balance.
3. Students will use scientific reasoning to find two objects with identical masses.
4. Students will measure and record objects that have identical masses, but different volumes.
5. Students will observe objects that have identical volumes, but different masses.

Materials:

For class demonstrations:
- Four large brown paper bags
- Materials of different densities to fill paper bags (such as Styrofoam, cotton, shredded tissue paper, container with rocks, cans of paint, heavy metal objects, etc.)
- Aquarium or other clear container filled with water
- Large piece of pumice

For each group of students:
- Small acrylic, wood, and Styrofoam squares, each with the same dimensions
- Balance or scale
- 1 regular soda and 1 diet soda

Safety Procedures: none

Procedure

Activity One:

Foundation:

1. Before the lesson, fill two large brown paper bags with light-weight materials, such as Styrofoam, cotton, shredded tissue paper, etc. Fill two large brown paper bags with heavy-weight materials, such as container filled with rocks, cans of paint, heavy metal objects, etc. Close the bags and number each bag. Make the exterior of the bags look the same.
2. As students enter the room have an aquarium filled with water and a large piece of pumice floating in it. Ask students to explain in writing why this particular rock floats and other rocks sink. Explain that by the end of the lesson, they will be able to explain why this rock floats, using the terms *mass*, *volume*, and *density*.
3. Place the four bags next to each other on a table. Ask the students if they can tell anything about how heavy each bag is by mere observation. Ask them to predict the relative weights of the four bags. Next, have one member of each group come up and pick up each of the bags and arrange the bags in descending order of mass. Discuss with students the fact that although the bags looked very similar and seemed to occupy the same amount of space (volume), they had different masses. Explain that volume is how much space something takes up.
4. To further demonstrate the concept of volume show the PowerPoint Volume Quiz Show.

Activity 2

Simulation:

5. Hold up two cans of soda, one diet and one regular. Ask students if they weigh the same and how they know. (*Check for understanding: If students say they weigh the same because they're the same size, remind them of what they learned in activity one.)*
6. Give students a balance and two sodas for each group (diet and regular). Let them measure the mass of each. Discuss with students that the cans have the same volume, but the mass of each is different. Let them share their ideas about why the masses are different. (*Note to teachers: Students may focus on the difference in ingredients between the two sodas without relating it to the mass of the sodas. Be sure to focus students on the concepts of mass, volume, and density before giving the following assignment.)*
7. When students are finished present them with the following scenario:

    The Coca-Cola Company has been getting angry letters from drinkers of Diet Coke. Because their soda weighs less they feel like they're getting ripped off. If they pay the same amount for a diet coke it should have the same amount of soda in it. It is your job as manager of customer relations to answer these angry letters. For homework write a sample letter to be approved by the company president that contains the following: A scientific explanation of why the Diet Coke weighs less, and a sentence or two addressing the customer's concerns that they are getting less soda than in a regular can or bottle. Then, write a memo to the president of the company in which you outline at least one solution the company can do to fix this problem and make customers happy. Remember – your next promotion depends on how well you solve problems for the company!

Activity 3

8. Students should now know that objects can have the same volume but different masses. Now students will explore objects that have identical masses but different volumes. Challenge each group to find two different objects in the room with the same masses. They can not be two identical items. Students should record their trials in their science journals or on the data sheet provided.
9. Once each group is finished allow them to present their findings and discuss the rational for the items that they tried using the information from their data sheet.
10. Discuss with the class that some items have the same masses, but take up more or less space (volume.) Some items take up the same amount of space (volume) but have more or less mass. We have come up with a way to talk about the relationship between these two measurements (mass and volume) and we call it density.

Activity 4:

11. Give students the 3 cubes of different materials. Have them put them predict the order of density, greatest to smallest and record their predictions. Tell them that tomorrow they will be able to calculate the density and check their answers.

Evaluation:

1. Students will be evaluated on the Volume Quiz Show scores, the data recorded for their mass measurements and the rationale presented in their group for choosing objects of the same mass.
2. Student understanding of mass and volume will be evaluated using their letters to the Coca-Cola Company.

Attachments:

Mass of Objects Data Collection sheet
Printout of Volume Quiz Show slides

Differentiated Instruction techniques:

- Clearly state essential questions
- Continuous assessment and feedback
- Adjust content, process, and product in response to student readiness and learning profiles
    - Shortened and modified assignments
    - Time extensions allowed
    - Use of resource room
    - Notes and/or extra time allowed on tests
- Students and teachers collaborate in learning
- Goals for maximum growth and individual success are established and maintained
- Student ability grouping strategies are used in cooperative learning activities

- Stations are used in allowing for different students to work on different tasks
- Tiered activities are used to focus on essential understandings and skills at different levels of complexity, abstractness and open-endedness

Name ____________________________ Date _________ Per. _____

Masses of Objects Data Collection Sheet

Object:	Mass (gms):	Observations:
1.		
2.		
3.		
4.		
5.		
6.		
7.		
8.		
9.		
10.		
11.		
12.		
13.		
14.		

Lesson 2: The Nitty Gritty of Density

Lesson Goal: The purpose of this lesson is to apply the concept of density to liquids and to prepare them to complete a performance task related to their learning at the end of the unit.

Concepts to be developed:

1. Density is a property that can be measured.
2. Density is a property that is determined by the ratio of a substance's mass to its volume.

