Middle School Lesson Plans

Last updated 8/10/2009

Skill Set 1:
Science and Engineering

MESA Mathematics Engineering Science Achievement

Lesson Activity

Title	**Air Pressure Egg Plop (45-60 minutes)**
ID Number	MS-S-A1
Sequence and Duration	• Lead In: 10 minutes • Body Molecules: 10-15 minutes • Inflating Balloon: 10 minutes • Egg Plop: 10-15 minutes • Closure: 5-10 minutes
Age Level	Middle School
Essential Question	**How does air exert a force?**
Learning Objectives	• TSW act out the motion of cool and warm air molecules. • TSW predict and observe the behavior of a balloon/bottle setup in warm and cool water. • TSW predict and observe the behavior of an egg/bottle setup. • TSW apply their understanding of air pressure to devise a means to remove an egg from a bottle. • TSW draw diagrams to represent their understanding of the phenomena they observe.
Other Objectives	• TSW engage in a discussion about air molecules and air pressure. • TSW communicate with the group to develop a cooperative environment.
Key Terms	• Air pressure • Equalize • Dense • High pressure • Low pressure
Materials Needed	Teacher Demonstration – Inflating Balloon: • Shallow, heat-safe pan • Burner • Balloon • Glass bottle • Oven mitt and potholder • Second shallow pan (optional) Activity – Egg Plop: • Hard-boiled egg • Napkin • Jar or bottle with opening a little too small to let the egg pass through • Match (or lighter for the whole group) • Scrap or strip of paper to burn (4” by 4” is sufficient) Per Student: • Handout: Air Pressure Egg Plop worksheet
Lead In	1. Ask the students if they’ve ever flown in a plane or driven up and down mountains. Did they notice something funny happening in their ears? What happens? [Ears pop or feel plugged up.] What is it that makes this happen to your ears? Let the students discuss their experiences and talk about their ideas for why this happens. 2. Tell the students that when they change elevation quickly, like when they drive or fly to high altitudes, their ears experience a change in *air pressure*. Air pressure is the force exerted by air molecules as they move. It is often referred to as the “weight” of air, but it acts on surfaces in all directions. Have students hold their hands out flat in front of them. Can they feel the air pressure? Why not? [Because the force downward on the top of their hand is equal to the force upward on the bottom of their hand. 3. The air pressure at high altitudes is less than the air pressure closer to sea level, because the air is thinner. When you quickly rise to a high altitude, what happens to your ear? [Higher pressure air inside your ear pushes out on your ear drum more than the lower pressure air outside your ear pushes in.] When your ears “pop”, what happens? [Some of

	the high pressure air escapes, equalizing the pressure. If students want to know more about this, check out: http://www.physlink.com/Education/AskExperts/ae37.cfm.] 4. What does it mean to *equalize* pressure? [Equalize means to make even or equal, or to return to a balance. In terms of your ears, it means that the air pressure is the same on both sides of your ear drum.] 5. Ask students to think about other times when they might experience changes in air pressure. Allow them a few minutes to discuss.
Activity - Body Molecules	1. Ask the students if they know what happens when air heats up. [It rises.] Why does it rise? [Because it becomes less dense.] What does it mean for the air to be less *dense*? [Being less dense means the number of air molecules per unit of volume has gone down; there are fewer air molecules in a given volume than there were. Since air molecules don't "go away", this means the air molecules are spreading out into a larger volume.] 2. What makes the air molecules spread out? Ask the students to discuss their ideas. Help guide students' explanation; the heating of the air means that the air molecules are receiving an increase in energy. This energy increases the molecules' speed. Note: If applicable, remind students of their previous learning about kinetic energy, for instance if they have done the roller coaster activity. 3. Clear an open but contained space large enough for all students to move around in (e.g. a ring of desks or a walled-off section of the room, cleared of obstacles). Have the students stand in this space. 4. Tell the students they are air molecules in motion. Have them start walking slowly in straight lines; they should bounce off each other or the walls when they collide. When they hit the walls, they are giving them a force; this force is air pressure. 5. Now tell the students that heat energy has been added to their system. What will happen to their speed? [Their speed will increase, which increases the number of collisions they have with each other and the walls. Make sure the students do this safely without hurting each other or damaging anything.] 6. Have the students return to their desks. Ask them what they noticed from doing this activity. Which scenario represented cooler air, the first one or the second one? [The first one, when they were moving more slowly.] Which one represented warmer air? [The second one, when heat was added and they moved more quickly.] 7. During which scenario did the air have more volume? Why? [The volumes were the same in each scenario; the molecules took up the whole space both times. This is because the space was contained. If the space had been open, the warmer molecules would have spread out quickly, becoming less dense.] 8. During which scenario was the air pressure higher? Why? [The pressure was higher when the molecules were warmer, in the second scenario, because the molecules had more energy and bounced into the walls more often.]
Teacher Demonstration - Inflating Balloon	1. Heat an inch or two of water in the shallow pan on the burner. 2. Stretch the mouth of the balloon over the lip of the bottle. Ask the student what they predict will happen when you place the bottle in the pan of hot water. 3. Place the bottle in the pan for a few minutes and have the students watch what happens to the balloon. 4. Remove the bottle from the pan using the oven mitt and place it on the potholder or other heat-safe surface. Have the students predict what will happen to the balloon. Note: For a faster reaction, place the bottle into a second pan filled with cool water. 5. Ask the students to explain what happened. Why did the balloon inflate when the bottle was in the warm water? [The air in the bottle heated up and began moving around faster, increasing the air pressure inside the bottle. The air pushed its way into the balloon, and the high air pressure pushed against the sides of the balloon, inflating it.] 6. Why did the balloon deflate when the bottle was removed from the hot water? [The air cooled and slowed down, decreasing the air pressure inside the bottle and balloon. The air contracted, becoming denser.]
Activity - Egg Plop	1. Give each group of students a hard-boiled egg and a napkin. Tell them to peel their egg, being careful not to break it. [You can also peel the eggs before class if you have the time.] Meanwhile, hand out a bottle and scrap of paper to each group and an Air Pressure

	Egg Plop worksheet to each student. 2. Have the students crumple their paper so it will easily drop into the mouth of the bottle when dropped. 3. Show the students how you will light the paper and drop it into the bottle, and they will quickly place the eggs onto the bottles with the small end pointing down. The egg should *loosely* seal the bottle's opening. 4. On their worksheets, have them predict what will happen when the paper is lit and the egg placed on the bottle. 5. Walk around to each group lighting the paper scraps with the matches or lighter and dropping them into the bottles. As soon as the paper is in the bottle, have the students put the egg on the bottle neck, small side down. Tell them to then leave the setup alone and watch what happens to the egg. [Hands off while the experiment is in progress!]
Closure	1. Give the students time to think and talk about what happened and write their explanations on their worksheets. 2. After 4-5 minutes, have the students discuss their ideas with the whole group. How did the egg get into the bottle? [The fire added heat energy to the air in the bottle, and the air molecules sped up and increased the air pressure in the bottle. Some of the air escaped from under the egg; the students may observe the egg wobbling as the air pushes out from under it. When the air cools, the air molecules slow down and the pressure decreases, and because some air escaped there is now less air pressure than when the experiment started. The pressure outside the bottle is now greater than the pressure inside the bottle, so there is a greater force DOWN on the egg from the air outside than there is UP on the egg from the air inside. The force down pushes the egg into the bottle.] 3. Challenge the students to come up with a way to get the egg out of the bottle. If they have trouble coming up with a way, have them review what they did to get the egg in there: they changed the air pressure on one side so the force on one side was greater than the force on the other. How can they make the force from the inside greater than the force on the outside? [Either they can decrease the air pressure in the room – that would be difficult! – or they can increase the air pressure in the jar. They can do this by forcing air into the jar by blowing into it or pumping in air with a bike pump, e.g. The egg will need to seal the opening so the air can't escape. They'll have to be quick and strategic, and watch out for flying eggs!] 4. Have the students clean up their materials. 5. Give the students time to complete their worksheets. Once completed, have students discuss the final question on their worksheets, "How does air exert a force?"
Informal Assessment	• Monitor students for participation in activities. • Monitor students for participation in discussions.
Formal Assessment	• Completed worksheet. • Egg successfully retrieved from bottle.
Trouble Shooting	• Keep an eye on students' behavior during the body molecule activity. You may want to select a subset of students to act out the scenario if you have a large group. • Try the egg and bottle experiment ahead of time on your own to get a feel for how the setup will work. • Greasing the eggs with vegetable oil will make it easier to get them in and out of the bottles. • Juice and iced tea bottles (e.g. Sobe, Tropicana) work well for this experiment. Smaller bottles tend to work better. • The bottle does not need to be glass; the burning paper will not typically be hot enough to melt plastic. If you use plastic bottles that you don't mind destroying, the students can make a small hole in one end of the bottle and blow the egg out of the bottle using a straw. • You may want to show the students how to draw force diagrams on their worksheets, using arrows to indicate the direction and strength of the forces on the egg. In the "before" diagram, draw arrows, of all the same length, pushing on the egg from all sides. This represents equalized air pressure. Arrows on opposite sides of the egg cancel out, so the egg does not experience any net force from air pressure. In the "after" diagram, draw the other arrows as before, but draw the one pointing up from the bottom as shorter than the others. While all the other arrows cancel out, the down arrow is bigger than the

	up arrow, so the egg experiences a net force downward. Drawing these diagrams together may help the students visualize what's happening to the egg. • For the sake of completeness, you may want to add arrows to the force diagrams representing the force of gravity in the downward direction and the force of the bottle in the upward direction (by Newton's 3rd law). Because these forces are equal and in opposite directions, they cancel out and the egg is in equilibrium.
Citation	• Inflating Balloon: Ken Kakasuleff, Frankton Elementary School, http://www.grc.nasa.gov/WWW/K-12/Summer_Training/FranktonES/Convection_main_page.html • Egg Plop: Air Quality Planning & Assessment Division, Office of Air Quality, http://www.reachoutmichigan.org/funexperiments/agesubject/lessons/tnrcc/airpressurelesson.html

SEI Strategies Used

Preparation	Scaffolding	Grouping Options
☐ Adaptation of Content	☐ Modeling	☒ Whole class
☒ Links to Background	☐ Guided practice	☐ Small groups
☒ Links to Past Learning	☐ Independent practice	☒ Partners
☒ Strategies incorporated	☐ Comprehensible input	☐ Independent
Integration of Processes	**Application**	**Assessment**
☒ Reading	☒ Hands-on	☒ Individual
☒ Writing	☒ Meaningful	☒ Group
☒ Speaking	☒ Linked to objectives	☒ Written
☒ Listening	☒ Promotes engagement	☐ Oral

Arizona Math Standards Addressed	(none)
Arizona Science Standards Addressed	• S1C1: TSW formulate predictions, questions or hypotheses based on observations. • S5C1: TSW understand physical, chemical, and atomic properties of matter. • S5C2: TSW understand the relationship between force and motion.

Air Pressure Egg Plop

 

The First Experiment

1. What do you think will happen when the paper is lit?

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2. Describe what you saw happen when the paper was lit.

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3. Why do you think that happened?

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4. Draw a before-and-after diagram that explains what happened to the egg when the paper was lit.

The Second Experiment

5. Explain what you did to release the egg.

6. Draw a before-and-after diagram to explain how the egg was released.

After the Experiment

7. How does air exert a force?

Lesson Activity

Title	**The Air We Breathe (55-65 minutes)**
ID Number	MS-S-A2
Sequence and Duration	• Lead In: 15 minutes • Activity: 35-40 minutes • Closure: 5-10 minutes
Age Level	Middle School
Essential Question	**What's in the air we breathe?**
Learning Objectives	• TSW identify components of air by observing a Petri dish through a microscope. • TSW come up with an estimation strategy to estimate the number of particles on the dish. • TSW apply what they have learned about air and breathing to defend their opinions about breathing through the mouth or nose.
Other Objectives	• TSW watch and listen to a short film about the respiratory system. • TSW engage in group discussions about both breathing and estimation strategies. • TSW record observations through writing and drawings.
Key Terms	• Air • Particle • Respiratory system • Estimation
Materials Needed	Per Class: • Petroleum jelly • Computer, with projector, connected to the internet Per Team: • Petri dish with grid on the bottom • Microscope • Handout: What's In the Dish? Per Student: • Handout: Air Particles
Preparation	6. At least a week prior to this session, prepare the Petri dishes by spreading a very thin layer of petroleum jelly on the bottom of each one. Place the dishes in safe locations indoors (e.g. a windowsill) and outdoors (e.g. a balcony) where they can collect particulate matter for a week or more.
Lead In	1. Take a poll of the students: Who thinks it's better to breathe through your mouth? Who thinks it's better to breathe through your nose? 2. Ask the students what they know about why and what we breathe. (E.g. we breathe air into our lungs to take in oxygen and we breathe out to release carbon dioxide; there is oxygen and carbon dioxide in the air, as well as other gases.) 3. Show the students the Respiratory System animation at BrainPOP.com. 4. Ask the students what they learned from this film that they didn't know before. 5. Ask, the students, did you know that oxygen only makes up about a fifth (21%) of air's composition? What else is in the air we breathe? 6. Tell the students that today they will take a microscopic look at some of the things in air.
Activity	9. Break students into groups of four. Hand out the "What's in the Dish?" worksheets. 10. Tell the students that each group will use a microscope to examine a Petri dish that you set up to collect particles from the air. They will use estimation strategies to estimate the number of large, medium and small particles in the whole dish. 11. Ask the students why it might be better to estimate the number of particles instead of just counting. (Because it would take a lot of time to count all the particles on the whole dish using the microscope.) Have the students brainstorm ways to come up with an educated estimate. Discuss possible strategies. [For instance, have each student observe and count the particles in one square and have students find average particle counts per square, then multiply by the number of squares (or total

	area of the Petri dish in square centimeters).] 12. Have the students implement their plans, or the plan devised by the whole group by consensus. Give the students 20 minutes to complete their observations and data collection. Circulate through the groups to assist where needed. 13. When the students have finished making observations, have them clean up their materials and work spaces. 14. Give the students 5-10 minutes to come up with their estimates of the number of large, medium and small particles in their Petri dishes. Assist where needed. 15. Have the students share their estimates in a group discussion. How do the estimates compare? Did the estimates of particles in Petri dishes from similar locations turn out to be similar? Do the dishes from certain locations have noticeably more or fewer particles than those from other locations? Why might that be? (E.g. location was in an area of greater or lesser air flow, or near a source of certain particles such as animal hair or exhaust.)
Closure	6. Ask if the students were surprised to see the kinds of things that are floating around in the air. Did they ever think that they might be breathing in things like insect wings, eyelashes, sweater lint and dust? What other things might be in the air that they can't see through a microscope? (E.g. pollutants.) 7. Hand out the Air Particles worksheet to each student and give them one or two minutes to complete the activity and read the summary questions. Give them two minutes to discuss the questions with a partner. 8. Take another poll: Who thinks it's better to breathe through your mouth? Your nose? Why? Encourage a whole-group discussion about the summary questions. What did the students learn from this activity that influenced their decision?
Informal Assessment	• Monitor students' participation in group discussions. • Monitor students' participation in activity.
Formal Assessment	• Completed What's In the Dish? handout. • Assess students' arguments for their opinions in the post-activity poll.
Trouble Shooting	• The Respiratory System animation is available at http://www.brainpop.com/health/seeall/. BrainPOP is a subscription service, but you can view the video for free with a five-day trial subscription.
Citation	• Adapted from Thinkport.org, "Every Breath You Take." http://www.thinkport.org/Tools/ContentViewer/ContentPreview.aspx?ContentID=6836e981-60de-4f7a-b000-9d6feb09acc0

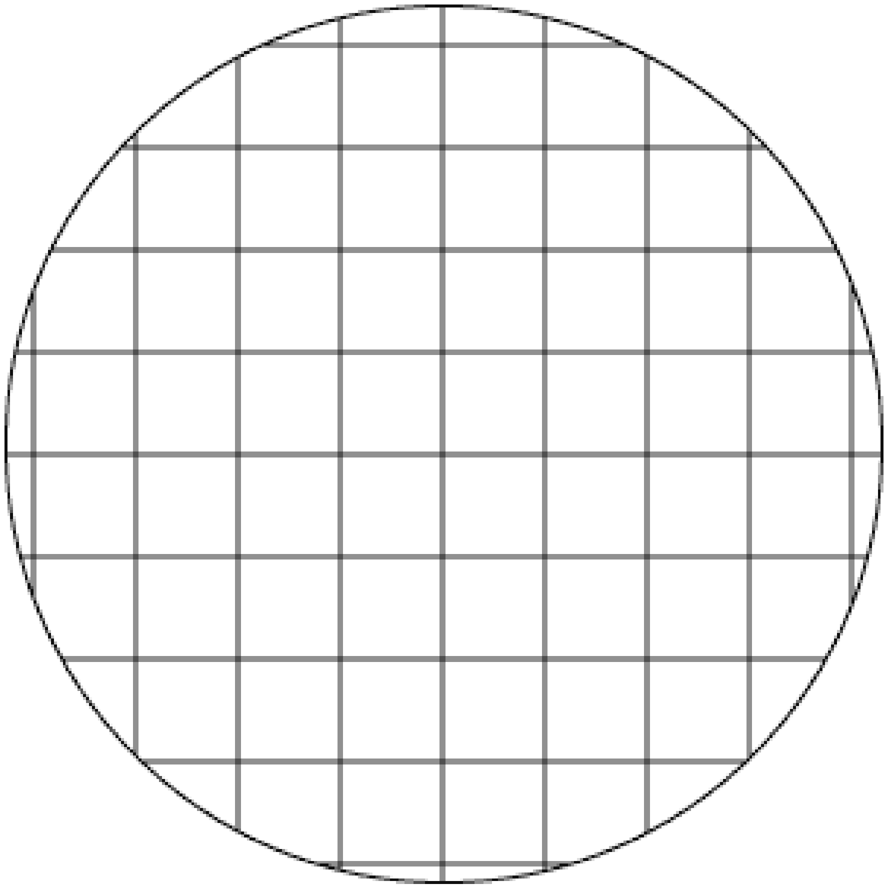
SEI Strategies Used

Preparation	Scaffolding	Grouping Options
☐ Adaptation of Content	☐ Modeling	☒ Whole class
☐ Links to Background	☒ Guided practice	☒ Small groups
☒ Links to Past Learning	☒ Independent practice	☐ Partners
☐ Strategies incorporated	☒ Comprehensible input	☐ Independent
Integration of Processes	**Application**	**Assessment**
☐ Reading	☒ Hands-on	☐ Individual
☐ Writing	☒ Meaningful	☒ Group
☒ Speaking	☒ Linked to objectives	☒ Written
☒ Listening	☒ Promotes engagement	☒ Oral

Arizona Math Standards Addressed	• S1C2: TSW understand and apply numerical operations and their relationship to one another. • S1C3: TSW use estimation strategies reasonably and fluently.
Arizona Science Standards Addressed	• S1C2: TSW design and conduct controlled investigations. • S1C3: TSW analyze and interpret data to explain correlations and results.

What's in the Dish?