Skills to be developed:

1. Students will use a graduated cylinder to measure volume of a liquid.
2. Students will use a balance to measure mass.
3. Students will divide mass by volume to determine density of liquids.
4. Students will present data as graph comparing densities of studied items.

Objectives:

1. Students will calculate the density of a solid.
2. Students will use the displacement method in a graduated cylinder or beaker to measure volume of a solid.
3. Students will describe the relationship in words or pictures between solids of similar size but different mass.
4. Students will describe in words or pictures the apparent relationship between liquids of different densities in the same container.
5. Students will calculate the densities of those liquids.

Materials:

For Class Demonstration:

- Bottle of Italian salad dressing, ping pong ball, bouncy ball, pool ball for lesson intro, (playground ball, volleyball, basketball, balloon optional)
- Three cubes from Lesson One, metric rulers, calculators

For each group of students:

- 100 ml graduated cylinder
- Clear plastic cup
- Sharpie marker
- Balance or scale

5-6 stations, each with a different liquid: Isopropyl alcohol, glycerin, water, soda, Epson salt solution, kosher salt solution, sugar solution. Use food coloring, if desired, to make the density differences more visual. Note to teacher: Be sure to try your own test of this simulation to get the correct density numbers using your lab equipment. The number of stations can be adjusted depending on the size of the class and number of stations desired.

Safety Procedures: Students should be instructed not to taste any of the liquids.

Procedure:

Foundation:

1. Ask students to share predictions about relative densities of cubes from last lesson. Instruct students to weigh each cube in grams using the scale. Then instruct each student to measure the dimensions of their cubes to the nearest cm. True cubes should be the same in all directions. Ask students to multiply the three numbers together to find the volume of their cubes in cubic cm. Then ask students to divide the mass of the cube by its volume to determine its density in grams per cubic centimeter. Have students record in their journal the densities of each cube and if their prediction as to the relative order of densities was correct.
2. After students have calculating the density of their cubes using the method in (1), they may determine the volume by observing how much water is displaced (how much the water level rises) when the cube is placed in a graduated cylinder or beaker. Use that volume number to calculate the density using the "displacement method".
3. Pass around balls of similar size but different mass. Ask for class comparisons or observations about the similarities and differences of the items. Prompt for correct usage of vocabulary developed in previous lesson. Ask students the difference between mass and weight. Review definition of mass as the amount of stuff in an object and introduce idea of weight as related to the pull of gravity. The gravity of the moon is 1/6 that of earth so an object will weigh 1/6 of its amount on the moon but its mass always stays the same.
4. Review the concept of determining volume by displacement of water with all students. Ask students how measuring the density of a solid in grams per cubic centimeter could be the same as determining the density of that same solid by how many milliliters of water it displaced. Prompt students to discover that the volume of 1 cubic centimeter is the same as 1 milliliter so those two measurements can be used interchangeably for density calculations.

Simulation:

5. Display unshaken bottle of Italian salad dressing or homemade concoction of fluids with different densities. Ask for observations about why the fluids are in different layers. Discuss immiscibility (oil and water don't mix) and guide students toward observation that fluids are in layers because one is more or less dense than another, meaning that the ratio of its mass to volume is different.
6. Shake the bottle. Draw or describe the settling process. "The fluids settled back into layers because the densities of the liquids are not the same. The one at the top is less dense than those below it. The density of the bottom layer is greater."

Construction:

1. Preparation: Each group should measure 100 ml of water in a graduated cylinder. Place an empty plastic cup on the balance and zero the balance to the weight of the cup. Pour the water into the plastic cup and check the mass of the water. Since the density of water is 1 gm/ml, the weight of the water should be 100 grams. Students should use this relationship to practice their accuracy at filling the graduated cylinder to 100 ml.

2. At each station, measure 100 ml of the liquid to be measured. Pour into empty plastic cup on balance that has been zeroed for the weight of the cup. Record the mass of the liquid on the data sheet. Rinse cup and dry.
3. Repeat procedure at each liquid station.
4. Divide mass of liquid by 100, because the volume of liquid was 100 ml, to determine the density of each liquid in grams per ml.
5. Plot densities of each liquid on a bar graph.
6. If supporting technology is available, classroom computers with spreadsheet programs could be used for data entry and graphing.

Connection:

7. In journal or notebook, predict the order into which the liquids would settle if they were all added to a clear bottle. Draw or describe the order.
8. If liquids have been colored with food coloring, add 10 ml of each liquid to a soda bottle and observe the results.

Evaluation:

1. Given the mass and volume of an unknown liquid, calculate its density.
2. Given a liquid of a certain density, where would it settle in the bottle?
3. Pure water has a density of 1 gm/ml. Salt water has a greater density of ___ gm/ml. (Use the numbers calculated earlier in this lesson.) Why is it easier to float in salt water than in fresh water?
4. Why did the pumice in Lesson 1 float?