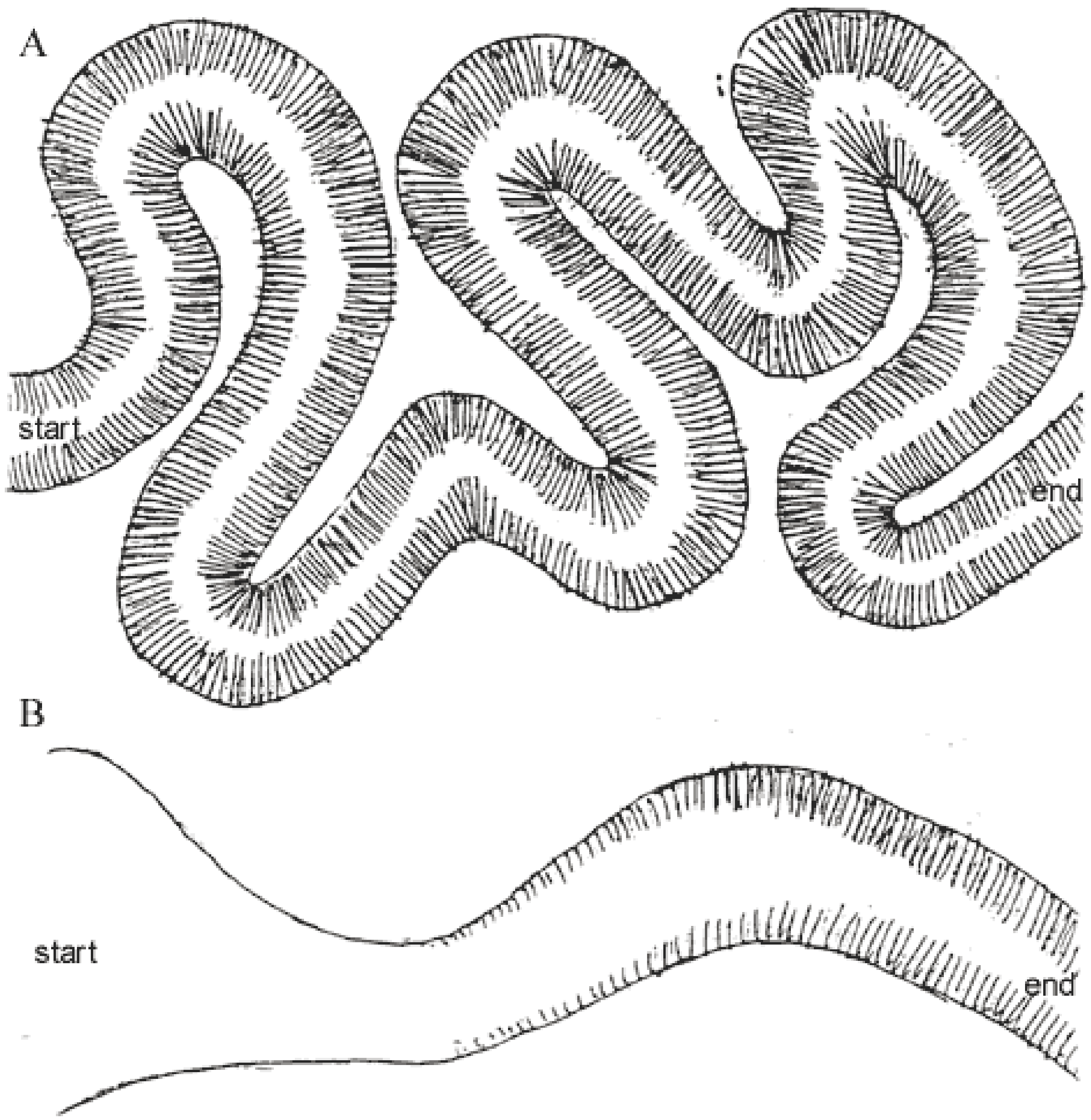
Directions:
In the circle below, sketch your observations of particulate matter captured in the Petri dish. Record information about the number of particles each group member observes, and include descriptions where needed.



	Number of Particles by Size			**Description**
	Smallest	**Medium**	**Largest**	
Group member:				
Group member:				
Group member:				
Group member:				

Air Particles

Directions:
Imagine that your pencil point is a small particle. With your pencil, try drawing a line from start to finish in each passage below. Do this as fast as you can without letting your "particle" get "caught" by crossing any lines or touching the sides.



Which diagram (A or B) represents the nasal passages, and which represents the mouth?

What does this say about whether it’s better to breathe through your nose or your mouth?

Mathematics Engineering Science Achievement (MESA)

Lesson Activity

Title	**Asphalt Cookies (40-50 minutes)**
ID Number	MS-S-A3
Sequence and Duration	• Lead In: 5 minutes • Activity: 25-30 minutes • Closure: 10-15 minutes
Age Level	Middle School
Essential Question	**How is making asphalt similar to making a no-bake chocolate cookie?**
Learning Objectives	• TSW identify the steps and materials involved in preparing asphalt. • TSW make a "chocolate asphalt cookie". • TSW compare and contrast the process of making the cookie with the process of making asphalt. • TSW predict the characteristics of chocolate "asphalt" made with different combinations of material.
Other Objectives	• TSW participate in discussions about the civil engineering and the properties of asphalt. • TSW listen to and follow verbal instructions.
Key Terms	• Asphalt • Civil engineering • Phase change • Properties • Aggregate • Binder
Materials Needed	Per Class: • Medium pot • Burner • Crock pot • Extension cord, if necessary • Large wooden spoon • Ladle • Measuring cups (1/4, 1/3, 1/2, 1 cup measures) • Measuring spoons (tablespoon measure) • Non-stick spray (optional) • 1/4 cup serving binder (see below) • 1 square foot of wax paper Per Batch of Binder (enough for 8 1/4-cup servings; double or triple as necessary) • 1/3 cup cocoa powder or carob • 1/2 cup milk • 1 stick of butter • 2 cups sugar Per Student: • 1/8 cup old fashioned oats • 1/8 cup quick oats • 1 tablespoon chopped nuts • 1 tablespoon flaked or shredded coconut • Steep-sided bowl or large paper cup • Sturdy spoons • 2 pieces of wax paper, each 1 square foot • Rolling pin or other heavy cylinder (e.g. sealed 16 oz. canned good) • Handout: Picture of Bitumen • Handout: Pictures of Aggregates • Handout: Pictures of Asphalt
Lead In	7. Ask the students if they've ever thought about all the products designed by

	engineers that they use every day and probably take for granted. What are some examples of such products? (E.g. cars, toasters, elevators, air conditioners.) 8. Ask the students, what about other products that you may have never thought of as being engineered? (E.g. soda pop-tops, door locks, sneaker soles, window panes.) 9. Did anyone think of asphalt (pavement)? Ask the students, what is asphalt engineered to do? What properties must it have? (E.g. it must be strong enough to withstand the weight of cars and trucks; it must be able to endure the weather conditions of the area where it is used; it must be pourable when wet but solid when dry, etc.) 10. What kind of engineer would be involved in developing and testing asphalt? You can have students try to find the answer using the internet, or tell them that it is civil engineers that work with asphalt. Civil engineers work in a variety of areas of construction, from buildings and bridges to highways and sewers. 11. Tell the students that today they will learn about how civil engineers have developed asphalt to best serve its purpose, and simulate the process of making and laying asphalt themselves.
Activity	16. Ask the students if they know what asphalt is made of. They may say that it is made of tar. If so, tell them they are partly correct: tar was an ingredient used to make asphalt in the past. Today the main ingredient is bitumen. Bitumen is very tar-like in how it looks and behaves, but is a form of petroleum while tar comes from coal. Handout the picture of bitumen and ask students to describe it and talk about its characteristics. What does it look like? What properties does it appear to have? 17. Tell the students that the class' first goal is to simulate bitumen. Bring out your pot and spoon and the ingredients for the chocolate. Gather the students around your burner, making sure they are a safe distance away. Have the students help you measure out the ingredients for enough bitumen for each of you (a 1/4 cup per student and a 1/4 cup for the demonstration). Pour the ingredients into the pot and heat until boiling, stirring frequently. Allow the mixture to boil for two minutes. 18. While you are preparing the "bitumen," tell the students that bitumen is naturally-occurring in the Earth, and as they might have noticed when they looked at the picture, it looks and behaves a lot like melted chocolate. Have the students observe the properties of the chocolate at various times as it cooks. 19. After two minutes of boiling, carefully pour the bitumen into the crock pot and turn the heat to high. Ladle out a scant quarter cup of the mixture onto a square of wax paper and have the students observe (without touching!) the change in properties as the chocolate cools. Bitumen behaves the same way; it hardens as it cools. Students may recognize this as a phase change: the mixture is liquid when it is hot enough, and becomes solid when it is cool enough. 20. When the chocolate is fully cooled, one or two student volunteers can handle it to explore its properties as a solid. Would this bitumen simulation make good pavement? Why not? (It's brittle, falls apart easily, would crack if laid over a curved surface, etc.) Have students return to their seats. 21. Tell the students that asphalt is actually a combination of two types of materials: aggregates and binder. Aggregates are particles of various sizes that are added to the asphalt to give it strength and durability. Binder is the material that sticks everything together. Which of these two types of material do students think bitumen is? (Binder.) 22. Tell the students that aggregates are classified by the size of their particles, from coarse (big particles) to very fine (small, dust-like particles). Civil engineers experiment with adding different types of aggregates in different amounts to produce asphalts with properties that are suited to the environments in which they'll be used. 23. Hand out the Pictures of Aggregates and two pieces of wax paper; have

	students make observations of the aggregates while you portion out the "aggregate" ingredients in small individual piles on their wax paper. Have the students compare and contrast their ingredients with the rock aggregates while you pass out the bowls/cups, spoons and rolling pins. 24. Ask the student to think about what it would be like to try to mix large quantities of bitumen with large quantities of rock particles. (It would be really difficult!) How do they think engineers solved this problem? They use machines to mix the asphalt ingredients. Hand out the Asphalt Pictures and have students examine the picture of the drum roller. The whole drum of the machine rolls to mix the ingredients. Does this machine look like anything familiar? (Students may notice similarities between the drum roller and a cement truck, or a large kitchen mixer.) The students will be acting as drum rollers for their small quantities of chocolate asphalt. 25. Have the students restate what the purpose of adding aggregates to binder is. (To strengthen the asphalt.) Ask the students to predict what properties their chocolate asphalt will have when it is mixed with the aggregate ingredients. 26. Have the students pour their aggregates into their mixing bowls or cups. 27. Tell the students that they will form a line with their cups at the crock pot, where you will pour some binder into their aggregates. They will start stirring immediately to mix the aggregates and binder together as they return to their seats. When they have the ingredients well-mixed, they will pour the mixture out onto one square of wax paper and cover it with the other square, then roll it out until it is flat. They will be creating their own small patch of pavement. 28. When you are sure that students know what to do, begin the procedure. Pour scant 1/4-cup servings of the chocolate into students' mixing bowls or cups, making sure all students stay a safe distance from the burner and don't touch the hot chocolate mixture. 29. As students are rolling out their mixtures, ask them if they've ever seen asphalt being rolled out in this same way. (How about in cartoons!) Asphalt is rolled into a thin mat by a heavy roller that pushes the air out and makes the pavement very strong. Tell the students to roll their asphalt out to about a quarter-inch thickness. Can they still identify all the ingredients in the mixture? 30. Have students place their hand over the tops of their pavement. Can they feel the heat? Asphalt is also still hot when it is first rolled out. Like the asphalt, this simulated pavement will harden as it cools.
Closure	9. When the asphalt cookies have hardened, have students investigate their properties. How do the students' predictions match up with what they observe? 10. Ask the students to hypothesize about how the cookies' properties would be different if they used different quantities of aggregates. What would make them harder? Softer? Less breakable? More flexible? 11. Tell the students that civil engineers test the properties of asphalt in small amounts. Have them look at the asphalt samples on the Pictures of Asphalt sheet. How do students think their simulated asphalt is similar to or different from real asphalt? (E.g. the chocolate will melt again when just a little heat is applied to it, while bitumen does not become liquid until it reaches 300 degrees Fahrenheit.) 12. Ask the students to consider in what way(s) is the engineering design process is similar to the scientific process. 13. Fully cooling the cookies until they are hard can take up to half an hour; you can have students leave the cookies to harden over night so they can explore them next time, or have them take the cookies home with them at the end of class.
Informal Assessment	• Monitor students for participation in discussions. • Monitor students' attention to the steps of the procedure.
Formal Assessment	• Completed cookie.
Trouble Shooting	• Before beginning this activity, be sure you are aware of any allergies your

	students have, especially severe nut allergies. Substitute ingredients with similar properties if need be (e.g. carob for chocolate, granola or raisins for nuts). You could even pose the need to substitute ingredients to your class as an engineering challenge. • If you have sufficient ingredients and large enough pots, you could make enough chocolate binder for students to have two portions each, so they can compare the properties of "asphalt" with and without "aggregates." • Having one or two student volunteers to help pass out the ingredients and other tools will make this process quicker and less stressful for everyone.
Citation	• Joanna Ambroz, Society of Women Engineers. (1995). Chocolate Asphalt Cookies. http://www.swe.org/iac/lp/asphalt_02.html.

SEI Strategies Used

Preparation
- ☐ Adaptation of Content
- ☒ Links to Background
- ☒ Links to Past Learning
- ☒ Strategies incorporated

Scaffolding
- ☒ Modeling
- ☒ Guided practice
- ☐ Independent practice
- ☒ Comprehensible input

Grouping Options
- ☒ Whole class
- ☐ Small groups
- ☐ Partners
- ☒ Independent

Integration of Processes
- ☐ Reading
- ☐ Writing
- ☒ Speaking
- ☒ Listening

Application
- ☒ Hands-on
- ☒ Meaningful
- ☒ Linked to objectives
- ☒ Promotes engagement

Assessment
- ☐ Individual
- ☒ Group
- ☐ Written
- ☒ Oral

Arizona Math Standards Addressed	(none)
Arizona Science Standards Addressed	• S1C1: TSW formulate predictions, questions, or hypotheses based on observations. • S1C2: TSW design and conduct controlled investigations. • S2C1: TSW identify individual, cultural, and technological contributions to scientific knowledge. • S5C1: TSW understand physical and chemical properties of matter.

Picture of Bitumen

Source: http://www.soci.org/SCI/groups/cmt/2006/reports/html/gs3730.jsp

Pictures of Aggregates

1/4" or smaller particles

1/2"' particles

3/4" particles

3/4" particles

Source: http://www.swe.org/iac/LP/asphalt_gallery.html

Pictures of Asphalt

Asphalt Drum Mixer
Source: http://obr.gcnpublishing.com/articles/mar06e.htm

Asphalt samples

Asphalt samples

Source: http://www.swe.org/iac/LP/asphalt_gallery.html

Lesson Activity

Title	**Balloon Rocket Cars (2 sessions, 60-80 minutes)**
ID Number	MS-S-C1
Sequence and Duration	Session 1: Background and Exploration • Lead In: 15-20 minutes • Initial Launch: 20-25 minutes • Investigation: 25-35 minutes Session 2: Testing • Testing: 30-40 minutes • Science Conference: 20-25 minutes • Closure: 10-15 minutes
Age Level	Middle School
Essential Question	**What variables affect how fast and how far a balloon rocket car travels?**
Learning Objectives	• TSW build a balloon rocket car to specs. • TSW design investigations to test variables related to the rocket's speed and distance. • TSW collect and analyze data from their investigation. • TSW communicate the results of their investigation to their classmates.
Other Objectives	• TSW develop a working plan with their group to develop a cooperative environment. • TSW communicate with their group by contributing their vocal input. • TSW write down the procedure they used to investigate the effect of their chosen variable. • TSW listen to their peers discuss the results of their investigation. • TSW contribute to a group discussion about the optimum characteristics of a balloon rocket car.
Key Terms	• Newton's 3rd Law: for every force, there is an equal force in the opposite direction. • Pressure: force per unit area. • Force: a push or a pull. • Chassis: body of a rocket. • Nozzle: opening from which gases to escape from a rocket. • Optimize: to make as effective or useful as possible.
Materials Needed	Per Class: • Extra materials: tape, straws, clay, bottle caps, skewers, balloons • Other materials students may want to try: tubing, larger bottle caps or lids, bottles of different sizes, other materials you have available • Meter sticks or tape measures • Stopwatches Per Team (Include a set for teacher demo): • Handout: Balloon Rocket Car Instructions • Handout: MESA Notebook • 1 plastic water bottle, 16-20 oz., empty • 5 drinking straws • 2 wooden skewers • 4 bottle caps • 1 balloon • roll of duct or masking tape • small nail

	• hammer • scissors • pea-sized ball of clay (optional) • scissors • ruler • small square of cardboard or foam board to protect surfaces
Session 1	**Background and Exploration**
Lead In	1. Ask students what they remember about Newton's 3rd Law. When did they learn about this before? [If you have done the Newton's Scooters activity, students may remember learning about Newton's Laws then.] What does Newton's 3rd Law say about forces? [Every action has an equal and opposite reaction, or every force is paired with an equal force in the opposite direction.] What does this have to do with the motion of an object? [If an object pushes on an object, whatever it is pushing on pushes *back* in the opposite direction. Unbalanced forces cause acceleration, so the object will accelerate in the direction of the force.] Have students explain Newton's 3rd Law in their own words and write this in their MESA Notebooks. 2. Ask students what Newton's 3rd Law has to do with rockets. What makes rockets move through space? [The rocket's fuel exhaust is pushed out of the rocket by the pressure inside the rocket; the rocket pushes the fuel gases out and in turn, the gases push back on the rocket, causing it to accelerate.] Note: It is a common misconception that rockets push against the *ground* when they take off, and that the ground pushes the rocket up to space. If this were the case, rockets would not be able to accelerate in space, because there would be no ground to push off from. This activity, in which the rockets clearly are NOT pushing against the ground, can help students confront this misconception. 3. Tell the students that in this activity they will be building balloon rocket cars. What do they think will make these rockets move? [Letting out the air in the balloons will push the rockets forward.] What does this have to do with Newton's 3rd Law? [The balloon pushes out on the air, and the air pushes back against the balloon. If the rocket is attached to the balloon, it will move with the balloon.] 4. Explain that the air in the balloon is under *pressure*. What does it mean to be under pressure? Allow students time to explain and give examples in their own words. [Sample definitions: to be pressed on, to be pushed against from all sides. Possible examples: pressure cooker, geysers, deep-sea animals, a student whose parents want her to get really good grades!] When you blow up a balloon, the air you put inside pushes against the inside of the balloon, which expands as its skin stretches. [Note: If students are familiar with the concept, you could introduce this as an example of potential energy.] The balloon wants to go back to its un-stretched state, so it constantly pushes back against the air, putting the air under pressure. This is why the air comes out so quickly when a balloon is opened up, and why the balloon zooms around as the escaping air pushes it all over the place! 5. Ask the students what they might want to investigate about how their rockets move. [E.g. how fast they go, how far they go, how long a time they travel, how quickly they accelerate, how many empty water bottles they can knock over, etc.] Note: How quickly and how far the cars travel are the inquiries emphasized for the purposes of this lesson plan, but accept all answers and be willing to pursue any that seem viable. 6. Explain that there are a number of variables that can affect their rocket cars' performances. Their task as a class will be to investigate ways to *optimize* these variables – that is, to make them as beneficial as possible for the purpose chosen. [For instance, if the purpose was to travel the furthest, what are the optimal characteristics of the cars that make them travel the furthest?] Engineers conduct experiments to determine the optimal characteristics for the products they design.

Initial Launch	1. State that in order to look at the variables that affect the cars' motion, each team needs a rocket car to examine. You will build your rocket cars together as a class, and launch one to observe its performance. 2. Get students into groups of 3 or 4 and hand out the supplies. Hand out the instructions for building the cars and walk through them with the students. Assist them as they build their cars. 3. Have the students gather their rocket cars and bring them to an open space clear of passers-by. Encourage students to ask questions, such as, what would happen if the cars had two balloons? What if the bottle had water in it? How many wheels are necessary? Tell students to keep these questions in mind for later. 4. Tell students to observe what happens as the rocket cars take off. Have one student from each group blow up the balloons and pinch the neck to keep the air from escaping. Have the other students fall back to a safe distance while the students with the rockets line up and launch their rocket cars. Draw students' attention to how far the rockets go and how fast they travel. If there are differences in terrain (i.e. some rockets launch on the pavement and some on the grass), have students make note of any differences in these rockets' performance.
Investigation	1. Gather students back in the classroom. Allow time for a brief discussion of what students observed when the rockets launched. 2. Remind students of their ideas for investigations about the rocket cars, and solicit questions that the students came up with during the initial launch. Remind them that there are numerous variables affecting the rocket's journey, and that their mission as a class is to decide what the purpose of the rocket car should be and try to optimize those variables. What are some of the variables? [examples: size and shape of chassis, amount of air in balloon, width of nozzle, number of wheels, type of axle, roughness of launching surface, etc.] In what ways can the variables be varied? How can the class test the influence of those variables? 3. Tell the students that their class is a community of scientists studying the rocket car. Each group will work independently, but ultimately, in order to best understand the optimal rocket car, all groups will need to share their results with everyone else. The class will decide which variable(s) are the most important to investigate and each group will choose one (or more) and design their investigation. After all groups have completed their investigations, they will share the information they gathered by communicating their results to the whole class in a science conference setting. 4. Give the students the amount of time that they will have to run their investigations (e.g. half of the next class session). Guide a discussion in which students come to an agreement about the best way to make use of their time with the number of groups they have. Do they have a shared opinion of the purpose for the rocket car? How many variables will they test? How many investigations will each team have time to do? Do some investigations need more time than others? If necessary, lead students to an understanding that only one variable can be tested at a time or it won't be possible to know which variable is having the greatest effect on the dependent variable [the purpose of the rocket car as determined by the class or team]. 5. With the remaining class time, students should prepare their investigations. They must be completely prepared to begin testing in the next session, so they must come up with hypotheses, procedures, data sheets, and a plan for communicating the results of their investigation to the class (e.g. with graphs, charts or drawings). Students can use their MESA Notebooks to organize their investigations.
Session 2	**Data Collection and Communication**
Testing	1. Allow students to make use of the allotted time to conduct their investigations. Ensure that proper safety precautions are taken every time a rocket car is launched.

	2. Make sure students are faithfully collecting data. Remind them to record their units. 3. When a group is finished testing, they can begin organizing and analyzing their data and/or assisting other groups with their launches. No group should be without something to do. 4. Although groups will vary in the amount of time it takes them to complete their data collection, do not allow any group to linger too long over their investigation at the expense of preparing to report out to the class. When the time for testing is up, make sure that all groups move on to communicating their data.
Science Conference	1. Give students sufficient time to pull their materials together, then have groups present the results of their investigations to the whole class. Allow the class to ask questions of the group. 2. After each group's presentation, write a conclusion statement on the board that reflects the group's results (provided by the group with the assistance of the rest of the class), for instance "Results indicate that ten breaths in the balloon is optimal for making the fastest rocket car." 3. Discuss the results of testing. Which rocket cars went the furthest or the fastest? What were the features of this rocket that made it so successful? What did other groups try? Allow time for discussion and debate, particularly if students' results seem to be in conflict with each other (e.g. if ten breaths is good for a fast car but 15 is better for knocking down obstacles). What features made these rocket cars successful or not so successful? 4. Ask groups to consider other variables that might be affecting the rocket's success that the class did not test. What kind of impact might these variables have on the groups' rocket cars? 5. Emphasize that all conclusions are tentative; the class' results are a good start, but further testing may lead to even better, more precise results. 6. Ask the students to consider, if they wanted to build the "best" rocket car, what features would it have?
Closure	1. In their MESA Notebooks, have students respond to this conclusion question (or a similar question more aligned with the class' activities): *What variables affect how fast and how far a balloon rocket car travels?* 2. Students can use the remaining time to finish their Notebooks with their groups, or they can finish them as homework.
Informal Assessment	• Monitor students' understanding of Newton's 3rd Law through discussion and questioning. • Monitor students' understanding of experimentation and control of variables during the Investigation phase. • Monitor students' participation in discussions and group work.
Formal Assessment	• Completed investigation materials: hypothesis, procedures, data collection instruments, data charts, etc. • Presentations of groups' investigation results. • Completed balloon rocket cars. • Completed MESA Notebooks.
Trouble Shooting	• Start collecting and encouraging students to collect bottles and bottle caps for this lesson well ahead of time. You will need one bottle for the teacher demo and one for each group, as well as several extras in the case that the class decides to build additional rocket cars during their experimentation. You'll need an even larger number of bottle caps, roughly one for each student if you have groups of four, plus additional caps for experimenting. • Prior to class, build a rocket car yourself so you know how the components fit together before trying it with the students. • Have duplicate materials as well as additional materials with which the students can experiment. You may also want to prepare for the possibility that students will want to experiment with ramps (a plank and a stack of textbooks would work), knocking down obstacles (perhaps markers stood on their ends), or redesigning the rocket car's design (e.g. by using a 2-liter bottle instead of a

	16 oz. bottle). As ever, feel free to improvise! • Don't worry if a rocket car doesn't work the first time! Allow students to troubleshoot with you. Is the seal with the nozzle tight enough? Are wheels aligned properly? Is the rocket car's weight unbalanced for any reason? Mistakes are opportunities for learning. • Students may be at a loss to draw conclusions from their data. Encourage them to try different means of demonstrating the relationship between variables. Some students may find that their results do not follow a linear pattern; encourage them to consider other possible relationships – the data may more closely fit a parabola.
Extensions	• If students get excited about conducting more investigations about their rockets, consider adding an additional class period(s) for testing their ideas. Assess students' interest to decide if this lesson should be extended; there are a great number of investigations that students can conduct if they wish.
Citation	Home Training Tools, http://www.hometrainingtools.com/articles/balloon-rocket-car-project.html

SEI Strategies Used

Preparation
- ☐ Adaptation of Content
- ☐ Links to Background
- ☒ Links to Past Learning
- ☒ Strategies incorporated

Scaffolding
- ☒ Modeling
- ☒ Guided practice
- ☒ Independent practice
- ☐ Comprehensible input

Grouping Options
- ☒ Whole class
- ☒ Small groups
- ☐ Partners
- ☐ Independent

Integration of Processes
- ☒ Reading
- ☒ Writing
- ☒ Speaking
- ☒ Listening

Application
- ☒ Hands-on
- ☒ Meaningful
- ☒ Linked to objectives
- ☒ Promotes engagement

Assessment
- ☐ Individual
- ☒ Group
- ☒ Written
- ☒ Oral

Arizona Math Standards Addressed	• S2C1: TSW understand and apply data collection, organization and representation to analyze and sort data.
Arizona Science Standards Addressed	• S1C1: TSW formulate predictions, questions, or hypotheses based on observations and evaluate appropriate resources. • S1C2: TSW design and conduct controlled investigations. • S1C3: TSW evaluate experimental design, analyze data to explain results and propose further investigations. • S1C4: TSW communicate results of investigations. • S5C2: TSW analyze relationships between forces and motion, using Newton's 3rd Law to explain forces as interactions between bodies.

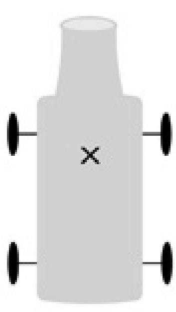
Balloon Rocket Car – Instructions

Materials:

Plastic water bottle
5 drinking straws
2 wooden skewers
4 bottle caps
Balloon
Piece of cardboard
Clay
Tape
Nail
Hammer
Scissors
Rule

Instructions:

1. The water bottle will be the *chassis*, or body, of the car. The wheels and rocket engine (balloon) will be attached to the chassis.
2. Next, you'll add two tubes, made from straws, that your car's wheel axles will go through. Measure the width of your water bottle. Cut two lengths of straw as long as the width of your water bottle. (You should be able to use one straw to make two axles.) Use strips of tape to attach the straws to the chassis, one at the front and one toward the back. Make sure you line them up as straight as possible so your wheels won't be crooked!
3. The bottle caps will be your wheels. Tap a hole through the center of each bottle cap using the hammer and nail. Use the cardboard to protect the table by placing it under the bottle cap you're working with.
4. The skewers will be your axles. Cut two lengths of skewer about 1.5 inches longer than you cut the straws. Thread the skewers through the straws and attach the wheels to the ends. If the caps don't fit snugly on the skewers, add a little modeling clay to hold them in place.
5. Make sure your car rolls smoothly. Make adjustments if necessary.
6. Prepare the balloon by stretching it out with your hands and blowing it up and deflating it a few times.
7. Create a *nozzle*, or opening, for the balloon out of straws. Tape 4 straws together in a bundle and insert them into the mouth of the balloon. Create a seal of tape around the balloon's mouth so air can only escape through the straws.
8. Next you'll need to mount the balloon on the car. *Carefully*, cut an "X" on the top of the car about 4 inches from the bottle's mouth. Poke the nozzle through the "X" and out the mouth of the bottle. Leave about an inch of the nozzle sticking out of the bottle. If necessary, tape the nozzle around the "X" to secure it.



Your rocket car is ready for testing

MESA Mathematics Engineering Science Achievement

Lesson Activity

Title	**Barbie Bungee (75-80 minutes)**
ID Number	MS-M-A1
Sequence and Duration	• Lead In (15-20 minutes) • Activity (45-50 minutes) • Closure (10 minutes)
Age Level	Middle School
Essential Question	**What is the maximum number of rubber bands that will allow Barbie to safely jump from a height of 400 cm?**
Learning Objectives	• TSW collect data on the distance Barbie falls. • TSW graph the distance versus the number of rubber bands used to make the bungee cord. • TSW generate a line of best fit to determine the relationship between the distance and the number of rubber bands. • TSW extrapolate from their lines of best fit the number of rubber bands needed to drop Barbie safely from 400 cm.
Other Objectives	• TSW communicate with their group by contributing their vocal input. • TSW write down and graph data. • TSW contribute to a group discussion about extrapolating from a small set of data.
Key Terms	• Scatter plot • Linear relationship • Line of best fit • Extrapolate
Materials Needed	Per Class: • Extra bags of identical rubber bands in case of breakage, loss, etc., and for building the final bungee cords • Extra graph paper Per Team: • 15-20 rubber bands, all alike, handing out 12 to start • 1 Barbie doll or doll/action figure of a similar size (all teams should have figures of identical or similar masses) • 6-inch piece of masking tape • Meter stick or tape measure • Calculator Per Student: • Handout: Barbie Bungee Activity Sheet • One piece of unbroken spaghetti • One or two pieces of graph paper • Handout: Scatter Plots • Handout: Linear Relationships – Line of Best Fit worksheet
Lead In	12. Ask students if they've ever done a bungee jump, or know anyone who has. What do they think it's like to fall like that and be caught by a bungee cord? 13. If you have access to the internet, show students the bungee jump video clip at http://www.extremeworld.com/attractions/bungee_jump/video.aspx. You can also show the video of a group of South Pacific islanders' jumping ritual at http://news.nationalgeographic.com/news/2005/11/1109_051109_video_landdive.html. [Note: Preview videos prior to showing to class.] Have the students compare the two set-ups. How does what the villagers experience differ from

	what a bungee jumper experiences? 14. Ask, what are the properties of a bungee cord that make it the material of choice for this kind of activity? [E.g. its strength, its elasticity, its length] How might these properties affect the jumper's experience? [The stretchiness of the bungee, combined with its length, affect how far the jumper will fall. The stretchier the bungee is, the more it will extend when the jumper falls, and the further the jumper will fall. Likewise, the longer the bungee is, the further the jumper will fall.] 15. Tell students that each group is a bungee jumping company. A very rich potential client, Barbie, is shopping for the thrill of a lifetime, and she wants a bungee jumping company that is concerned with her safety but able to provide as much excitement as possible. Ask students what their companies will need to consider when preparing to serve this customer. [She wants a big thrill, so they should get her as close to the floor as possible, but for her safety she needs to be far enough from the floor that she doesn't hit it and get hurt or killed.] 16. The students' mission will be to run an experiment to test bungee cord lengths (made of rubber bands) and collect data, so that they can come up with a prediction about what length Barbie's bungee cord should be so she can drop safely, but thrillingly!, from a 400 cm height. They will need to discover the relationship between the number of rubber bands and the distance that Barbie falls.
Activity	31. Have students get into groups of 3 or 4. Hand out the Activity Sheets to each student and a Barbie and two rubber bands to each group. Read through the instructions together, allowing time for students to make their predictions on page 1, and ensuring that students understand the procedure before they begin. Focus especially on the reason for taking data for three trials at each length and averaging [to have as accurate a final number as possible]. 32. Show students how to make a slipknot with the rubber bands (see Activity Sheet) and how to wrap the first rubber band around Barbie's feet. 33. Hand out the remaining materials to each group. Make sure each group has a space from which to drop their Barbie without interfering with other groups. 34. Give students approximately twenty minutes to complete their data collection. Circulate among the groups to ensure that students are measuring distances properly and recording data accurately. 35. When students are done collecting data, they should compute averages from the three trials at each cord length, then plot the points on graph paper or the graph area provided. 36. Tell students that they are making a *scatter plot*. Hand out the Scatter Plot handout. Show students that a scatter plot is a *plot* (or graph) on which points are *scattered*. (That is, they're not connected with a line like a game of connect-the-dots!) Scatter plots are good for telling if there's a relationship between two variables. Sometimes the points make a pattern; if that happens, you can tell there's a relationship between them. Ask students if any of the graphs on the handout look like they have a pattern [the second and third plots]. Ask if they can come up with any pairs of variables that they would expect to show a relationship like this [e.g. shoe size and height; number of calories eaten and weight; age and number of gray hairs]. 37. If the points are randomly scattered on the graph, with no pattern, you can conclude that there is no relationship between the two variables. Which of the graphs looks like a plot of two variables with no relationship? [the first one] Ask students to come up with examples of pairs of variables that you would NOT expect to be related [such as shoe size and number of siblings; number of leaves on the ground and number of cars in the parking lot; typing speed and date of birth]. 38. When students have their points plotted, ask if they see a pattern. What is the

	pattern? [diagonal line] Is there relationship between the two variables? [yes] What is the relationship? [As one variable increases, the other increases as well.] When the students are all comfortable with seeing the relationship, tell them that there is a *linear relationship* between the two variables. A linear relationship is one in which the two variables are directly proportional to each other; if you double one variable, the other variable also doubles. This kind of relationship looks like a straight line. 39. Tell students that when there is a linear relationship between the two variables of a scatter plot, you can draw a *line of best fit* that approximates the relationship. The line of best fit is a straight line that falls as close to possible to all the data points; it may or may not go through any of the points students plotted. It is a best-guess representation of the data, and the equation of the line is a best-guess approximation of the relationship between the two variables. 40. Hand out pieces of spaghetti and the Linear Relationships - Line of Best Fit worksheet to students. Have them place the spaghetti on their graphs so that they find a place where it is as close to as many data points as possible. When they have placed it where they think it should go, have them trace the line it makes on their graphs (making sure their spaghetti strand is actually straight!). 41. They can then *extrapolate* (infer other values based on information they have) by projecting their line outward to solve for a value of 400 cm. They can do this by extending their line of best fit out to 400 cm on the x-axis. Students may need extra graph paper to do this. [Note: Students can work individually and come up with their own predictions, but have each group come up with a single prediction to test, in order to save time.] 42. Once the students have their predictions, have them construct their bungee cords for Barbie. 43. Bring all the Barbies and bungees to the 400 cm drop zone. The advisor or other adult should drop all the Barbies one by one while the students observe the results from below.
Closure	• Back in the classroom, discuss the results. Which group got Barbie closest to the ground without getting her *too* close? Were there any surprises? Did any groups vastly under or over-estimate the number of rubber bands that would be needed? What might account for sources of error in groups' predictions?
Informal Assessment	9. Monitor students for participation in activity and discussions. 10. Monitor students' understanding through one-on-one questioning and discussions.
Formal Assessment	• Completed Barbie Bungee data table and graph. • Completed line of best fit and prediction. • Constructed bungee cord for 400 cm drop.
Trouble Shooting	• Set up an area for the 400 cm drop ahead of time. 400 cm is 4 meters, which is approximately thirteen feet. Other heights can be used; choose your drop zone and set the height accordingly. • Try out the experiment yourself and try to determine how many rubber bands are needed for your height, so you will have a gauge for determining approximately how many rubber bands each group will need, and for informally assessing students' predictions.
Extension	• If students are getting the hang of recognizing patterns on a scatter plot, you can talk to them about positive and negative correlations. With a positive correlation, as one variable increases, the other increases as well. This is the case in the third plot on the Scatter Plot handout, and it will be the case for their own plots of rubber bands and distance fallen. With a negative correlation, as one variable increases, the other *decreases*. This is the case in the second plot on the Scatter Plot handout. Have students come up with pairs of variables they would expect to have a negative correlation, such as amount

	spent and amount saved for a given month's salary; temperature and number of people wearing winter coats; or amount of pollution in the air and number of stars you can see in the sky. • If students are comfortable with the idea of a linear relationship, you can introduce the concept of the *non-linear* relationship, where there is a pattern but it cannot be represented by a straight line. A non-linear relationship can be represented by a curved line, such as a parabola or sine function. An example of a non-linear relationship would be hours of sunlight vs. day of the year; the amount of sunlight does not keep increasing with every additional day, but rather increases and decreases as the year progresses. Have students try coming up with other pairs of variables that would have a non-linear relationship, such as amount spent advertising a product and amount of profit; amount of rain and number of flowers in a garden; or temperature and number of joggers in the park. • If students have a familiarity with graphing and algebra, you can have them try to determine their prediction mathematically rather than having them extend the line of best fit manually. See the high school version of this activity (HS-M-A1) for Line of Best Fit worksheet with the mathematical derivation.
Citation	National Council of Teachers of Mathematics, http://illuminations.nctm.org/LessonDetail.aspx?ID=L646

SEI Strategies Used

Preparation
- ☐ Adaptation of Content
- ☐ Links to Background
- ☐ Links to Past Learning
- ☒ Strategies incorporated

Scaffolding
- ☐ Modeling
- ☒ Guided practice
- ☒ Independent practice
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Grouping Options
- ☐ Whole class
- ☒ Small groups
- ☐ Partners
- ☒ Independent

Integration of Processes
- ☒ Reading
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Application
- ☒ Hands-on
- ☒ Meaningful
- ☒ Linked to objectives
- ☒ Promotes engagement

Assessment
- ☒ Individual
- ☒ Group
- ☒ Written
- ☒ Oral

Arizona Math Standards Addressed	• S2C1: Understand and apply data collection, organization and representation to analyze and sort data, including identifying (grade 6, PO6) and interpreting (grade 7, PO7) a trend in data, formulating reasonable predictions based on a set of data (grade 8, PO7), evaluating the effects of missing/incorrect data on the results of an investigation (grade 8, PO 10), and identifying a line of best fit for a scatter plot (grade 8, PO 11). • S3C2: Describe and model functions and their relationships, by describing the rule used in a simple grade-level appropriate function (Grade 5-8, PO 1) and distinguishing between linear and non-linear functions (grade 8, PO 2). • S3C3: Represent and analyze mathematical situations and structures using algebraic representations. • S3C4: Analyze change in a variable over time and in various contexts.
Arizona Science Standards Addressed	• S1C2: Design and conduct controlled investigations. • S1C3: Analyze and interpret data to explain correlations and results; formulate new questions.

Barbie Bungee

Your mission today is to add some excitement to Barbie's life by preparing her for the bungee jump of a lifetime! Barbie will be jumping from a height of 400 cm at the end of the class, and you need to determine how many rubber bands will be needed for her to jump safely from this height. Experiment with the materials you have to determine the relationship between the number of rubber bands and the distance Barbie falls.

Read through all instructions before beginning your experiment!

Overview:

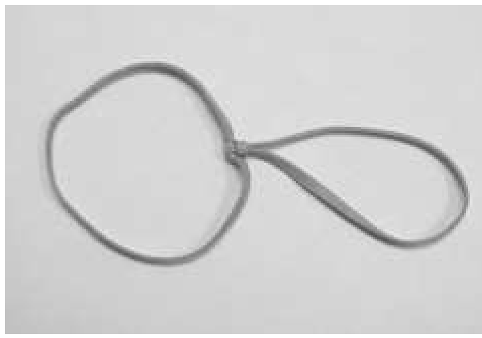
- Measure the distance Barbie falls with a bungee cord of two rubber bands, four rubber bands, six rubber bands, etc. Run three trials for each bungee cord length.
- Average the 3 distances for each cord length.
- Plot the averages on a graph of cord length vs. distance fallen.
- Figure out if there's a relationship between cord length and distance fallen.
- If there is, figure out what cord length (how many rubber bands) you'll need for a distance of 400 cm.