Differentiated Instruction techniques:

- Clearly state essential questions
- Continuous assessment and feedback
- Adjust content, process, and product in response to student readiness and learning profiles
    - Shortened and modified assignments
    - Time extensions allowed
    - Use of resource room
    - Notes and/or extra time allowed on tests
- Students and teachers collaborate in learning
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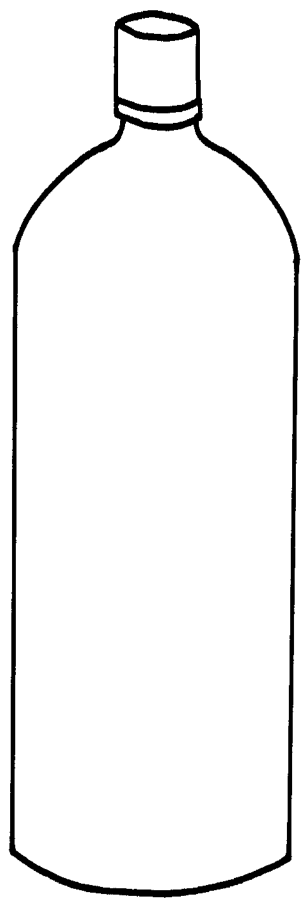
Name ____________________________ Date _________ Per. _____

Station 1:	Mass of 100 ml.	Mass/100 =	gms/ml
Station 2:	Mass of 100 ml.	Mass/100 =	gms/ml
Station 3:	Mass of 100 ml.	Mass/100 =	gms/ml
Station 4:	Mass of 100 ml.	Mass/100 =	gms/ml
Station 5:	Mass of 100 ml.	Mass/100 =	gms/ml
Station 6:	Mass of 100 ml.	Mass/100 =	gms/ml
Station 7:	Mass of 100 ml.	Mass/100 =	gms/ml
Station 8:	Mass of 100 ml.	Mass/100 =	gms/ml
Station 9:	Mass of 100 ml.	Mass/100 =	gms/ml
Station 10:	Mass of 100 ml.	Mass/100 =	gms/ml

Name ______________________________ Date __________ Per. _____

Liquid Layers



Lesson 3: Wet goes up, must come down

Lesson Goal: The purpose of this lesson series is to introduce students to the concept of density, as it applies to the water cycle and for the students to complete a performance task in which they will show density's role in the water cycle.

Concepts to be developed:

1. Density is a principle that is found in many of Earth's processes, including the water cycle.
2. Water vapor is less dense than the surrounding air and therefore rises, allowing water to be recycled.
3. Water droplets that collect in clouds are denser then the surrounding air and therefore fall as precipitation.

Skills to be developed:

1. Students will describe how density plays a role in the water cycle.
2. Students will continue to develop and refine their skills in the scientific process.
3. Students will continue to develop and refine cooperative working skills in a laboratory environment.

Objectives:

1. Students will describe in writing how density plays a role in the water cycle.
2. Students will list and define the steps of the water cycle.
3. Students will design a replicable model showing density at work in the water cycle.

Materials:

For each student:

- A sheet of computer paper, colored pencils

For each group of students:

- Waterproof plastic container, cellophane wrap, ice cubes, water, rocks and/or sand, heat lamp and bulb.
- Lab handout (see attached)

Safety Procedures: Warn students not to burn themselves on the heat lamp.

Procedure

Foundation:

1. Review what is now known about density.
   - Density is a measurement of the compactness of an object.
   - Density is a property that is determined by the ratio of a substance's mass to its volume.
   - Less dense objects will rise above objects with a greater density.
   - Denser objects will fall below objects with less density.

2. Introduce and discuss the water cycle.
    - The water cycle is a process that allows water to be recycled over and over again.
    - There are three main parts to the water cycle:
        - Evaporation—the process in which water is heated, therefore changing states from liquid to gas, called water vapor. (Like steam from a pot of boiling water, or the steam that makes your bathroom mirror cloudy when you take a hot shower.)
        - Condensation—the process in which water vapor is cooled, changing its state from a gas back to a liquid. (Like when water vapor is cooled off from touching the cooler bathroom mirror resulting in water dripping down it.) These tiny water droplets then cling to dust particles in the air, forming clouds.
        - Precipitation—occurs when clouds accumulate enough water that the water droplets become denser then the surrounding air and fall as rain.

Simulation:

- Have the students draw a model of the water cycle, illustrating, labeling and explaining evaporation, condensation, precipitation and the different densities of water vapor and water.

Construction:

- Explain to students that their task will be to make a working model of the water cycle and to explain how it works.
- Show students the materials and brainstorm as a class how those materials can be used in constructing a working, replicable model of the water cycle.
- Distribute and explain lab handout (attached).
- Go over safety procedures.
- Place students in cooperative groups and allow them to begin their task.

Connection:

- Have students share their results with the class, being sure to explain how the water cycle works.

Evaluation:

Students will be evaluated on their lab handouts (to be placed in their science notebooks) and on the sharing of their results with the whole class.

Attachments

Lab handout

Differentiated Instruction techniques:

- Clearly state essential questions
- Continuous assessment and feedback
- Adjust content, process, and product in response to student readiness and learning profiles

  - Shortened and modified assignments
  - Time extensions allowed
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Name ______________________________ Date __________ Per. _____

Wet goes up must come down!

Question: Where are differences in the density of water visible within the water cycle?

Model: List the details of your model.

____
____
____
____
____

Observations: Draw a picture of your working model in the box below. Label the three ways water moves within the water cycle.

Now describe what you see.

____
____
____
____

Conclusion: Where can you observe the property of density differences in water within the water cycle?
Describe what you now know.

____
____
____
____

Lesson 4: Density is in the Air

Lesson Goal: The purpose of this lesson is to challenge students to apply their knowledge of mass, volume, and density and use the information from a computer simulation to design a hot air balloon that will float.