Prediction:

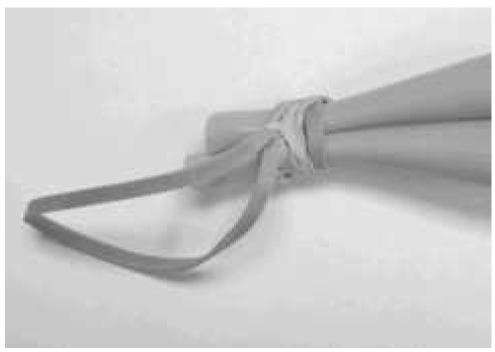
What is the maximum number of rubber bands that will allow Barbie to safely jump from a height of 400 cm? Write your prediction for the number of rubber bands that will be needed: ___________________________

Instructions:

1. Tape a piece of masking tape to the wall at a height of about 6 feet. This is the line from which Barbie will "jump". Try to make sure the line is as level as possible.
2. Connect two rubber bands together with a slip knot.



3. Wrap the open rubber band tightly around Barbie's feet.



4. Attach another rubber band to the first with a slipknot – this now makes two rubber bands for Barbie's bungee cord.

5. One team member will hold the end of the cord to the line with one hand and "stand" Barbie on the line with the other. Member name: ________________

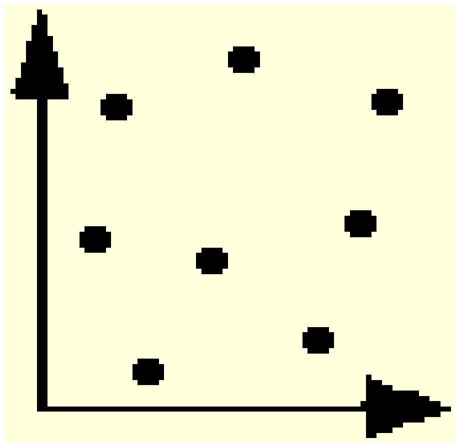
6. Let Barbie fall (head first) from the line while you hold onto the cord.
7. One team member should keep track of the lowest point Barbie reaches when she drops. Member name: _________________
8. Another team member should measure the distance from this point to the line for each drop. Member name: _________________
9. One team member should be in charge of recording this data for the team. Member name: _________________
10. Repeat the drop for three trials at each bungee cord length. (Why?)
11. Add two rubber bands for each new cord length.
12. All team members should fill in the data sheet with the data recorded by the team recorder.
13. Make sure you record your data in centimeters!
14. Find the average jump distance for each bungee cord length.

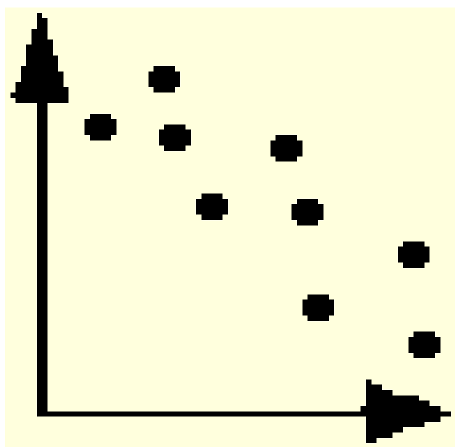
Barbie Bungee Data Sheet

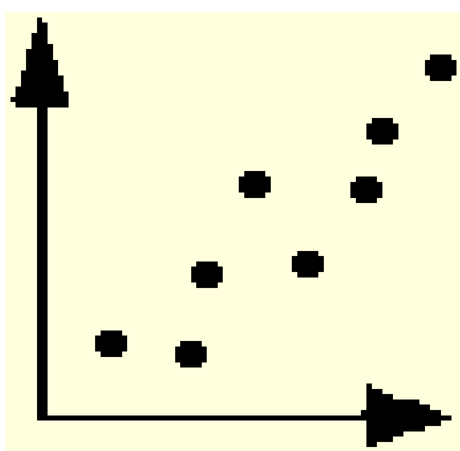
Number of Rubber Bands	Jump Distance – Trial 1 (cm)	Jump Distance – Trial 2 (cm)	Jump Distance – Trial 3 (cm)	Jump Distance - Average (cm)
2				
4				
6				
8				
10				
12				

15. Now create a scatter plot of your data. Make sure to indicate the scale of each axis, and to label your axes.

Scatter Plots

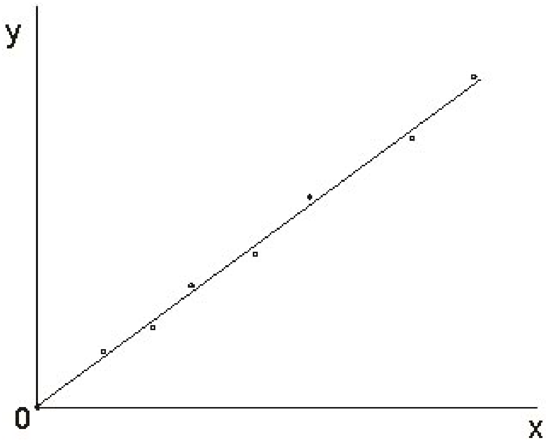






http://quest.nasa.gov/space/frontiers/activities/aeronautics/m.html

<u>Linear Relationships – Line of Best Fit</u>



A line of best fit comes as *close* as possible to *as many* points as possible on a scatter plot. The line of best fit is an *approximation*, or best estimate, of the relationship between the two variables represented by the scatter plot.

The line may or may not actually go through any of your plotted points, and it may or may not go through zero.

Line up your piece of spaghetti on your graph, so it gets as close as possible to your plotted points. When you have it where you want it, trace the line onto your graph. This is your line of best fit!

Mark the x-axis all the way out to 400 cm. If you need more paper, ask your advisor for another piece. Line a ruler up with your line of best fit and extend the line out to 400 cm. Find the point where the line reaches 400 cm on the x-axis. What is the y-coordinate of this point? ____________

How many rubber bands (y) will you need to drop Barbie from a height (x) of 400 cm? Remember that she needs to clear the floor! Should you use a value of exactly 400 cm? Slightly less? Slightly more?

Write your prediction for the length of Barbie's bungee cord: ____________
You'll be able to test your prediction with the class!

Lesson Activity

Title	**Body Astronomy (60-80 minutes)**
ID Number	MS-S-A4
Sequence and Duration	• Lead In: 10-15 minutes • Scale of the Sun/Earth System: 10 minutes • Reasons for Seasons: 35-45 minutes • Closure: 5-10 minutes
Age Level	Middle School
Essential Question	**Why is it warmer in the summer and cooler in the winter?**
Learning Objectives	• TSW describe the distance between the Earth and Sun relative to the scaled sizes of the two bodies. • TSW explain why the following are not good explanations for why we have seasons: the Earth being closer to the Sun; one of the Earth's hemispheres being closer to the Sun. • TSW explain how the Earth's tilt contributes to longer days and more direct sunlight, which result in warmer weather in the summer.
Other Objectives	• TSW engage in kinesthetic activities to learn or relearn basic astronomy concepts. • TSW listen to and follow verbal instructions.
Key Terms	• Kinesthetic • Meridian • Rotation - daily • Orbit - yearly • Tilt • Direct/indirect light
Materials Needed	Scale of the Sun/Earth System: • Softball, or other sphere with a similar diameter • Pen Reasons for Seasons: • Yellow helium balloon or other object to represent the Sun • Map of North America • "Polaris" object (e.g. a large star sticker), mounted high on a north wall • Large white piece of paper or large whiteboard • Flashlight Per Student: • Blank piece of paper for writing • "East" and "West" indicators (e.g. index cards with large black Es and Ws, attached to popsicle sticks)
Lead In	17. Ask the students when they've learned about astronomy in school. What do they know about the seasons? How did they learn it? 18. Hand each student a piece of blank paper, or ask them to take out a notebook. Give them two to four minutes to write their responses to this question: *Why is it warmer in the summer and cooler in the winter?* Tell them they may draw diagrams to assist their explanations if they choose. 19. Ask for volunteers to share their explanations. Accept all answers; ask students to elaborate on their ideas for clarification, but do not comment on whether different explanations are correct or not. It may be useful to list the different ideas on the board for later in the lesson. 20. Tell the students that after today's activity, they will be able to answer the

	question *kinesthetically*, with their bodies.
Scale of the Sun/Earth System	44. Hold up the softball-sized sphere and tell the students that this object will represent the Sun. Ask the students to predict what size the Earth would be if it were at the same scale as this object. Accept all answers. 45. Reveal that the Earth would actually be about the size of a pen tip in comparison to the soft ball. 46. Now have the students predict how far apart these objects should be if their distance was to scale with the Sun/Earth system. Have one student hold the pen and another hold the soft ball and have them move according to the suggestions of their classmates. 47. Tell the students that the two objects would need to be fifty feet apart to be to the proper scale. Have the students either measure out this distance or estimate it by pacing about fifty steps. (You will probably need to go outdoors for this!) Have the two students with the soft ball and pen tip stand at these distances and hold up their objects. 48. Using a loud voice so even the two students standing 50 feet apart can hear you, ask the students to reflect on this scale model of the Earth/Sun system. Are they surprised by the relative sizes and distance? 49. Return to class.
Reasons for Seasons	*Daily Motion of the Earth (10-15 minutes)* 14. Place the Sun object in the center of the room at approximately eye level. A floating yellow helium balloon is even better, but any object representing the Sun that can be seen by all students (e.g. yellow circles taped to the front and back of a chair in the middle of the room) will serve this purpose. 15. Have students stand in a circle around the "Sun." Each student is an "Earth." Their tailbones are the South Pole. Where is the North Pole? (On top of their heads.) 16. If North America is on their fronts and Asia is on their backs, which hand represents East and which hand is West? (East is left and West is right. For students who have trouble, it is useful to have a globe/map for students to hold up to their bodies. If some students are still having difficulty, try having them picture a map of the US on the person across from them. Which side would New York be on? Which side would LA be on?) 17. Tell the students that there is an imaginary line from the top of their heads, down their noses to the floor, which is called the *meridian*; it is the center of their "sky." Have all students face the Sun. What time is it for a person standing on their meridian? (noon) For a person standing on the back of their heads? (midnight) 18. Give the students E and W signs and have them experiment moving so that the Sun rises in their east and sets in their west. (Rotate counter-clockwise.) Assess their understanding by telling students to stand at sunset (West hands pointing to the Sun); sunrise (East hands pointing to the Sun); noon, and midnight. 19. Ask students the meaning of a day. (One complete rotation of the Earth.) Tell them to make a day on their "Earth." *The Earth's Orbit (10-15 minutes)* 1. Ask students if what they've done so far is a good representation of the Earth's motion. Does the Earth move in other ways? How else does it move? 2. Ask students the meaning of a year. (One complete orbit around the Sun.) Have all students make a year for their Earth. (Students should move in a counter-clockwise circle around the Sun and return to the point where they started.) 3. Ask students if this is what the Earth looks like when it orbits the Sun. What should students do to better represent the Earth's motion? (They should be tilted.) Point out an object you've chosen to serve as "Polaris," the North Star

(either an object high off the ground in the north, or the posted sign of Polaris from the Kinesthetic Astronomy kit), and have students tilt toward Polaris.

4. [Optional] The tilt is about 23 degrees, which is roughly half of 45 degrees. Have students try to do a 90 degree tilt, then half of that for 45 degrees, then half of that for 23 degrees.
5. Now, while still tilting toward Polaris, have students go to noon. Have the students look around the room. Does everyone look the same? Why do all the students look different? (Depending on where they are relative to “Polaris,” all students have to bend their bodies differently to tilt toward it. Some students will have to bend forward, some will bend backward, and some will bend sideways.)
6. Keeping their tilts but ignoring the time of day, have students move one quarter of the way around the circle. Now go to noon, keeping the tilt. Ask students, relative to the Sun, are you now in the same position or a different position than you were when you started? (Students will be tilted more toward the Sun or more away from the Sun, depending on their location in the orbit.)
7. Ask the students what effect their positions have on a person living on their North Pole? On your South Pole? (People living on the Poles have opposite tilts from each other (if one is tilted toward the Sun, the other is tilted away from the Sun; whether they are tilted toward or away from the Sun depends on the position in the orbit. If any students are at the location of the equinox, neither person at their poles will be tilted toward or away from the Sun).
8. Ask the students, what affect does your tilt have on a person on your nose? On the back of your head? (People at the same latitude are both tilting the same way, so both of these people experience the same effect.)

Seasons (10-15 minutes)

1. Ask a student who is tilted away from the Sun what season he/she is experiencing. (Winter.) Similarly, ask the same about a student who is tilted toward the Sun. (Summer.) Ask the class to try to explain why these two are experiencing winter and summer.
2. Point out a student whose tilt is neither toward nor away from the Sun. What season is he/she experiencing? (Spring or Fall; this student’s position represents an equinox.) Challenge the students to explain why they think what they think.
3. Ignoring Polaris, ask all students to arrange themselves as if their northern hemisphere is in winter (all tilting away from the Sun). Where does the Sun appear in their sky? (Low, close to their “horizon.”)
4. Now ask all students to arrange themselves in the summer. Where does the Sun appear in the sky? (High in the sky.)
5. Have students experiment with making days when their northern hemisphere is in summer and when it is in winter, paying attention to the motion of the Sun. What differences do they notice? Allow the students to discuss their observations and how they relate to the seasons. In summary, explain how in the winter the sun is lower and moves through less of the sky; it has less time to heat the Earth, making it colder. In the summer it is higher and moves through more of the sky over a longer time, giving it more time to heat the Earth.
6. Ask one student to model summer. Ask the class if the student’s northern hemisphere is closer to the Sun than the southern hemisphere is. (It is.) Ask if this model is to scale. (It’s not!) Remind students about the scale model from earlier in the activity. Would the northern hemisphere of the pen tip be significantly closer to the Sun than the southern hemisphere? (Not at all; this change would not make a difference to a person on Earth.)
7. Give students time to experiment with recreating all the motions of the Earth around the Sun at the same time: the tilt, daily motion and yearly motion.

	8. Monitor the students and ask follow-up questions if necessary in order to assess each student's understanding. *Direct and Indirect Sunlight (5-10 minutes)* 1. Ask students if they learned about direct and indirect sunlight when they learned about seasons. Ask students the meaning of "direct" and "indirect" sunlight. (Students may be unclear as to the meaning of these terms. Direct refers to light coming in nearly perpendicular to the ground, while indirect refers to light coming in at a glancing angle.) 2. Bring the students over to an area with a large piece of paper or whiteboard lying on the floor. Dim the lights and turn on a flashlight. Holding the flashlight at a constant height above the paper, demonstrate how the angle of the light source influences how much of the paper is covered with light, even though the amount of light doesn't change. (Point the flashlight straight down onto the paper for direct light, and tilt it by 30-40 degrees to spread out over the paper for indirect light. It is important to keep the flashlight at roughly the same height when it is displaying direct and indirect light, so you aren't changing the *total amount* of light falling on the paper) 3. Have students draw a line around the brightest spot when the light is direct and again when it is indirect. Which area is larger? (The spot from the indirect light.) For which angle, direct or indirect, is the light being spread out more? (Indirect.) 4. Ask students if you would feel warmer under the small spot of light (direct) or the large spot of light (indirect). (You would feel warmer under the direct light because the light is more concentrated – more light per area). 5. Draw a picture on the board to depict direct and indirect light. Elicit ideas from students about explanations and models they have seen in the past to represent these ideas, and make connections between what the students have seen before and what they now understand about direct and indirect light.
Closure	1. Ask students to explain, in writing or orally, why it is warmer in the summer and cooler in the winter. 2. Teach them the rhyme: "Length of days, angle of rays, nothing to do with farther away!" Ask them to explain the meaning of this rhyme as they would to a younger student. 3. Remind students that it's ok if they were "wrong" at the beginning of the lesson. Tell them that understanding why they thought what they thought *before*, as well as why they think what they think *now*, is a good way for them to understand what they learned today as well as how they might learn other scientific concepts in the future. 4. Give students an opportunity to write if they wish to make changes to what they wrote earlier in the class.
Informal Assessment	11. Monitor students' participation in the activity. 12. Monitor students' participation in discussion.
Formal Assessment	• Monitor students' understanding through the imbedded assessment questions and tasks. • Monitor students' construction of the concept by their explanations in the pre and post writing assignments.
Trouble Shooting	• For print-outs of the direction hand signals and Polaris indicator necessary for this lesson, you can download the materials from the Kinesthetic Astronomy website cited below.
Extensions	• Consider incorporating cultural elements into this lesson, by weaving storytelling into the activity or inviting students or their family/community members to comment on different cultures' understanding of the cycles of the sky. • For a longer term activity, encourage students to collect their observations

	(drawings, descriptions or measurements) of the motion of the Sun over the course of the school year. For instance, students could record qualitative or quantitative data regarding the locations from which the Sun rises or sets and how high it is at noon.
Citation	• Adapted from the "Sky Time" lesson of *Kinesthetic Astronomy*, Dr. Cherilynn Morrow and Michael Zawaski. Available at http://www.spacescience.org/education/extra/kinesthetic_astronomy/index.html.

SEI Strategies Used

Preparation
- ☒ Adaptation of Content
- ☐ Links to Background
- ☒ Links to Past Learning
- ☐ Strategies incorporated

Scaffolding
- ☐ Modeling
- ☒ Guided practice
- ☒ Independent practice
- ☒ Comprehensible input

Grouping Options
- ☒ Whole class
- ☐ Small groups
- ☐ Partners
- ☒ Independent

Integration of Processes
- ☐ Reading
- ☒ Writing
- ☒ Speaking
- ☒ Listening

Application
- ☒ Hands-on
- ☒ Meaningful
- ☒ Linked to objectives
- ☒ Promotes engagement

Assessment
- ☒ Individual
- ☒ Group
- ☒ Written
- ☒ Oral

Arizona Math Standards Addressed	(none)
Arizona Science Standards Addressed	• S6C3: TSW understand the relationships of the Earth and other objects in the solar system.

Lesson Activity

Title	**Design a Roller Coaster (2 sessions, 60-80 minutes)**
ID Number	MS-S-C2
Sequence and Duration	Session 1: Background and Planning • Lead In: 30-40 minutes • Activity: 20-30 minutes Session 2: Building and Testing • Activity: 40-45 minutes • Closure: 20-30 minutes
Age Level	Middle School
Essential Question	**What affect do Newton's Laws and the Law of Conservation of Energy have on the motion of roller coasters?**
Learning Objectives	• TSW use the Law of Conservation of Energy to explain the layout of a roller coaster. • TSW explain how a roller coaster works in terms of physics concepts. • TSW design and build a roller coaster that fits within the given specifications. • TSW identify and explain the features of their roller coaster and describe how it works.
Other Objectives	• TSW develop a working plan with their group to develop a cooperative environment. • TSW communicate with their group by contributing their vocal input. • TSW write down the procedure they used to design their project.
Key Terms	• Gravity • Potential energy • Kinetic energy • Law of Conservation of Energy • Newton's 1st Law • Newton's 2nd Law • Acceleration • Velocity • Inertia • Centripetal force • Thrill elements
Materials Needed	For Group: • Box of assorted materials for building, such as: popsicle sticks, pipe cleaner, oak tag, paper towel rolls, empty 2-liter bottles, plastic tubes, scissors, glue, tape • Roller coaster kit (optional; can check out from EAO) Per Student: • Handout: MESA Notebook Per Team: • Handout: Design a Roller Coaster Competition • Handout: "Roller Coaster Run" MESA Day Event Specifications • Drawing paper • Colored pencils • Meter stick • Stopwatch • Marble

Session 1	Background and Planning
Lead In	1. Ask students about their experiences with roller coasters. How many of them have ever ridden one? Who loves roller coasters; who hates them? Why? What is it about roller coasters that makes them fun/scary? Allow time for students to relate their experiences and discuss roller coaster elements they have seen or heard about that they find especially exciting or frightening. 2. Ask students if they know what makes a roller coaster work. Guide students to an understanding that roller coasters are powered by *gravity*. Make sure students have a solid understanding of gravity: the force of attraction between two masses; on Earth, the force that pulls objects toward the center of the Earth. Write this term on the board and have students write it and define it in their MESA Notebooks. 3. Ask students if they can think about what all roller coasters have in common at the beginning of the ride. [They are pulled up to the top of a big hill to start the ride; this hill is the biggest hill on the track.] Why do all roller coasters start this way? What does this do? [Going to the top of the hill provides the roller coaster with enough *potential energy* to complete the rest of the track.] Ask students if they've ever learned about potential energy before, and if they can think of any examples (batteries store energy; energy is stored in springs when you compress them; energy is stored in a bow's string when you pull it back, etc.). When an object has potential energy, it has the *potential* to do something. In the case of something at the top of a hill, it has the potential to come down the hill. The higher up it is, the more potential energy it has. Have students think about whether they'd rather drop a penny into their hand from two feet up, or from 200 feet up! The penny at the greater height would have more potential energy, so it could *potentially* hurt you when it hit your hand. Have students write and define the term in their MESA Notebooks. Example definition: stored energy. In the case of roller coasters, they have the potential to fall toward the ground when they are at the top of the hill. How much potential energy the roller coaster has depends on how high it is lifted at the beginning of the ride. 4. Ask students what happens once the coaster is let go at the top of the hill [it rolls faster and faster down the hill]. When the roller coaster starts moving, the potential energy is converted into *kinetic energy*, the energy associated with motion. Have students write this term in their Notebooks and define it in their own words. Ask students to give example of objects that have kinetic energy (e.g. a moving car, a running person, a river, the wind, a watch hand, etc.). What would they expect has more kinetic energy, something moving fast or something moving slow? (something moving fast) The faster something is moving, the more kinetic energy it has. Also, the more massive something is, the more kinetic energy it has. Which would case more damage, a mouse running into a wall or a car running into a wall? The car is more massive so would cause more damage, even if it and the mouse were moving at the same speed. 5. Ask, "Why do they call them 'roller coasters'? What does it mean to *coast*?" Guide students to an understanding that all the energy for the ride comes from the potential energy of being at the top of the first hill, and that the coaster uses this energy to coast along the rest of the track. [Note: There are some roller coasters that use other sources of power at certain points of the ride, but true roller coasters simply coast the whole way.] 6. Ask if anyone has heard of the Law of Conservation of Energy [energy cannot be created or destroyed; it can only be transformed (changed from one type to another) or transferred (exchanged between objects)]. Have students discuss this concept until they can define it in their own words in their MESA Notebooks. Ask, "How does the Law of Conservation of Energy apply to roller

	coasters?" [The roller coaster's potential energy from being at the top of the first hill is transformed into kinetic energy as it falls down the hill; the energy is often transformed multiple times as the roller coaster goes over additional hills and loops.] 7. Ask, "Why does the first hill have to be the tallest? Why can't there be any taller hills later?" [There isn't sufficient energy in the system for the coaster to climb a taller hill.] "Why can't there be any hills just as tall as the first one later in the ride?" [Even though the coaster begins with enough energy to climb a hill equally tall as the first one, the system constantly loses energy to *friction*. Friction of the wheels on the tracks, as well as friction from air resistance, causes some energy to be converted to heat, which then escapes. Make sure students understand that the energy is lost to the *system*, not the Universe! Energy is still being conserved.] Make sure students can define friction, and write this in their Notebooks. Example definition: the force of rubbing between two objects that works against motion. 8. Ask students to think about what they've learned about objects in motion (Newton's Laws from previous lesson on Newton scooters). Have students discuss Newton's Laws of motion as they relate to roller coasters. Newton's 2nd Law states that force equals mass times acceleration, or acceleration equals force over mass. Make sure that students are able to explain this in their own words: the greater the force on the object, the more it will accelerate; the more massive the object, the smaller the change in acceleration for a given force. Ask, "What does it mean to *accelerate*?" [to experience a change in velocity] "What is *velocity* (or speed)?" [how fast an object is going] "What are some ways that velocity can change?" [it can increase (go faster), decrease (go slower, or *decelerate*), or change direction] Have students write these terms in their Notebooks. 9. Have students talk about what it *feels* like to accelerate. Tell students that they've all experienced the different types of acceleration when they've ridden in a car. What happens to your body when the car speeds up? [your body goes backward] When the car slows down? [your body goes forward] When the car changes direction, like going around a turn? [your body moves in the opposite direction] What makes your body do these things when the car accelerates? [your inertia] Make sure students write *inertia* in their Notebooks and can describe it in their own words: a tendency to keep doing what you're doing, or a tendency to continue moving at a constant velocity (even if that velocity is zero). Remind students that this is Newton's 1st Law. 10. Explain that it is inertia that keeps people from falling out of the roller coaster when it goes through a loop. Your body wants to keep moving in a straight line, regardless of what the roller coaster is doing. When you get to the top of the loop, both you and the roller coaster want to keep going in a straight line headed away from the track, but the track pushes against the roller coaster to keep it in the loop, and the roller coaster pushes against you! This push is toward the center of the loop, and is called the *centripetal force*. The centripetal force is what keeps objects moving in a circle instead of continuing off on a straight line. Students can play with centripetal force by swinging objects *carefully* around their heads on a piece of string, or you can demonstrate this motion for the class. What is providing the centripetal force? [the string and your hand] Ask students to predict what will happen if you let go of the string – will the object keep moving in a circle? (It is a common misconception among students that it will.) Demonstrate that the object does indeed continue moving in a straight line when the centripetal force toward the center of the circle is no longer acting on it. Have students write *centripetal force* in their Notebooks and ensure that they understand it by describing it in their own words.

	11. Loops and other parts of the roller coaster ride that are especially exciting are called *thrill elements*, and they include hills (where the roller coaster slows down going up and speeds up coming down), turns (where the roller coaster changes direction), and loops (where it changes in speed and direction!). Have students think about thrill elements they've experienced or seen on roller coasters, and what makes them thrilling. They will find that many of these thrill elements are thrilling because they involve acceleration. The feeling of your body's inertia reacting to the acceleration of the roller coaster cart is what makes roller coasters so exciting (and scary!).
Activity	1. Tell students that their mission is to design a roller coaster for a marble "rider" that satisfies the specs on the handout they will receive. Their roller coasters must have at least two thrill elements and must safely deliver the marble to the end of the track after a ride of 10-25 seconds. 2. Hand out the Design a Roller Coaster instructions and the drawing paper and colored pencils. Tell them they have the rest of the session to come up with their design and to try out different things using the materials available in class. The marble will be provided and the classroom materials will be available, but they must bring any other objects they might need from home to build their final roller coaster designs. [Note: Strips of oak tag work well as a cheap material for prototyping designs.] 3. Write the following questions on the board: What thrill elements will your coaster have? How will you control the length of the marble's ride? How can you minimize friction so the marble has enough energy to finish the ride? How will you make sure the marble completes the ride safely? How will you get your marble to a complete stop at the end? 4. Monitor and check student progress. Before students begin building, make sure their concept drawing addresses competition rules and specifications. Make sure their materials are reasonable things they can easily get from home or the classroom. 5. Have students identify on their drawings where the roller coaster will experience maximum potential energy (at the top of the first hill) and where it will experience maximum kinetic energy (at the bottom of the first hill). Have them identify where the coaster experiences a centripetal force, and the direction of that force (centripetal force comes into play whenever the roller coaster travels on a curve, and the force points toward what would be the center if the curve were a complete circle). 6. During the last 5 minutes of project time, tell teams to assign materials. Who is going to bring materials for the next meeting? (You may want to follow up this meeting with an email to all MESA students reminding them to bring their materials for the next meeting.)
Session 2	**Building and Testing**
Activity	1. Have students get with their teams and get out their designs and the materials they brought from home. Tell teams that they can use the classroom supplies as well. 2. Give them 5 minutes to gather their supplies and to go through your supplies. 3. After 5 minutes, ask teams if they need to modify their drawings based on their supplies. If they do, they may do so now. Pass out colored pencils to the teams that need to modify their design. 4. Tell teams they have 25-40 minutes to build their roller coasters. Advise them to work together in their teams and to ask for help if they need it or if they have questions. 5. Monitor student progress and check to make sure their construction follows their design concept and the competition specs closely. 6. When teams begin to wrap up their construction, encourage them to test their designs and make modifications as necessary.

	7. When time is up, have students clean their areas and bring their roller coasters to a common area.
Closure	1. When all students have had a chance to finish building and testing their designs, allow each team an opportunity to demonstrate their coaster and explain their design for the whole class. Have the rest of the class point out ways each team satisfied the specs and how the team's creativity came through. 2. Review the ways the physics concepts discussed the previous week affected the roller coasters. Revisit the questions on the board from last week and ask the students to talk about how they answered those questions with their designs. 3. Make sure students can apply the concepts they've copied into their MESA Notebooks to their experience with their roller coasters. 4. Tell students they have the remainder of the time to complete the MESA Notebook. They may work with their team. Write the following 'conclusion' questions on the board and tell them to answer them using what they have learned from the activity: • *How do Newton's laws of motion affect the motion of roller coasters?* • *How does the Law of Conservation of Energy apply to roller coaster design?* • *How does friction affect roller coasters? How can friction be reduced?* • *If you could do this activity again, what changes would you make to your roller coaster to make it better?* 5. Monitor their progress. 6. Students may complete their MESA Notebook at home. 7. Optional extension: Explain that for the MESA Day competition, the roller coaster will need to have a theme. What themes could work for a roller coaster design?
Informal Assessment	13. Monitor students as they progress through the project. 14. Monitor students to check for understanding periodically. 15. Informal Oral Presentation of team design and roller coaster.
Formal Assessment	• Completed roller coaster design. • Completed roller coaster. • Completed MESA Notebook.
Trouble Shooting	• Use visuals and manipulatives to demonstrate concepts in Session 1 as much as possible. You can use a toy car track or model roller coaster to point out concepts such as potential energy, kinetic energy, acceleration, and friction. You can also fashion your own roller coaster design, but be wary of the possibility that students might mimic your design rather than come up with an original design and construction technique. • Consider having students build roller coaster prototypes with cheaper materials, such as strips of oak tag, to test out their ideas about how the marble will move, prior to building with more expensive or harder to come by materials. • Encourage students to be creative in their design and choice of materials. Each roller coaster should be unique!

SEI Strategies Used		
Preparation ☐ Adaptation of Content ☒ Links to Background ☒ Links to Past Learning ☒ Strategies incorporated	Scaffolding ☐ Modeling ☐ Guided practice ☒ Independent practice ☒ Comprehensible input	Grouping Options ☒ Whole class ☒ Small groups ☐ Partners ☐ Independent
Integration of Processes ☐ Reading ☒ Writing ☒ Speaking ☒ Listening	Application ☒ Hands-on ☒ Meaningful ☒ Linked to objectives ☒ Promotes engagement	Assessment ☐ Individual ☒ Group ☒ Written ☒ Oral

Arizona Math Standards Addressed	(none)
Arizona Science Standards Addressed	• S5C2: TSW understand the relationship between force and motion by explaining how Newton's laws apply to objects in motion. • S5C3: TSW understand that energy can be stored and transferred.

Team Members:____

Design a Roller Coaster Competition

Goal:

Your mission is to design a roller coaster that satisfies the specifications below. In teams of three or four, you will first draw your design on paper. If you are not sure if something will work, try it out with materials like paper, cardstock and masking tape. Once you have a final design, have your advisor approve it and you can start building with materials of your choosing. Choose your materials wisely, and BE CREATIVE!

Roller Coaster Specifications:

- Fit within a 70x70x70 cm^3 space and weigh no more than 10 kg
- Have at least 2 thrill elements
- Keep contact with the marble at all times
- Consist of a ride of 10 – 25 seconds, more points for longer rides without going over
- Get the marble to a complete stop at the end

Treat the marble like a car full of people – make sure it reaches the end of the track safely! Don't allow the marble to do anything that roller coaster designers wouldn't allow with people: no flying through the air, crashing, etc.

Team Materials:

Design Drawing

- Drawing paper
- Colored Pencils

Roller Coaster

- One marble (provided by advisor)
- Meter stick
- Stopwatch
- Any other materials decided upon by each team

Instructions:

Day 1:

1. Design your roller coaster with your team.
2. Draw your design on the drawing paper provided by your advisor. Use colored pencils.
3. Your drawing must show what types of materials are being used in your design.
4. Identify on your drawing the place where the roller coaster will experience the maximum potential energy.
5. Identify on your drawing the place where the roller coaster will experience the maximum kinetic energy.
6. Identify on your drawing any place where the roller coaster experiences a centripetal force, and draw an arrow indicating the direction of that force.
7. If there are any components you want to test out before you prepare your final design, take some time to use the materials set out by your instructor to construct a model to test.
8. Have your advisor approve your design before you build your final design.
9. Be creative!

Day 2:

a. Check to make sure your team has all the materials needed for your roller coaster. If not, you need to modify your drawing.
b. Build your roller coaster with your team.
c. Test your roller coaster with any remaining time.

Lesson Activity

Title	**Float Your Boat (35-45 minutes)**
ID Number	MS-S-C3
Sequence and Duration	• Lead In (5-10 minutes) • Activity (25 minutes) • Closure (5-10 minutes)
Age Level	Middle School
Essential Question	**How does the modification of clay affect whether it floats in water?**
Learning Objectives	• TSW compare the flotation abilities of different clay shapes. • TSW explain why modifying the shape of modeling clay allows it to float. • TSW manipulate the shape of their clay so that it does float in water. • TSW hypothesize the reason for a structure's ability to float and apply their reasoning to their own clay model. • TSW deduce that more surface area allows the water molecules to push against the surface of the clay, allowing it to float. • TSW deduce that clay spread over more surface area displaces more water, allowing it to float. • TSW communicate the results of the activity to their peers.
Other Objectives	• TSW develop a working plan with their group to develop a cooperative environment. • TSW communicate with their group by contributing their vocal input.
Key Terms	• Hypothesis: a prediction or educated guess. • Modify • Surface area • Molecules and Water Molecules (optional)
Materials Needed	Per Group • Chunk of modeling clay for demonstration • Large bowl or tub of water • Marbles • Paper towel Per Team (2 students) • Modeling Clay- 1" square or 50g • MESA Notebook Handout
Lead In	1. Pass out MESA Notebook handout. Quickly review how to complete handout. 2. Direct student's attention to teacher demonstration. 3. Hold up a ball of modeling clay. 4. Ask, "When I drop this in the water, who thinks it will float? (pause and wait for responses) Who thinks it will sink? (Pause and wait for responses) 5. Ask students to defend and explain their predictions. 6. Write the term 'hypothesis' on the board and instruct students to write it in the 'key term' section of their MESA Notebook handout. 7. Ask, "What is a hypothesis?" Most students will know; guide them to a class definition and put it on the board. Have students write the class definition on their handout. 8. Apply the definition to the hypothesis they just made about whether or not the ball of clay will float. 9. Drop clay into the water. (Clay should sink) 10. Ask students, "What can I do to this clay to try to make it float?" Solicit answers and discuss. Students will make the same suggestions such as flatten it out, make

	it thin, make sure there are walls on the edges so water doesn't get in… 11. Write the term 'modify' on the board and instruct students to write the term in the 'key term' section of their handout. Ask one student to look up the definition in a dictionary. The general definition is 'to change'. This simple definition can be used as the student definition. 12. Now ask, "How can I modify this clay to try to make it float?" Students will make the same suggestions such as flatten it out, make it thin, make sure there are walls on the edges so water doesn't get in… 13. Point out that 'to modify' something is 'to change it' so it works better. 14. Use student suggestions to guide them to a communal understanding that the more spread out the clay is, the better chance it has of floating. 15. Write the term 'surface area' on the board. Ask students to come up with a definition of the term on their own using word recognition strategies. Guide students by using other objects in the room that have large surface areas. Many will already know what surface area is. Write a communal definition on the board and have them copy it on their handout. 16. Review how their suggestions of spreading the clay out will give the clay a better chance of floating because of the increase in surface area. 17. Ask, "When my clay boat floats, what is keeping it from sinking?" Student suggestions will vary. You can help them by asking, "To keep something from going down, something has to push it up. What could be pushing up against my boat to keep it from going down?" Guide students so they understand that the water is pushing up against the boat. 18. Review how surface area spreads the clay out; now guide students to understand that the more surface area there is, the more areas there are for water to push up against. You may introduce water molecules here.
Activity	1. Tell students that they are to use the concepts of 'modifying' and 'surface area' to design and mold a chunk of clay into a boat that can float. Their boat has to float and hold a minimum of 5 marbles. 2. Pass out the clay and allow students 5 minutes to come up with a boat. *Remind students to write the materials in the 'materials used' section of the MESA Notebook.* 3. Have them test it. 4. Give them another 5 minutes to modify their design. 5. Test all the boats.
Closure	1. Ask students to hold up their boats and explain how their team arrived at the final design. 2. Ask students to describe any problems they had in designing and constructing their boat. 3. Ask students to describe what they would change to make their boat better if they had more time. 4. Instruct students to complete the 'procedure' section of the MESA Notebook. It should be a sequential description of their team's design and construction of their boat. 5. Instruct students to answer the following question in the 'conclusion' section of the MESA Notebook: *How does the modification of clay affect whether it floats or not?* **Note: Students may complete the 'Procedure' and 'Conclusion' section of the MESA notebook at home before the next MESA meeting if time is an issue.*
Informal Assessment	16. Monitor students to check for understanding. 17. Monitor students to check for participation. 18. Student oral presentation explaining their team's procedure.
Formal Assessment	• Completed Clay Boat. • Completed MESA Notebook Handout (They may complete this before the next MESA meeting).
Trouble Shooting	• Keep an eye on the time. Don't linger too long over a single component or you will

	run out of time. • Make sure all students participate in clean up. • Before lesson, fill bowl/tub with water. • Keep an eye on the marbles.

SEI Strategies Used

Preparation	Scaffolding	Grouping Options
☐ Adaptation of Content	☐ Modeling	☐ Whole class
☐ Links to Background	☒ Guided practice	☐ Small groups
☐ Links to Past Learning	☐ Independent practice	☒ Partners
☒ Strategies incorporated	☒ Comprehensible input	☐ Independent

Integration of Processes	Application	Assessment
☐ Reading	☒ Hands-on	☐ Individual
☒ Writing	☒ Meaningful	☒ Group
☒ Speaking	☒ Linked to objectives	☒ Written
☒ Listening	☒ Promotes engagement	☒ Oral

Arizona Science Standards Addressed	• S1C1: TSW formulate predictions and questions based on observations. • S1C2: TSW design a controlled investigation and keep a record of their observations, notes, and sketches. • S1C4: TSW communicate the results of their investigation and create a list of instructions that others can follow. • S2C2: TSW understand how science is a process for generating knowledge and apply scientific processes to problem solving situations.