Concepts to be developed:

1. Density is the measurement of the compactness of an object.
2. If an object is less dense than the material around it, it will float.
3. A hot air balloon floats because the components of its design make it less dense than the air around it and it floats because of that density difference.

Skills to be developed:

1. Students will interpret the density of objects compared to air.
2. Students will manipulate variables related to mass and volume.
3. Students will use a flow chart to document their problem-solving strategies.
4. Students will use problem-solving.

Objectives:

1. Students will investigate the variables affecting the volume and mass of a hot-air balloon.
2. Students will use information gained from investigating variables of mass and volume to build a hot-air balloon that floats.
3. Students will complete a flowchart documenting how they determined a satisfactory design using the simulation.
4. Students will work cooperatively in groups to solve a scientific problem.

Materials:

- One helium balloon
- One electrical or battery-operated appliance: lamp, CD player,

For Each Group:

- Materials for building balloons to match those used in computer simulation: tissue paper, garbage bags, newsprint/Ziploc bags, newspaper
- Patterns for three sizes of 3–dimensional objects (sphere, rectangular prisms, and pyramid) to match the size and shape of the options available in the computer simulation.
- Sterno can
- Various building tools: Tape of various kinds, scissors, rulers, glue, etc.
- One sticky note per student

Safety Procedures: Students will be cutting materials with scissors. Balloons will be launched outside using sterno cans. Close adult supervision is required at all times.

Procedure

Foundation:

1. Release the helium balloon in front of the students. Ask them why it floats on the ceiling (because it is less dense than air, the gas helium is less dense than the mixture of gases that make up the air in our classroom). Ask students how a balloon floating is different than an airplane flying. (A balloon "floats" because the heat source makes the air inside the balloon less dense so the balloon can float up through it while an airplane flies because its design and the lift of its engines make it aerodynamic) Tell students that they will be building a balloon that will also be less dense than air. Ask students what variables can affect the density of a hot-air balloon (mass and volume).
2. Give each student a sticky note and have them think of a specific part of constructing a hot air balloon that would relate to the mass or volume of that balloon. Example: how heavy the basket is, how many people it would carry, how big the balloon is, what shape it is. List the headings Mass and Volume on the board. Have students put their ideas on the board under the appropriate column. If the fact that air density changes with elevation has not been discussed make sure that it is included as a variable under volume.
3. Discuss the variables as a class and move sticky notes around as necessary to reinforce the concepts of mass and volume. Remind students that in order for something to float above something else, it must be less dense than the object it floats. Tell students that to simplify the building process and increase the chances of success they will only have a few variables to work with.
4. Ask students how engineers build a bridge or a building. Through discussion, have students understand that first a design of the bridge or building is made when the need for the bridge/building is determined, then the design and materials for the bridge/building are tested, and then the bridge/building is actually constructed. Engineers do not just make things from scratch, so neither will they. To make sure that they don't build a balloon that doesn't fly there is a simulation program they can work with first. This will be like an engineer's test phase.

Simulation:

1. Show students the selected appliance. Inform students that you have discovered that it does not work and ask students what you should do to find out why. Guide students toward answers that suggest testing some aspect of how it works, not just why it does not work. After soliciting lots of suggestions, decide on one aspect to test first. Show students the flowchart diagram, either on the board or on an overhead, and put the first question in first box.
2. Return to the list of mass and volume variables that has been generated by the class and remove each one that is controlled by the simulation. Review with students that the heat source, the amount of heat added, the weight of the basket and passengers, and any wind or weather factors are assumed to be constant by the simulation. Review with students that the simulation will prompt the user for the local elevation in meters which will be used to determine the target air density. Review with students that they will be able to experiment with four different

shapes, sizes, and materials for construction of a balloon and have them talk about how varying each one might affect the ability of their balloon to float.

3. Allow students, working in groups of 3-4, to access the java applet on their computers (or demonstrate on one classroom computer.) Let students work through the program trying the different variables. When they find a combination of variables that work in simulation, allow them to print their results. They now have a description of what to build. Students should record their design process to determine a successful design on the provided sheet.
4. The calculations, formulas, and constants used by the simulation are included as Appendix 1. If teachers will be having their students construct balloons using the same dimensions as the simulation, they may wish to prepare templates for the students to trace.

Construction:

1. When students have identified their final design, they should gather their materials and begin building. They should be working in their design groups which are now the test groups. The building should take 1-2 class periods.
2. When all groups are finished take the students outside for Launch Day. Discuss the density of air (this was calculated in the java applet). Ask to students what the density of air inside their balloons must be in order for them to fly. Light the sterno cans for groups one at a time. The balloons should be able to fly. Teachers may wish to choose a different heat source to better suit the needs of the class and the location of the flights. The risk of fires started by a floating, flaming tissue paper balloon should be adequately assessed by each teacher for their individual situation! Perhaps some teachers would like to experiment with balloons constructed only from flame retardant materials!
3. After the flights have students complete the testing portion of their Engineering Process Report worksheet.

Evaluation:

1. Students will be evaluated on the completion of the java applet simulation and of the flowchart showing how the variables were tested.
2. Students will be evaluated on their problem solving skills and group cooperation during the building process by self-reflection and teacher observation.
3. Students will be evaluated on their analysis of success of their balloon flight and of their understanding of the design, test, and construct process on the Engineering Process Form.
4. Students will be evaluated on their self-evaluation of their learning using the simulation and construction process and how this process is used by engineers.

Extension:

1. The simulation/construction process utilized in this lesson has students constructing their balloons from a pre-determined size with pre-determined materials. Students do not need to calculate either the volume of the balloon shape or the mass of the materials and enclosed air in order to make a density determination.

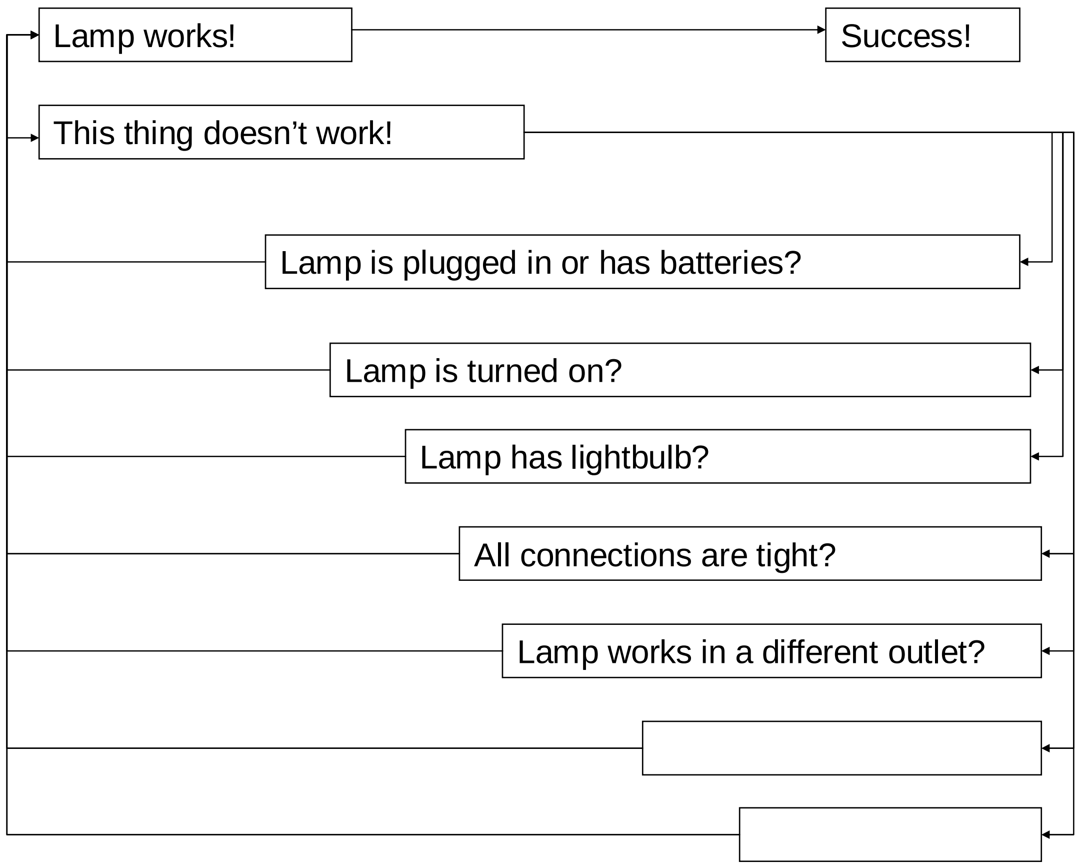
2. A possible extension would be to have students truly design their own balloon shape, using the simulation values as parameters for success, and present the calculations to determine whether or not the balloon should fly before testing.

Differentiated Instruction techniques:

- Clearly state essential questions
- Continuous assessment and feedback
- Adjust content, process, and product in response to student readiness and learning profiles
    - Shortened and modified assignments
    - Time extensions allowed
    - Use of resource room
    - Notes and/or extra time allowed on tests
- Students and teachers collaborate in learning
- Goals for maximum growth and individual success are established and maintained
- Student ability grouping strategies are used in cooperative learning activities
- Stations are used in allowing for different students to work on different tasks
- Tiered activities are used to focus on essential understandings and skills at different levels of complexity, abstractness and open-endedness