MESA® Mathematics Engineering Science Achievement

Lesson Activity

Title	**Genetics (2 sessions, 50-65 minutes)**
ID Number	MS-S-A5
Sequence and Duration	<u>Session 1</u>: Inventory of My Traits (50-65 minutes) • Lead In: 10 minutes • Activity: 30-40 minutes • Closure: 10-15 minutes <u>Session 2</u>: Family Health History (50-65 minutes) • Lead In: 5-10 minutes • Activity: 40-45 minutes • Closure: 5-10 minutes
Age Level	Middle School
Essential Question	**How are traits inherited through generations?**
Learning Objectives	• TSW complete a data table and bar graph of their own and their classmates' observable traits. • TSW describe how an individual's traits make him or her unique. • TSW create a genetic pedigree of a fictional family by randomly choosing inherited genes. • TSW describe how genetics determine whether an individual inherits a disease or not. • TSW collect health information from their family members. • TSW prepare a genetic pedigree of their own families and assess the prevalence of genetic diseases in their family histories.
Other Objectives	• TSW represent data numerically, graphically and kinesthetically. • TSW communicate with the group to create a collaborative environment. • TSW interpret procedures from written instructions.
Key Terms	• Trait • Gene • Genetics • Polygenic • Risk
Materials Needed	<u>Session 1</u>: Per Class: • Large graph paper (optional) • Markers (bingo markers would work well) or colored stickers (e.g. "gold star" stickers) Per Team: • Handout: Inventory of My Traits - Data Table • Handout: Inventory of My Traits – Graph • Markers, colored stickers, colored pencils or crayons Per Student: • Handout: Inventory of My Traits - Survey • Handout: Family Health History instructions • Handout: What's Your Story Health Family Tree Information Box (2-3 copies) <u>Session 2</u>: Per Team: • Handout: Polygenic Pedigree Challenge – Instructions • Handout: Polygenic Pedigree Challenge – Student Pedigree

	• Colored pom-poms, at least: 10 red, 2 yellow, 1 each of blue, green & orange • 2 cups • Markers, colored pencils or crayons Per Student: • Large piece of paper (or several pieces of construction paper taped together) • Piece of drawing paper • Handout: Creating Your Health Family Tree – Instructions • Handout: Draw Your Family Pedigree - Instructions • Health Family Tree Information Box, filled out by students and returned
Session 1	**Inventory of My Traits**
Lead In	21. Ask the students what characteristics of people they are aware of that tend to be passed down from generation to generation. For instance, what kinds of things are common among their family members but not so common in other people? (E.g. hair color, shape of nose, height, good singing voice, body shape, ability to draw, color blindness, etc.) 22. Tell the students that observable characteristics are called *traits*, and some traits can be passed down from parent to child through generations via *genes*. Genes are segments of DNA, and each gene defines a specific trait. Individuals possess a wide variety of traits that define everything from the curl in their hair to the shape of their toenails, and the specific combination of each person's traits is what makes them unique from everyone else. 23. Tell the students that some traits are common in a population. Ask everyone who is right-handed in the class to stand, and count how many students possess this trait. In the population of your MESA class, this trait is (probably) common. 24. Tell the students that other traits are less common. Ask everyone who has a cleft chin to stand and make note of the number of students with this trait. Tell the students that the commonness or uncommonness of a trait doesn't make it good or bad, it just happens to be something that shows up more or less frequently in the overall population. 25. Tell the students that the science that studies how we inherit genes and traits is called *genetics*. Today the students will act as geneticists, collecting data on their own traits and seeing how common these traits are in the whole class.
Activity	50. Break the students into groups of three or four and give each group a Data Table and blank Bar Chart handout. 51. Hand out an Inventory of My Traits Survey handout to each student. 52. Tell the students that each of them will fill out the survey, then they will tally their results for the whole group. Then they will create a bar chart that represents their group's data. Finally, the whole class will create a bar chart that collects the data from everyone. 53. Give the students 15-20 minutes to complete the group work. While the students work, prepare the skeleton of a bar chart on the large graph paper or the board, with enough space to accommodate the data of all students. 54. When the students are done preparing their bar charts, choose one or two student volunteers to mark the class bar chart. Have the volunteers call out the trait they will be marking and have a representative from each group call out their results. 55. When the class bar chart is complete, discuss the results. What percentage of the class is color-blind? What percentage of the class crosses their left thumb over their right? 56. Have the students predict the number of traits it will take to isolate a single student volunteer. Have all the students stand. The student volunteer will read down the list of his/her traits on the survey, and all the students who do not share the trait will sit down. Continue this until the volunteer is the last

	one standing. Compare the number of traits it took to eliminate the last competitor(s) to the number of traits predicted by the students. 57. You can repeat this for another one or two volunteers.
Closure	1. Tell the students that some health problems are traits that can be inherited, so they tend to run in families. Examples of such health problems are diabetes, heart disease, asthma, and depression. Health problems tend to be complex and are caused not only by our genetics but also by other factors associated with how we live, so health problems can also be common to family members who are not biologically connected (e.g. adopted children, spouses). 2. Ask the students if they are aware of how their family health histories affect them. Do they know if there are any diseases or conditions that run in their families? Encourage them to discuss. 3. Hand out the What's Your Story? Health Family Tree Information Box handout. 4. Review the handout and make sure the students know what it is they will be doing. They will be interviewing key family members (parents, grandparents, siblings, and possibly others) about any health problems. If they do find a family member with a health problem, they are to ask follow-up questions to help them understand more about the problem. They will record all this information on the Health Family Tree Information Box. 5. Remind students to be respectful of their family members and not make them uncomfortable or upset with too many personal questions. Tell them to let their family members know that they should only tell the student what they are comfortable having them know. 6. Remind students to bring back their filled-out Health Family Tree Information Box next time (or to the session in which you will be continuing the discussion of genetics).
Session 1	**Family Health History**
Lead In	1. Ask what the students learned from talking to their family members about the Health Family Tree activity. Did they discover anything about their family's *genetics* that they didn't know before? Allow time for a brief discussion. 2. Tell the students that today they will play a game to explore how traits can be passed down from one generation to the next, and then they will create a family tree from their own family members' information. 3. Hand out the Polygenic Pedigree Challenge handouts. Tell the students that they will be doing a simulation that traces the inheritance of heart disease in a family. Heart disease is a *polygenic* disease, meaning that it is controlled by multiple (*poly*) genes, as well as other environmental factors associated with an individual's lifestyle. The inheritance of diseases like this is much harder to predict because there are many factors that influence its presence in an individual. However, there are certain genes that increase an individual's *risk* of having the disease. In this simulation, they will explore a simplification of the way that risk factors can be passed down through families.
Activity	1. Pass out the other materials (2 cups, pom-poms and markers) to the students in groups of 2 or 3. 2. Review the instructions and complete the first few steps together to ensure all students understand. 3. Give students 10-15 minutes to complete the challenge. 4. When the students are finished, ask them to report out on their findings. Ask them such questions as: a. The grandfather in this family has high risk for heart disease. How many of his children did you find to be high or medium risk? How many of his grandchildren? (Answers will vary; remark on how there is an element of randomness or "chance" in genetics.) b. If a parent has heart disease, will his/her children and grandchildren have it too? (Not necessarily; the risk generally decreases over

	generations as the probability of inheriting a specific gene decreases when the genes of other parent/grandparents are factored in.) c. Is it easy or difficult to predict whether a child will develop heart disease? (Difficult; not only is there an element of randomness, but heart disease is also a polygenic disease influenced by an unknown number of genes and also by environmental factors.) 8. Have the students get out their Information Boxes that they filled out after interviewing their family members. 9. Hand out the "Creating Your Health Family Tree" and "Draw Your Family Pedigree" handouts as well as the large paper and drawing paper. 10. Review the instructions if necessary. 11. Give students time to complete their family pedigrees and track a disease through the generations.
Closure	1. Ask the students to discuss what they learned from completing their health family trees. 2. Ask the students why completing a family health history is important. (It makes you aware of certain diseases you may be at risk for that you can work to understand and maybe prevent.) 3. Ask the students to discuss ways that a geneticist's work can be important or useful.
Informal Assessment	19. Monitor students' participation in activities. 20. Monitor students' participation in discussions. 21. Monitor students' understanding of written and verbal instructions. 22. Monitor students' responses to verbal questions.
Formal Assessment	• Completed survey. • Completed data table. • Completed bar chart. • Completed class bar chart. • Completed Family Health History Information Boxes. • Completed Polygenic Pedigree Challenge. • Completed family pedigree.
Trouble Shooting	• Ideally, try to schedule these two lessons so that the students can fill out the Family Health History information during a holiday for which families are likely to gather (e.g. Thanksgiving). • These activities and associated handouts are also available in Spanish. Visit the website in the Citations information for bilingual materials.
Citation	• Learn.Genetics, University of Utah. "Inventory of My Traits," "What's Your Family Health History?" and "Pick the Risk: Polygenic Pedigree Challenge." http://learn.genetics.utah.edu/teachers/tindex/.

SEI Strategies Used

Preparation
- ☐ Adaptation of Content
- ☒ Links to Background
- ☐ Links to Past Learning
- ☐ Strategies incorporated

Scaffolding
- ☐ Modeling
- ☒ Guided practice
- ☒ Independent practice
- ☐ Comprehensible input

Grouping Options
- ☒ Whole class
- ☒ Small groups
- ☒ Partners
- ☒ Independent

Integration of Processes
- ☒ Reading
- ☒ Writing
- ☐ Speaking
- ☐ Listening

Application
- ☒ Hands-on
- ☒ Meaningful
- ☒ Linked to objectives
- ☒ Promotes engagement

Assessment
- ☒ Individual
- ☒ Group
- ☒ Written
- ☒ Oral

Arizona Math Standards Addressed	• S2C2: TSW understand and apply the basic concepts of probability.
Arizona Science Standards Addressed	• S4C2: TSW understand the basic principles of heredity.

Name ______________________________

Date ________________

An Inventory of My Traits – Survey

What combination of these traits do you have? Complete the survey to find out.

1. I have detached earlobes	☐ Yes	☐ No
2. I can roll my tongue	☐ Yes	☐ No
3. I have dimples	☐ Yes	☐ No
4. I am right-handed	☐ Yes	☐ No
5. I have freckles	☐ Yes	☐ No
6. I have naturally curly hair	☐ Yes	☐ No
7. I have a cleft chin	☐ Yes	☐ No
8. I have allergies	☐ Yes	☐ No
9. I cross my left thumb over my right when I clasp my hands together	☐ Yes	☐ No
10. I can see the colors red and green (I am not color blind)	☐ Yes	☐ No
11. The hairline on my forehead is straight.	☐ Yes	☐ No
12. I am a:	☐ Male	☐ Female

Adapted from "Alike But Not The Same" in Human Genetic Variation, NIH Curriculum Supplement Series 1999. http://science-education.nih.gov

Name ______________________________

Date ________________

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Adapted from "Alike But Not The Same" in Human Genetic Variation, NIH Curriculum Supplement Series 1999. http://science-education.nih.gov

An Inventory of My Traits – Data Table

How many people in your group have each trait?
Fill in the data table below by counting the number of people who marked "yes" and the number of people who marked "no" for each trait.

TRAIT	YES	NO
Detached earlobes		
Tongue rolling		
Dimples		
Right-handed		
Freckles		
Naturally curly hair		
Cleft chin		
Allergies		
Cross left thumb over right		
See the colors red and green		
Have a straight hairline		

Name ____________________

Date ______________

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An Inventory of My Traits – Graph

Make a bar graph showing how many people in your group answered "yes" for each trait. Be sure to label each trait under the bar you draw for it.

What's Your Family Health History Story?

How to Gather **Family Health** Information

*"The knowledge a person has of their family's health history could be life saving, if that person chooses to heed the possibilities"
- Judy*

Recording family health information and sharing it with your doctor is an important first step to improving your health, regardless of your family structure.

Tracking diseases that run in your family will help your doctor better predict what you need to do to stay healthy.

The next time you're at a family gathering, make sharing your family health stories a tradition. It may save your life and the lives of those you love!

Getting Started

Explain to your relatives that you are interested in the family's health story. Collect some basic health information about your family members using the What's Your Story? Health Family Tree Information Box. Let them know that any information they provide will help you and your entire family improve their health.

Common Health Problems that Run in Families

- Heart disease
- Cancer
- Stroke
- Diabetes
- Asthma
- Osteoporosis
- High blood pressure
- High cholesterol
- Depression

*" The only thing you have control over in your family health history is to empower yourself enough to be aware of what you're potentially at risk of so you can recognize the symptoms or prevent the disease from occuring."
- Arianna*

How to Interview Your Family

The health stories of your siblings, parents and grandparents will be the most useful to your doctor. You may also want to gather information about your aunts and uncles, half-brothers or half-sisters (if any) and cousins.

Who Do I Need to Interview in my Family?

Most Important	Also Important
• Parents	• Aunts and Uncles
• Brothers and Sisters	• Half-Brothers and Half-Sisters
• Grandparents	• Cousins

Follow-up Questions

If a relative has experienced a health problem, ask follow-up questions that will help you learn more. Find out how old they were when the health problem started, and ask about any lifestyle factors that may have contributed to the problem (diet, exercise, overweight, smoking, etc.).

Important to Find Out

- A description of any health problems
- The age at diagnosis (when the condition started)
- Allergies to foods or medications
- Lifestyle and health habits
- If deceased, the age and cause of death

Living relatives can also provide important health information about family members who are deceased. Find out how old a family member was when they died and ask about the cause of death.

Remember to be respectful of others' wishes. Some family members may be reluctant to share their health information with you. Just ask them to share what they can.

Additional Resources

Visit the following websites to obtain more information about family health history, including additional tools your family can use!

Learn.Genetics (http://learn.genetics.utah.edu) *Using Family History to Improve Your Health* contains information about common diseases that run in families, and what it means to be "at risk".

"I try to be a good example and share what I know about our family health history so future generations won't have to worry about repeating the same fate." - Marian

"I was surprised to learn what I did about my health family history. It wasn't until I put it into a pedigree, or family tree, that I began to see the pattern of depression that ran from generation to generation." - Jenny

The Utah Department of Health (http://health.utah.gov/genomics/familyhistory/toolkit.html) *Family Health History Toolkit* contains materials for your family, plus links to more information about the importance of knowing your family's health history.

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What's Your Story?
Health Family Tree Information Box

Family member first name:
Relationship:
Date of birth:
Health problems (*check all that apply*):

Age of onset:

- ❑ Heart Disease ________
- ❑ Cancer ________
- ❑ Stroke ________
- ❑ Diabetes ________
- ❑ Asthma ________
- ❑ Osteoporosis ________
- ❑ High Blood Pressure ________
- ❑ High Cholesterol ________
- ❑ Depression/Mental Health ________
- ❑ Other ________ ________

Does this family member smoke?
❑ Yes ❑ No
If yes,
Cigarettes smoked per day:
Number of years smoking:

Is this family member deceased?
❑ Yes ❑ No
If yes,
Age at death:
Cause of death:

Health-related lifestyle or environmental factors for this family member:

Family member first name:
Relationship:
Date of birth:
Health problems (*check all that apply*):

Age of onset:

- ❑ Heart Disease ________
- ❑ Cancer ________
- ❑ Stroke ________
- ❑ Diabetes ________
- ❑ Asthma ________
- ❑ Osteoporosis ________
- ❑ High Blood Pressure ________
- ❑ High Cholesterol ________
- ❑ Depression/Mental Health ________
- ❑ Other ________ ________

Does this family member smoke?
❑ Yes ❑ No
If yes,
Cigarettes smoked per day:
Number of years smoking:

Is this family member deceased?
❑ Yes ❑ No
If yes,
Age at death:
Cause of death:

Health-related lifestyle or environmental factors for this family member:

Family member first name:
Relationship:
Date of birth:
Health problems (*check all that apply*):

Age of onset:

- ❑ Heart Disease ________
- ❑ Cancer ________
- ❑ Stroke ________
- ❑ Diabetes ________
- ❑ Asthma ________
- ❑ Osteoporosis ________
- ❑ High Blood Pressure ________
- ❑ High Cholesterol ________
- ❑ Depression/Mental Health ________
- ❑ Other ________ ________

Does this family member smoke?
❑ Yes ❑ No
If yes,
Cigarettes smoked per day:
Number of years smoking:

Is this family member deceased?
❑ Yes ❑ No
If yes,
Age at death:
Cause of death:

Health-related lifestyle or environmental factors for this family member:

Family member first name:
Relationship:
Date of birth:
Health problems (*check all that apply*):

Age of onset:

- ❑ Heart Disease ________
- ❑ Cancer ________
- ❑ Stroke ________
- ❑ Diabetes ________
- ❑ Asthma ________
- ❑ Osteoporosis ________
- ❑ High Blood Pressure ________
- ❑ High Cholesterol ________
- ❑ Depression/Mental Health ________
- ❑ Other ________ ________

Does this family member smoke?
❑ Yes ❑ No
If yes,
Cigarettes smoked per day:
Number of years smoking:

Is this family member deceased?
❑ Yes ❑ No
If yes,
Age at death:
Cause of death:

Health-related lifestyle or environmental factors for this family member:

Adapted with permission

Name ______________________________

Date ____________

You are a researcher investigating heart disease. You know there are 6 genes in humans that can contribute to heart disease risk. All humans have these 6 genes, but we can inherit slightly different forms or "flavors" of these genes. Your challenge is to track and record the passage of these 6 genes (signified by colored pom poms) through generations of a family using a pedigree. Then, predict which members of this family are most likely to develop heart disease.

Follow the steps below to complete this challenge.

Part 1:

1. Obtain a blank pedigree, colored pencils or crayons, 2 disposable cups, and an assortment of colored pom poms from your teacher.

2. Choose one cup that will represent a grandmother. Place inside the cup 5 red pom poms (5 "normal" genes that do NOT contribute to heart disease) and 1 blue pom pom (1 gene that increases heart disease risk).

3. Choose one cup that will represent a grandfather. Place inside the cup 3 red pom poms (3 "normal" genes that do NOT contribute to heart disease), as well as 1 orange, 1 green, and 1 yellow pom pom (3 genes that increase heart disease risk).

4. On the pedigree, record the colors of pom poms present in both the grandmother and grandfather by filling in the blank circles using crayons or colored pencils.

5. With closed eyes, mix and randomly draw out 3 pom poms from each grandparent (6 pom poms total). This will represent the genetic information inherited by their first child.

Remember: No peeking! This needs to be random.

6. On the pedigree, color in the combination of pom poms that were passed on to the child.

7. Return the pom poms to the appropriate grandparent. (Give grandma's genes back to grandma, and give grandpa's genes back to grandpa.)

8. Repeat steps 5-7 for each child represented in the pedigree.

Name ______________________________

Date ________________

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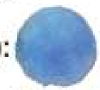
9. Diagnosis:

Look at each individual's 6 heart disease susceptibility genes (their combination of colored pom poms). Remember: The forms or "flavors" of a gene that increase heart disease risk are

yellow(Y):  **orange(O):**  **green(G):**  **blue(B):** 

Label each individual in your pedigree as low, medium or high risk according to the chart below.

High Risk **Medium Risk** **Low Risk**

Part 2:

10. One of the children married a "low risk" individual. Place inside a cup 5 red pom poms and 1 yellow pom pom to represent the 6 heart disease susceptibility genes for this individual.

11. On the pedigree, color in the combination of pom poms (or genes) carried by the spouse.

12. The couple has children. With closed eyes, mix and randomly draw out 3 pom poms from each parent (6 pom poms total). This will represent the genetic information inherited by their first child.