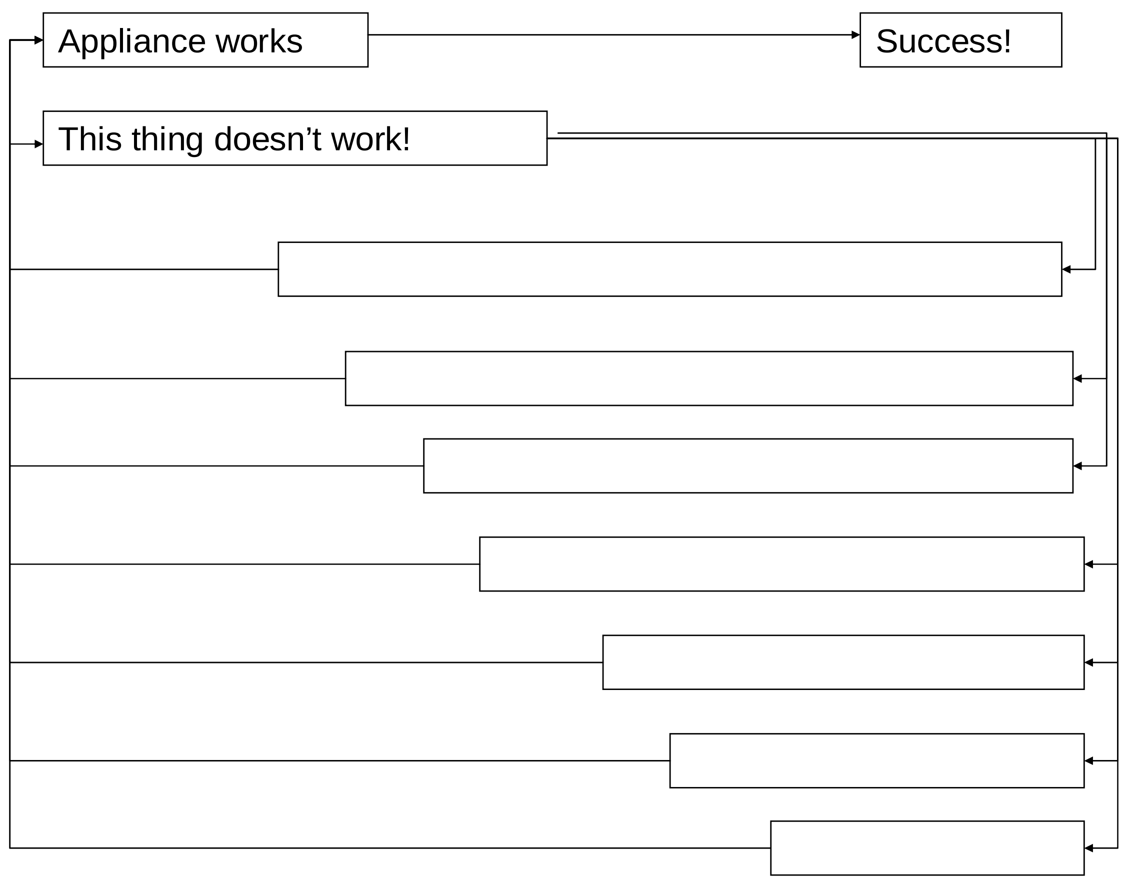
Name ____________________________ Date _________ Per. _____

Broken Item Flow Charts



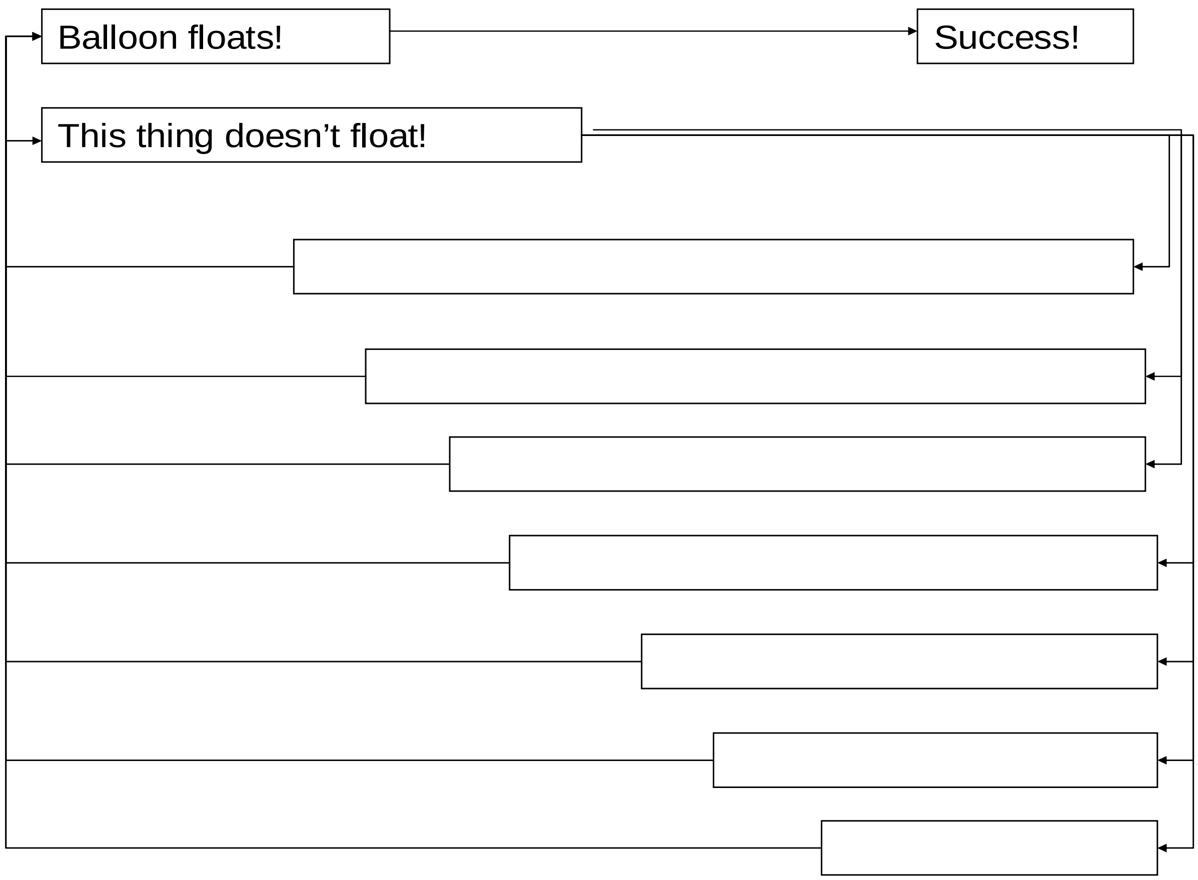
Name ______________________________ Date __________ Per. _____

Appliance Flow Chart



Name ______________________________ Date __________ Per. _____

Balloon Flow Chart



Engineering Process Report:

Balloon Design:

Based on your results from the computer simulation, what designs of balloon do you think will be successful? Circle your choices.