13. On the pedigree, color in the combination of pom poms that were passed on to the child.

14. Return the pom poms to the appropriate parent.

15. Repeat steps 12-14 to determine the genetic make-up of the other two children represented in the pedigree.

16. Label each individual that has been added to your pedigree as low, medium or high risk.

Name ______________________
Date ______________

Student Pedigree

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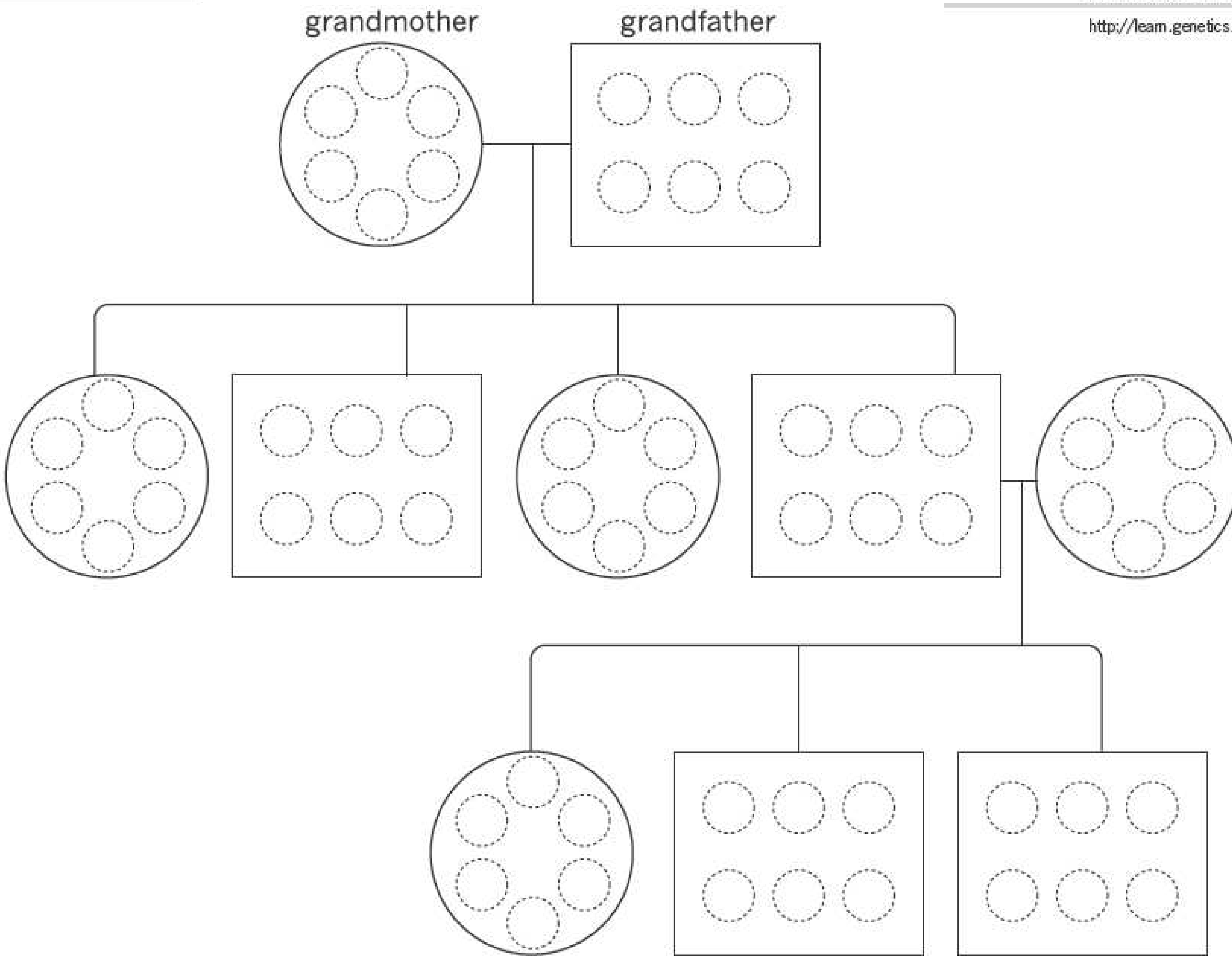
Genetic Science Learning Center



S-4

Creating Your Health Family Tree

After having conversations with each family member organize your family health history into a pedigree chart.

Here's How:

1 Cut out each family member's Health Family Tree Information Box checklist

2 Arrange the checklists on a poster or large piece of paper in the following manner. ***Do not tape or glue the checklists until the last step!***

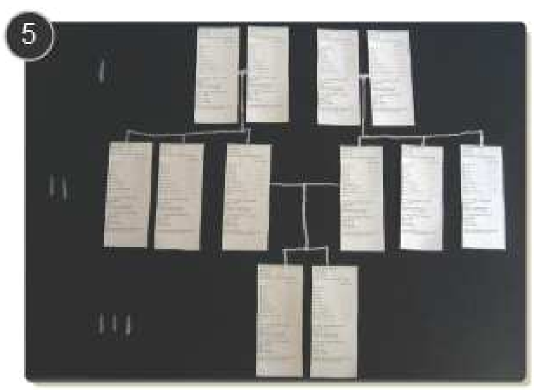
Starting with the oldest generation, place parents together.
This is Generation I.

3 Place the children of each set of parents below each couple in birth order.
This is Generation II.

4 Place the children of the members of Generation II below their parent in birth order. Add the children's second parent.
This is Generation III.

Continue adding generations in this manner until you have correctly arranged all of your family members.

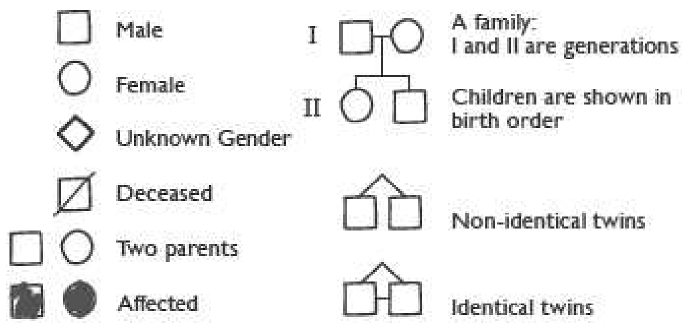
5 Tape or glue the arranged checklists to your poster or paper. Draw lines between the checklists to indicate their relationships.



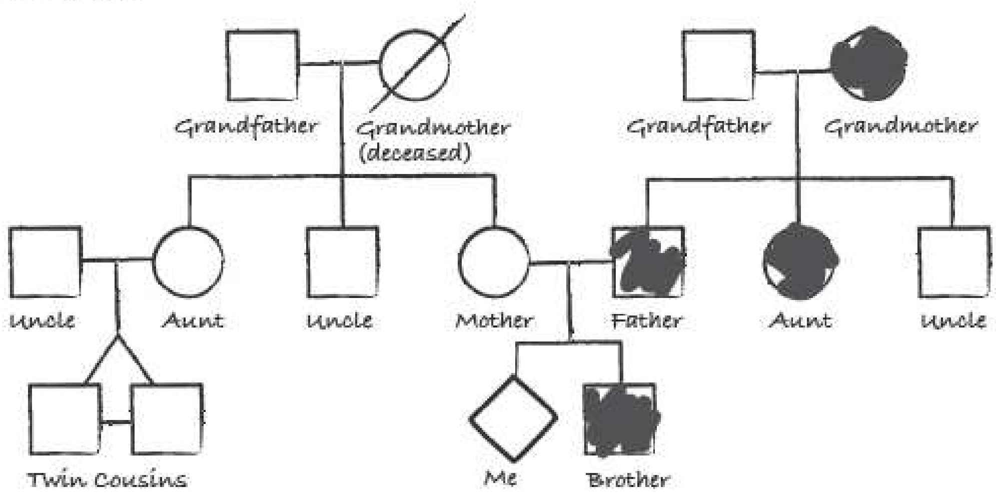
Draw Your Family Pedigree

On a separate sheet of paper, create a pedigree for your family, tracking one of the health problems listed on the Health Information Record. The symbol key and example below will help you get started.

Symbol Key:



Example Pedigree:



MESA Mathematics Engineering Science Achievement

Lesson Activity

Title	**Keep a Cube (50-55 minutes)**
ID Number	MS-S-C4
Sequence and Duration	• Lead In (5-10 minutes) • Activity (15 minutes) • Wait (20 minutes) • Closure (10 minutes)
Age Level	Middle School
Essential Question	**How does insulating an object keep it from melting quickly?**
Learning Objectives	• TSW discuss how objects are kept from getting hot. • TSW apply their understanding of heat to develop an engineering plan to keep an ice cube from melting using given materials. • TSW design their ice keeper to maximize the efficiency of all materials. • TSW define 'insulation' and apply this concept to their design. • TSW describe how different variables can affect the quality of their design.
Other Objectives	• TSW communicate the results of their investigation to their peers. • TSW listen as their peers discuss the design of their investigation. • TSW write down the procedure they used to design their project.
Key Terms	• Insulation
Materials Needed	Per Group • Ice Cube (for demonstration and to keep 'time') Per Student • Handout: MESA Notebook • 1 ice cube • Wax paper • Masking tape • Newspaper • Aluminum foil • Rubber band(s) • Paper plate • Other assorted materials that the teacher feels will add to the design element *examples include cardboard, pipe cleaners, straws, etc…* (REMEMBER: All students should get the <u>same amount</u> of materials to ensure that the design process is objective)
Lead In	1. Pass out new MESA Notebook handout. 2. Write the term 'insulation' on the board. Instruct students to write term on their MESA Notebook handout. 3. Ask students to give examples of types of insulation. Ex. Human fat, house insulation, jackets, etc… 4. Guide students to define insulation in their own words. Ex. Insulation is something that prevents heat from passing through easily. 5. Have students write this definition down on their MESA Notebook handout. Tell them to add examples of insulation next to the definition. 6. Hold up one ice cube. Ask students to describe what will happen if you leave it on a desk. Student responses will be that it will melt. 7. Ask students, "How can we insulate the ice cube so it doesn't melt?" Get various answers and discuss. Review what insulate means and how it applies to keeping the ice cube from melting. [Insulation keeps the heat from the air from reaching

	the ice cube as quickly.]
Activity	1. Tell students that they will be constructing insulation for an ice cube. 2. Hold up the materials that each student will be getting. Tell them that they are all getting the same amount of materials and that they can use it any way they want. They do not have to use all of their materials, but they can't give away their unused materials either. 3. Instruct students to write the materials under the 'materials used' section of their MESA Notebook handout. 4. Pass out the materials to students. 5. Tell them they have 10 minutes to insulate their ice. Show them a separate ice cube and put it on the table in the front. Tell them when this ice cube melts all the way, all students will unwrap their insulated ice cube to compare and see whose insulation worked the best. 6. After 10 minutes, have students keep their insulated ice cube at their table/desk. 7. Instruct students to complete the 'procedure' section of their MESA Notebook handout. 8. Have another activity to do while the ice cube melts. Expect to have approximately 20 minutes for the ice cube to melt completely.
Closure	1. Have students unwrap their cube. 2. Compare student ice cubes to see which student has the most of their ice cube left. Let this student describe their design and explain how they developed it. 3. Compare and contrast various design components. 4. Tell students to answer the following question in the 'conclusion' section of their MESA Notebook handout: *How does insulating an object keep it from melting quickly?* Tell them to make references to their design. 5. Clean up.
Informal Assessment	23. Monitor students to check for engagement. 24. Monitor students to check for understanding.
Formal Assessment	• Completed insulated ice cube. • Completed MESA Notebook handout.
Trouble Shooting	• After students insulate their ice cube, start another activity. <u>Check the melting ice cube on the desk continually. The student insulated ice cubes must be checked as soon as the desk ice cube melts.</u> • Keep an eye on the time. Don't linger too long over a single component or you will run out of time. • Make sure all students participate in clean up. • Have all materials ready before students come, or you will waste a lot of time. For example, have the sheets of foil already cut and ready to pass out. Have the wax paper already cut and ready to pass out.

SEI Strategies Used

Preparation
- ☐ Adaptation of Content
- ☒ Links to Background
- ☒ Links to Past Learning
- ☒ Strategies incorporated

Scaffolding
- ☒ Modeling
- ☐ Guided practice
- ☐ Independent practice
- ☒ Comprehensible input

Grouping Options
- ☐ Whole class
- ☐ Small groups
- ☐ Partners
- ☒ Independent

Integration of Processes
- ☒ Reading
- ☒ Writing
- ☒ Speaking
- ☒ Listening

Application
- ☒ Hands-on
- ☒ Meaningful
- ☒ Linked to objectives
- ☐ Promotes engagement

Assessment
- ☒ Individual
- ☐ Group
- ☐ Written
- ☐ Oral

Arizona Science Standards Addressed	• S1C2: TSW design and conduct a controlled investigation demonstrating safe behavior and appropriate procedures and keeping a record of their observations, notes and sketches. • S1C4: TSW communicate the results of their investigation and create a list of instructions that others can follow in carrying out a procedure. • S5C1: TSW understand the physical properties of matter.

Mathematics Engineering Science Achievement

Lesson Activity

Title	**Kinetic Sculpture**
ID Number	MS-E-C5
Sequence and Duration	• Lead in: 5 minutes • Activity: 25 minutes • Closure: 10 minutes
Age Level	Middle School
Essential Question	**What design elements allow a kinetic sculpture to be stable in windy conditions?**
Learning Objectives	• TSW design a art sculpture with moving design elements • TSW construct an art sculpture using given materials to reflect their design and is stable in windy conditions • TSW evaluate the stability and creativity of their design • TSW compare their design to other students' • TSW predict which sculpture will withstand the windy conditions and explain why they are making the prediction(s)
Other Objectives	• TSW discuss their design and construction with the group
Key Terms	• Kinetic • Design process • Stability • Force
Materials Needed	Per Class: • Electric fan Per Team: • Ruler • Cardboard • Markers • Paper cups • Scissors • Wooden skewers • Construction paper • String • Masking tape • Metal washers or knick knacks of assorted sizes • Handout: Kinetic Sculpture Challenge Per Student: • MESA Notebook
Lead In	1. Ask students to describe how the wind affects an object, a community, etc… 2. Ask students how structures, like buildings, are built to withstand windy conditions? Discuss their answers and come up with common design elements. 3. Tell students that they will be designing and building art structures. Their art structure has to survive the wind. This means it can't be knocked over by a fan. 4. Ask students what design elements they can use to make their art structure. They will all come up with various responses based on earlier discussion. 5. Tell them that there is a challenge to this challenge. Their art sculpture has to have 2 moving parts on it. You can explain this by gestures, diagrams, pictures, etc… 6. Pass out the handout: Kinetic Sculpture Challenge. Read and discuss with the

	students. Check for understanding. 7. Have students divide into groups of 2-3. 8. Pass out materials.
Activity	1. Tell students they have 15-20 minutes to construct their sculpture. 2. Monitor students to make sure they are following the size guidelines. 3. Collect structures at the end of time. 4. Have students look at all the structures to determine which one they feel will withstand the wind and explain the design elements that are influencing their prediction. Guide students to common understanding.
Closure	1. Test the sculptures. 2. You may also give a prize for the most creative, because art sculptures have to be pleasant to the common eye.
Informal Assessment	• Check to make sure all students are participating • Make sure students are following challenge guidelines
Formal Assessment	• Wind challenge
Trouble Shooting	• Students may disagree over which sculpture is the most creative • Constantly ask they to check the size of their sculpture or they will be disqualified • You can bring examples of hanging kinetic sculpture like art- mobiles

SEI Strategies Used

Preparation
- ☐ Adaptation of Content
- ☒ Links to Background
- ☒ Links to Past Learning
- ☒ Strategies incorporated

Scaffolding
- ☐ Modeling
- ☐ Guided practice
- ☐ Independent practice
- ☐ Comprehensible input

Grouping Options
- ☒ Whole class
- ☒ Small groups
- ☐ Partners
- ☐ Independent

Integration of Processes
- ☒ Reading
- ☐ Writing
- ☒ Speaking
- ☒ Listening

Application
- ☒ Hands-on
- ☒ Meaningful
- ☒ Linked to objectives
- ☒ Promotes engagement

Assessment
- ☐ Individual
- ☒ Group
- ☐ Written
- ☐ Oral

Arizona Math Standards Addressed	• S5C2PO2: TSW identify the conditions under which an object will continue between its state of motion • S5C2PO3: TSW describe forces as interactions between bodies
Arizona Science Standards Addressed	•

Kinetic Sculpture Challenge!

Goal:
Each team will make a sculpture that is at least 6 inches tall and has two moving parts that move in the wind. But, be careful because the wind can blow your sculpture over.

Materials:
- Ruler
- Cardboard
- Markers
- Paper cups
- Scissors
- Wooden Skewers
- Construction paper
- String
- Masking tape
- Metal bits

Rules:
1. Use only the materials provided.
2. Follow the size dimensions for height.
3. The sculpture needs 2 moving parts. The moving parts make it a kinetic sculpture- kinetic means it moves
4. Your sculpture needs to be stable and not blow over in the wind.
5. The sculpture cannot be taped to the table.

The competition:
The sculpture that is withstands the wind AND is most creative wins the challenge. Good Luck!

MESA Mathematics Engineering Science Achievement

Lesson Activity

Title	**Making Ice Cream (60-70 minutes)**
ID Number	MS-S-A6
Sequence and Duration	• Really Cold Activity (Teacher Demonstration) 10-15 minutes • Making Ice Cream (30-35 minutes) • Introduction to MESA (15 minutes)
Age Level	Middle School
Essential Question	**How do the concepts of melting point depression and endothermic melting help to make ice cream?**
Learning Objectives	• TSW visualize how salt affects the endothermic melting of ice. • TSW compare and differentiate between the different states of matter. • TSW define, recall, and apply their understanding of the term 'melting point depression'. • TSW describe how the process of endothermic melting makes ice cream.
Other Objectives	• TSW develop a working plan with their group to develop a cooperative environment. • TSW communicate with their group by contributing their vocal input.
Key Terms	• Melting point depression • Mixture • Solid • Liquid • Gas • Absorption of heat
Materials Needed	**Really Cold Activity Teacher Demonstration** • 1 ice cube • 1 teaspoon of salt • 25 cm of string **Making Ice Cream (per 1 student)** • Recipe posted on wall or handed out • ½ cup milk • ½ teaspoon vanilla • 1 tablespoon sugar • 4 cups crushed ice • 4 tablespoons salt • 2 quart size Zip-loc bags • 2 gallon size Zip-loc freezer bags • 1 plastic spoon • Paper towels
Lead In	**Teacher Demonstration of Really Cold Activity** 1. Put a wet string on top of the ice cube. 2. Put salt on top of the string. 3. Let it sit for 1 minute. 4. Ask students what they think is going to happen. Discuss answers. 5. Pick up ice cube with the string. 6. Ask students to explain what they think happened. Discuss answers. 7. Write the following terms on the board: solid, liquid, gas 8. Students will define in their own words each term and give examples of each. 9. Write states of matter on the board and connect it to sold, liquid, and gas.

	Discuss for clarity. 10. Redirect students to the demonstration. Ask, would the string still pick up the ice cube if we didn't use salt? Solicit answers and discuss. 11. Ask, "What do you think the salt does that makes the string stick to the ice cube?" You can lead them to the answer by asking, why do things freeze? What does it mean to freeze? (Students may respond by saying, "there is a lack of heat", "the molecules stop moving", etc… Use all their responses to guide the discussion. Introduce following concepts: melting point depression, endothermic process. *Putting salt on the ice results in the depression, or lowering, of the ice's melting point. This means that the ice will melt at a cooler temperature than it normally would.* *The melting of ice is an endothermic process. Endothermic means that the process takes heat from its surroundings. The temperature of the surroundings decreases. When salt is sprinkled on the string and the ice cube, some of the ice melts. As it melts, it absorbs heat from its surroundings, which included the damp string. As the string loses heat, the water in the string freezes causing it to attach to the ice cube.*
Activity	**Making Ice Cream** 1. Ask students what their favorite ice cream flavor is. Discuss. 2. Ask students to describe how ice cream is made. Discuss. 3. Pass out the instructions for making ice cream. See Attachment. 4. Pass out materials to each group. 5. Have students read instructions individually. 6. Have students retell the directions in their own words by calling on students at random to describe the steps sequentially. 7. Allow 15 minutes for them to make ice cream. 8. Clean up.
Closure	1. Gather students together while they eat their ice cream. 2. Guide students to the previous demonstration. Ask, "How could salt help to make ice cream?" Refer students to conclusion question #1 and tell them to write down an answer based on the discussion. [The salt lowers the temperature at which the ice melts; when the ice melts it takes energy from its surroundings, cooling them to their freezing point.] 3. Redirect students to previous question of "How do things freeze?" and the term endothermic process. Refer students to the conclusion question #2 and tell them to write down an answer based on the discussion. 4. Guide discussion until students can apply the concepts of endothermic freezing to the making of their ice cream.
Informal Assessment	25. Monitor students to check for understanding of terminology and its application to the activity. 26. Monitor the students to check for participation.
Formal Assessment	• Students should have created acceptable-tasting ice cream for their group. • Conclusion questions on handout.
Trouble Shooting	• Make sure each group has instructions. • Make sure they are measuring correctly. • Make sure they shake bags gently. • Monitor to check for clean up.
SEI Strategies Used Preparation	Scaffolding Grouping Options

☐ Adaptation of Content ☐ Links to Background ☒ Links to Past Learning ☒ Strategies incorporated	☐ Modeling ☐ Guided practice ☒ Independent practice ☒ Comprehensible input	☐ Whole class ☐ Small groups ☒ Partners ☒ Independent
Integration of Processes ☒ Reading ☐ Writing ☒ Speaking ☒ Listening	Application ☒ Hands-on ☒ Meaningful ☒ Linked to objectives ☒ Promotes engagement	Assessment ☒ Individual ☐ Group ☐ Written ☒ Oral

Arizona Math Standards Addressed	• None
Arizona Science Standards Addressed	• S1C2: Conduct controlled investigations using safe behavior and appropriate procedures. • S1C4: Communicate the conclusions of the investigation. • S5C1: Understand physical properties of matter. Identify different kinds of matter based on their physical properties. Investigate how the transfer of energy can affect the physical properties of matter.