Sphere	S	Tissue Paper
Rectangular Prism	M	Garbage Bag
Pyramid	L	Newsprint
	XL	Newspaper

Explain in terms of density why you think this design will be successful?

Test Results:

Did your balloon successfully float?

What are some variables in the construction process that might have affected the success of your balloon test?

If your balloon did not float, what could you do to find out why it didn't float?

If your balloon did fly, what one variable would you like to change to see if it would still float?

Analysis:

What did you learn about the design, test, and construct processes of engineering from doing this unit? How would you have made a hot air balloon if you had not had the simulation to help you? How will you be a better engineer because of this experience?

Assessment Instruments for Data Collection:

Choose the best answer:

1. The mathematical formula to use when calculating the density of an object is:

a) volume divided by mass
b) mass times volume
c) mass plus volume
d) mass divided by volume

2. Which of the following statements is true about a bottle containing liquids that appear to be stacked?

a) the liquid at the top is the most dense
b) the liquid at the top is the least dense
c) the liquid have the same volume
d) the liquids have the same density

3. Which of the following is not a part of the water cycle?

a) Condensation
b) Evaporation
c) Decomposition
d) Precipitation

4. The density of water is 1 gm/ml. An object has a mass of 58 grams. What volume must it have in order to float in water?

a) 45 ml
b) 50 ml
c) 55 ml
d) 60 ml

5. Within the water cycle, water vapor rises back into the atmosphere because

a) the water vapor is less dense than the surrounding air
b) the water vapor is denser than the surrounding air.
c) the water vapor is the same density as the surrounding air.
d) the water vapor is decomposed in a chemical reaction.

6. Your friends at your lunch table all have different stuff in their lunch. Liquid A has a density of 1.07 gms/ml, Liquid B has a density of 0.98 gms/ml, Solid C has a density of 1.12 gms/cc, and Mush D has a density of 1 gm/cc. You decide to make a gross combination of the four in your water bottle. Which order will they appear in, from bottom to top?

a) Solid C, Mush D, Liquid A, and Liquid B on top?
b) Solid C, Mush D, Liquid B, and Liquid A on top?
c) Solid C, Liquid A, Mush D, and Liquid B on top?
c) Liquid A, Liquid B, Solid C, and Mush D on top?

Mark each statement as True or False

1. _____ The liquids with the highest density floated at the top of the bottle.
2. _____ The correct metric unit for density of a liquid is grams/milliliter.
3. _____ The weight of an object and its mass are always the same.
4. _____ The air pressure at higher elevation is the same as the air at sea level.
5. _____ When designing a hot air balloon, the mass of the balloon must also include the weight of the air inside the balloon.
6. _____ The densities of pure water, salt water and sugar water are always the same.

Answer each question using complete sentences.

1. Describe two ways to calculate the density of an object.
2. Explain why the liquids in a salad dressing bottle settled back into the same order after they were shaken up.
3. Give an example of three objects that are close to the same size but very different in density.
4. Explain how the property of density allows water to be recycled through the water cycle.
5. Explain why pumice floats while a rock of similar size will sink in the same tank of water.
6. Explain why it is easier for a person to float while swimming in the Great Salt Lake than it is at Lake Tahoe.

Scenario: Your class is placed in charge of designing a hot air balloon to fly in the Balloon Races next fall. List, draw, or describe all of the things you would have to take into consideration. What information would you need to collect about what materials to use, what shape the balloon should be, and how big it could be? What other factors would you want to get more information about?

Assessment Instruments for Data Collection:

Choose the best answer:

1. The mathematical formula to use when calculating the density of an object is:
   e) volume divided by mass
   f) mass times volume
   g) mass plus volume
   d) mass divided by volume

2. Which of the following statements is true about a bottle containing liquids that appear to be stacked?
   e) the liquid at the top is the most dense
   f) the liquid at the top is the least dense
   g) the liquid have the same volume
   h) the liquids have the same density

3. Which of the following is not a part of the water cycle?
   e) Condensation
   f) Evaporation
   g) Decomposition
   h) Precipitation

4. The density of water is 1 gm/ml. An object has a mass of 58 grams. What volume must it have in order to float in water?
   e) 45 ml
   f) 50 ml
   g) 55 ml
   h) 60 ml

5. Within the water cycle, water vapor rises back into the atmosphere because
   e) the water vapor is less dense than the surrounding air
   f) the water vapor is more dense than the surrounding air.
   g) the water vapor is the same density as the surrounding air.
   h) the water vapor is decomposed in a chemical reaction.

6. Your friends at your lunch table all have different stuff in their lunch. Liquid A has a density of 1.07 gms/ml, Liquid B has a density of 0.98 gms/ml, Solid C has a density of 1.12 gms/cc, and Mush D has a density of 1 gm/cc. You decide to make a gross combination of the four in your water bottle. Which order will they appear in, from bottom to top?
   a) Solid C, Mush D, Liquid A, and Liquid B on top?
   b) Solid C, Mush D, Liquid B, and Liquid A on top?
   c) Solid C, Liquid A, Mush D, and Liquid B on top?
   c) Liquid A, Liquid B, Solid C, and Mush D on top?

Mark each statement as True or False

7. ______ The liquids with the highest density floated at the top of the bottle. (F)
8. ______ The correct metric unit for density of a liquid is grams/milliliter. (T)
9. ______ The weight of an object and its mass are always the same. (F)
10. ______ The air at higher elevation is the same as the air at sea level. (F)
11. ______ When designing a hot air balloon, the mass of the balloon must also include the weight of the air inside the balloon. (T)
12. ______ The densities of pure water, salt water and sugar water are always the same. (F)

Answer each question using complete sentences.

7. Describe at least two ways to calculate the density of an object.

   Measuring the mass using a scale or beam balance and measuring the volume by measuring the length, width, and height of a regularly-shaped object.
   Measuring the mass using a scale or beam balance and measuring the volume by seeing how much water is displaced when the object is put in a graduated cylinder.

8. Give an example of three objects that are close to the same size but very different in density.

   Pool ball, ping pong ball, and bouncy ball or cubes from lesson one…or their own example.

9. Explain why the liquids in the salad dressing bottle settled back into the same order after they were shaken up.

   One liquid is less dense than another and so it floats on top. The liquids are immiscible and do not mix.

10. Explain why pumice floats while a rock of similar size will sink in the same tank of water.

    Pumice floats because the holes formed by the gas bubbles escaping provide space for air pockets so that the overall density of the rock is less than that of water.

11. Explain why it is easier for a person to float while swimming in the Great Salt Lake than it is at Lake Tahoe.

    A person can float easier in the Great Salt Lake than in Lake Tahoe because the water in the Great Salt Lake is denser so it can hold up the same person better.

12. Explain how the property of density allows water to be recycled through the water cycle.

    When water evaporates, the water vapor is less dense than the surrounding air and rises. After the water condenses and forms clouds, the water droplets become denser than the surrounding air and fall as precipitation.

Scenario: Your class is placed in charge of designing a hot air balloon to fly in the Balloon Races next fall. List, draw, or describe all of the things you would have to take into consideration. What information would you need to collect about what materials to use, what shape the balloon should be, and how big it could be? What other factors would you want to get more information about?

Interview Protocol

1. How would you define density?

2. Give an example of how density affects you in real life, or how you see it at work in the real world.

3. How do we measure mass?

4. Explain why a hot air balloon floats.

5. Using the concept of density, explain why it is important to shake up your Italian salad dressing.

6. Pretend you go on a camping trip and open your cooler to find that all of the labels have come off of your soda bottles. Without opening the bottles to taste them, how can you tell which ones are diet and which ones are regular?

7. What is the relationship between mass, volume and density?

8. Which learning activity most helped you understand the concept of density?

Appendix 1: Explanation of the Simulation

Here is an explanation of what the simulation actually calculates and the formulas to back up the work.

1. The user enters the local elevation in meters. That value is part of a calculation to determine the density of air at any given location. This density value will become the target density for the balloon design configuration.

Air Density (D) = 1.226 – (1.194×10^{-4})*elevation

2. The user may choose one each of the following design options.

Shape	Size	Material
Sphere	S	Tissue Paper
Rectangular Prism	M	Garbage Bag
Pyramid	L	Newsprint
	XL	Newspaper

3. The simulation will calculate the volume of the balloon based on provided dimensions and formulas.

Volume of a Sphere: $4/3\ \Pi\ r^{2}$ Surface Area: $4\ \Pi\ r^{2}$

Dimensions of Given Spheres:
S: r = 5 cm
M: r = 10 cm
L: r = 15 cm
XL: r = 20 cm

Volume of a Rectangular Prism: L x W x H Surface Area: 2(LW + LH + WH)

Dimensions of Given Rectangular Prisms:
S: 10 cm x 10 cm x 15 cm
M: 15 cm x 15 cm x 20 cm
L: 20 cm x 20 cm x 25 cm
XL: 20 cm x 20 cm x 30 cm

Volume of a Pyramid: $\frac{1}{3}b^2h$ where h is the height of the center of the pyramid.
Surface Area of a Pyramid: $b^2 + 2bh$ where height is the height of the side of the pyramid

	Base	Height	Side Height
S:	7 cm	24 cm	25 cm
M:	10 cm	24 cm	26 cm
L:	15 cm	20 cm	25 cm
XL:	20 cm	30 cm	36 cm

3. Next the simulation should calculate the mass of the material used to make the balloon by multiplying the surface area of the balloon by the factors for each of the materials. The spreadsheet converts these to gms/cm^3 by dividing by 100 so that the units agree with the volume calculations.

Tissue paper:	8 gms/m^3
Garbage bag:	16 gms/m^3
Newsprint:	32 gms/m^3
Polyester	32 gms/m^3
Newspaper:	48 gms/m^3
Cotton	80 gms/m^3
Brown grocery bag:	128 gms/m^3

4. After the simulation calculates the volume of the balloon, then that volume of air is multiplied by the density determined based on elevation and then by 0.93 as the heating will reduce the density by 7%. This value is the mass of the air inside the balloon.

5. The mass of the material and the mass of the air make up the total mass of the balloon.

6. The total mass divided by the volume give the density of the balloon design configuration, with the affect of the heat source taken into consideration as the density of the air inside the balloon was reduced by 7%. If the balloon density is less than the air density at that elevation, in theory, the balloon should float.