Making Ice Cream

Goal:

Your will make edible ice cream using the supplied materials.

Team Materials:

- ½ cup milk
- ½ teaspoon vanilla
- 1 tablespoon sugar
- 4 cups crushed ice
- 4 tablespoons salt
- 1 quart sized Zip-Loc bag
- 1 gallon sized Zip-Loc freezer bag
- Paper towel

Instructions:

1. Gather supplies from your advisor.
2. Mix the milk, vanilla, and sugar together in the quart sized Zip-Loc bag.
3. Get as much air out of the bag as you can and seal the bag tightly. If there is a lot of air in the bag, it will open and your ice cream will be ruined.
4. Put the quart sized bag inside the gallon sized Zip-Loc freezer bag.
5. Add the ice to the gallon sized Zip-Loc freezer bag.
6. Sprinkle the salt on top of the ice.
7. Get as much air out of the gallon sized Zip-Loc freezer bag as you can and seal it tightly.
8. Wrap the bag in a paper towel.
9. Shake the bag gently. Massage the bag gently for 5-8 minutes. Make sure the ice surrounds the cream mixture.

Conclusion Question:

1. Why do you think we double bagged the cream mixture?

2. How does the salt help to make ice cream? Use what you learned about the 'endothermic process'.

MESA Mathematics Engineering Science Achievement

Lesson Activity

Title	**Newton's Scooters (3 sessions, 60-80 minutes)**
ID Number	MS-S-C5
Sequence and Duration	• Session 1: Background and Design (40-50 minutes) • Session 2: Review and Construction (65-70 minutes) • Session 3: Application and Competition (60-80 minutes)
Age Level	Middle School
Essential Question	**How do Newton's Laws of Motion affect how far and fast a vehicle such as a scooter moves?**
Learning Objectives	• TSW identify and recognize Newton's 3 Laws of Motion. • TSW describe how Newton's 1st Law affects the motion of an object. • TSW describe how Newton's 3rd Law affects the motion of an object. • TSW design and construct a scooter using materials brought from home. • TSW devise a scooter design that incorporates and addresses Newton's 1st and 3rd Laws of motion and labels how friction and air resistance will affect their scooter's performance. • TSW modify their design to improve the overall structure. • TSW submit a final scooter that addresses the following challenges: travels 3 meters within a measured width of track powered by a movement mechanism that uses Newton's 3rd Law of Motion. • TSW evaluate the strengths and weaknesses of their design and their scooter. • TSW compare their design concept and their scooter design to those of their peers. • TSW describe the process they took to complete the scooter project. • TSW explain how Newton's Laws are affecting the motion of their car.
Other Objectives	• TSW develop a working plan with their group to develop a cooperative environment. • TSW communicate with their group by contributing their vocal input. • TSW listen as their peers discuss the design of their investigation. • TSW write down the procedure they used to design their project.
Key Terms	• Motion • Force • Friction • Gravity • Mass • Accelerate
Materials Needed	<u>Session 1</u> Per Group • Newton's First Law Demonstration- toy car, ball, flat sheet of paper, paper airplane • Newton's Second Law Demonstration- student desk, teacher desk or table • Newton's Third Law Demonstration- balloon, chair with wheels, Newton's Cradle (optional) Per Student • Handout: Newton's Laws of Motion • Handout: MESA Notebook Per Team • Drawing Paper • Colored Pencils

	<u>Session 2</u> Per Student • Handout: Newton's Laws of Motion • Handout: Newton's Scooter • Handout: MESA Notebook Per Team • Scooter Sketch • Materials brought from home to construct scooter <u>Session 3</u> Per Group • Masking tape: to measure out Newton Scooter track on a flat, smooth surface. Track measures 1m x 3m. Vehicles/scooters must travel a distance of 3m and stay within a 1m boundary. Per Student • Handout: Newton's Scooter • Handout: MESA Notebook Per Team • Newton Scooter
Session 1	**Background and Design** 1. Pass out Handout: Newton's Laws of Motion. 2. Pass out Handout: MESA Notebook. Remind students to fill in MESA Notebook as they progress through the project. Point out 'Key Terms' section, as they will be writing in this section today. 3. Have 1 student read aloud Newton's First Law of Motion. 4. Ask, "What does this mean?" Solicit ideas from group and discuss. Guide discussion to demonstration. 5. Roll a ball across the floor. When it stops, ask why it stopped. Answers will vary from 'it's rubbing against the floor' to 'it slowed down'. Write down general responses. 6. Roll the toy car across the floor. Ask them again, why did it stop? Discuss and write down answers again. Some answers will be the same. 7. Fly a paper airplane across the room. Ask them why it stopped. Answers will be like 'it ran out of power', 'it ran out of energy', 'gravity made it stop', etc… Write these responses on the board. 8. Drop a sheet of paper on the floor and ask them why it stopped. Answers will be like 'it hit the floor', 'it had nowhere else to go', 'gravity pulled it down'. Write answers on the board. 9. Guide students back to Newton's First Law. Ask another student to reread the law. 10. Write the word 'motion' on the board. Ask them to define it in their own words. Discuss orally and write a class definition on the board. Simple definition: to move. 11. Teacher will reread Newton's First Law. Emphasize, an object in motion will remain in motion… Ask students to explain this in their own words. 12. Hold up the toy car. Ask students to use the toy car to explain Newton's first law. The car is the object. If an object in motion stays in motion, what does that mean for the car? Have a student demonstrate this by coming up and moving the car. Newton's first law would mean that the car would always move, never stopping. 13. Ask students, 'If Newton's first law says that an object in motion will stay in motion, why did the car stop when we pushed it?' Solicit answers and discuss. Use the other examples (ball, airplane, paper). 14. Ask another student to reread Newton's 1st law. Emphasize 'unless acted upon by an outside force.' Ask, 'the car stops moving, right? What kind of force is making it stop?' Solicit answers and discuss. 15. Write the word 'force' on the board. Ask students to come up with a group

	definition for force and to list some examples. (ex. Friction, gravity, air resistance) Guide the discussion. Simple definition: An action on an object, or a push or a pull. It might be easier to let students list types of forces first and use these examples to develop a definition. 16. Reread Newton's 1st law. Ask 4 students to come up. Give each student an object and have them explain how Newton's first law affects the motion of each object. Have them describe the types of outside forces that are acting on the object. Clarify with group. 17. Have one student read Newton's 2nd law of motion. Ask students, 'what is mass?' Write the term on the board and find a group definition. Simple def: mass is the amount of stuff in an object. You may want to clarify the difference between mass and weight if time permits. 18. Write the term, 'accelerate' on the board. Come up with a group definition. Guide discussion. Simple def: a change in the speed of an object. 19. Have another student reread Newton's 2nd Law. Point to the definitions of 'mass', 'accelerate', and 'force' as they read the law aloud. 20. Hold up the toy car. Teacher will reread Newton's second law of motion. Emphasize 'the greater the mass of an object, the greater the force needed to accelerate it'. Ask, 'which has more mass? This little toy car or my car outside in the parking lot?' Solicit answers. Teacher's real car outside has more mass. Refer back to Newton's second law. "The greater the mass of an object, the greater the _____ needed to accelerate it." Students will say force. Ask them to refer back to the definition of force. (A push or pull, an action on an object) 21. Ask students to explain in their own words what Newton's second law of motion is saying. Refer them back to definitions of 'mass', 'accelerate', and 'force'. 22. Ask 2 students to come up to the front. 23. Have one student push a student desk. Have the other student push the teacher desk, or something else that is significantly heavier than the student desk. Ask them to use this example to explain Newton's second law of motion. 24. Have 1 student reread Newton's second law of motion aloud and clarify its meaning with the class. 25. Have 1 student read Newton's third law of motion. 26. Ask, "Now, what do you think this means?" Discuss possibilities with class. 27. Hold up a balloon. Blow it up and ask students what will happen when you let it go. Discuss student expectations and rational behind their explanations. 'It's gonna fly away', 'it's gonna let all the air out'. 28. Guide discussion to what is making it fly away and what the air is doing inside the balloon when it is released. 'What is the air inside going to do to the air outside?' 'What is making the balloon fly away, why doesn't it just stay in one place and let the air out there?' 29. Let the balloon go and ask students to describe what made the balloon go forward. Come up with a group explanation. Simple ex. The balloon pushes against the air inside it, and the air inside it pushes against the balloon. This makes the balloon go forward. 30. Use the balloon to explain this in slow motion. (Kinesthetic explanation) 31. Have 2 students come up. Have one student sit in a chair with wheels. Have the other student stand in front of them. Ask student in chair to push the student standing. (Ideally, student in chair should move) Ask why the student in the chair moved. Discuss and guide students to explain how when the student pushed against the standing student, the standing student pushed back with an equal force; this force was big enough to overcome the force of friction on the chair's wheels. This is another example of Newton's third law. 32. Reread Newton's third law. Ask students to come up with other examples of how an object moves using Newton's third law. (Rockets being launched, a car rolling on the road)

	33. Clarify Newton's third law and check for understanding. 34. Have 1 student read each law and explain what it means using the objects in the demonstration. 35. Tell students that they will be constructing a vehicle that will illustrate Newton's Three Laws of Motion. They will be working together in teams of 2-3 students. Have them divide into teams now. 36. Tell them they will be constructing their vehicles from scratch. List types of items they can bring from home: matchbox, soda cans, Gatorade bottles, etc… 37. Tell them that the only rule is it has to move using Newton's Third Law of Motion. Illustrate by using the toy car. Tell them that if the toy car is their Newton Scooter, as soon as you put it down on the floor, it will move on its own. For every action, there is an equal reaction. The student cannot move the car by their own force, nor can they use gravity in the form of an incline. Ask, what examples of Newton's third law have we seen? (The most obvious is a balloon and a rocket) Tell them to steer clear of CO2 and/or antacid rockets, although these are excellent examples of Newton's third law. They could use the spring mechanism of a mousetrap, too. 38. Tell them that Newton's Scooters are not limited to vehicles on wheels. Point out the paper airplane. This is an example of a vehicle and Newton's third law could be applied to it. (Paper airplane propelled by a balloon. It would need to be set on a string track to keep within the track boundaries, though.) 39. Tell students that they need to design a Newton Scooter vehicle with their team by the end of today. Their vehicle needs to travel 3 meters on its own and stay within a width of 1 meter. 40. Review all of Newton's Laws of Motion to discuss types of strategies. For example, the heavier a Scooter is, the more force is needed to move it. 41. Pass out drawing paper and colored pencils. 42. Allow students the remainder of the time to sketch out the scooter with their team. 43. Collect MESA Notebook Handout and Newton's Laws of Motion Handout. 44. Monitor student progress by asking, 'how is Newton's third law moving this?' and collect sketches before they leave. 45. Remind students to bring their materials to the next meeting. Each team is responsible for assigning team members supplies to bring.
Session 2	**Review and Construction** 1. Have students get into their Newton Scooter Teams. 2. Pass out Sketches from the last meeting. 3. Pass out Handout: Newton's Laws of Motion. 4. Pass out Handout: Newton's Scooters. 5. Check to make sure teams brought their supplies to construct their vehicles. 6. Review Newton's 3 Laws of Motion. Ask students to explain using objects in the room. 7. Review types of forces that can act on an object. Ask students to explain using objects in the room. 8. Have teams read the Handout: Newton's Scooters aloud. Clarify rules for them. 9. Tell them they have the remainder of the time to construct their vehicles. They must build their vehicles using their sketch as a guide. They may need to modify their sketch when and if they realize it is not working. Monitor student progress and check for understanding periodically. 10. When time is up, show teams where they may store their vehicles until the next meeting. Collect sketches and handouts.
Session 3	**Application and Competition** 1. Pass out team sketches. Tell them that today they will be testing their vehicles to see how well they understand and can apply Newton's 3 laws of motion. 2. Tell them that they will be presenting their sketches and describing how they are

	using Newton's 3rd law to move it. Write the following terms on the board: 'gravity', 'friction', and 'air resistance'. Review what each force is and how it acts on the motion of objects. 3. Tell each team to label where 'gravity' is acting on their vehicle. They may draw it in using their pencils/pens. 4. Tell each team to label where 'friction' is acting on their vehicle. 5. Tell each team to label if and where 'air resistance' is acting on their vehicle. 6. Monitor team sketches to check for understanding. 7. Tell teams to collect their vehicles and check for repairs that may need to be done. 8. Allow students 10 minutes to fix their vehicles. 9. Allow students 15 minutes to test their vehicles on the track. 10. Gather students into groups. Tell each team to present their sketch and scooter to the group. Each team will point out what their scooter is built from, how it uses Newton's 3rd law to move, and how the forces of gravity, friction, and air resistance act on their scooter. 11. After all teams have presented, teams will take vehicles to the race track for final test. 12. Test each vehicle individually.
Closure	1. After completion of scooter test, teams will discuss their project. 2. Ask, "What would you do differently next time?" "How could you improve your scooter?" "What problems did your team encounter in building your scooter?" 3. Write the following conclusion question on the board: How do Newton's Laws of Motion affect how far and fast a vehicle such as a scooter moves? 4. Have students complete their MESA Notebook including the conclusion using the conclusion question.
Extensions	• Scooter Competition: Fastest, furthest, most imaginative design. • Graph the speed of each scooter.
Informal Assessment	27. Monitor students as they progress through the project. 28. Monitor students to check for understanding periodically. 29. Informal Oral Presentation of team sketch and scooter.
Formal Assessment	• Completed scooter sketch. • Completed scooter. • Completed MESA Notebook.
Trouble Shooting	• Make sure teams bring their supplies. • Have track laid out with masking tape before session 3 meeting begins.

SEI Strategies Used

Preparation	Scaffolding	Grouping Options
☒ Adaptation of Content	☒ Modeling	☐ Whole class
☐ Links to Background	☐ Guided practice	☒ Small groups
☒ Links to Past Learning	☐ Independent practice	☐ Partners
☒ Strategies incorporated	☒ Comprehensible input	☒ Independent
Integration of Processes	**Application**	**Assessment**
☒ Reading	☒ Hands-on	☒ Individual
☒ Writing	☒ Meaningful	☒ Group
☒ Speaking	☒ Linked to objectives	☒ Written
☒ Listening	☒ Promotes engagement	☒ Oral

Arizona Math Standards Addressed	• (none)

Arizona Science Standards Addressed	• S1C2: TSW design and conduct an investigation demonstrating safe behavior and appropriate procedures while keeping a record of observations, notes, sketches, and questions. • S1C4: TSW communicate the results of their investigation. • S5C2: TSW understand the relationship between force and motion.

First Law of Motion

According to Newton's first law...

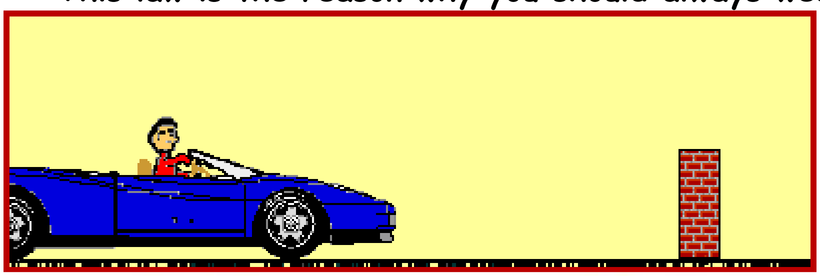
An object at rest will remain at rest unless acted on by an unbalanced force. An object in motion continues in motion with the same speed and in the same direction unless acted upon by an outside force.

This law is often called "the law of inertia".

What does this mean?

This means that there is a natural tendency of objects to keep on doing what they're doing. All objects resist changes in their state of motion. In the absence of an outside force, an object in motion will maintain this state of motion.

This law is the reason why you should always wear your seatbelt.



Second Law of Motion

According to Newton's second law...

Acceleration is produced when a force acts on a mass. The greater the mass (of the object being accelerated) the greater the amount of force needed (to accelerate the object).

What does this mean?

Everyone unconsciously knows the Second Law. Everyone knows that heavier objects require more force to move than lighter objects.

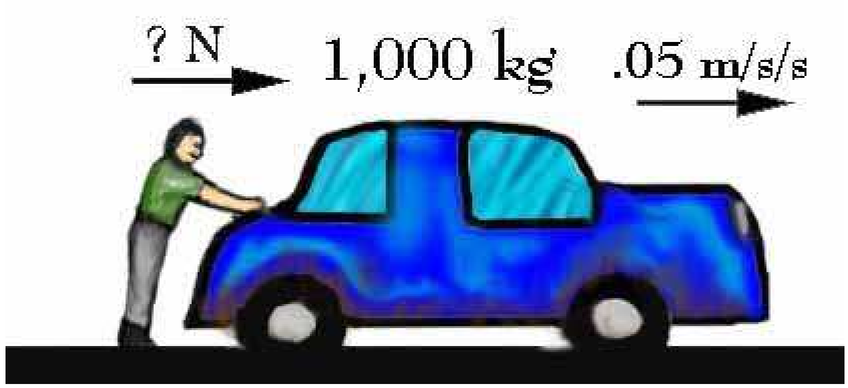
However, the Second Law gives us an exact relationship between force, mass, and acceleration. It can be expressed as a mathematical equation:

F = M A

or

FORCE = MASS times ACCELERATION

This is an example of how Newton's Second Law works:

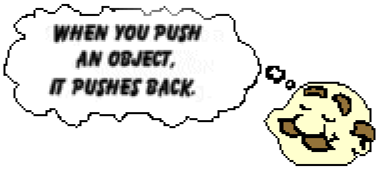


Mike's car, which weighs 1,000 kg, is out of gas. Mike is trying to push the car to a gas station, and he makes the car go 0.05 m/s/s. Using Newton's Second Law, you can compute how much force Mike is applying to the car.

F=1,000 X 0.05

Answer = 50 kg*m/s^2, or 50 Newtons

Third Law of Motion



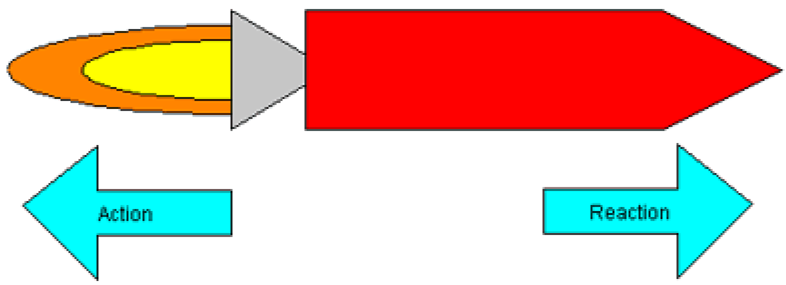
According to Newton's third law...

For every action there is an equal and opposite reaction.

What does this mean?

This means that for every force there is a reaction force that is equal in size, but opposite in direction. That is to say that whenever an object pushes another object it gets pushed back in the opposite direction equally hard.

Let's study how a rocket works to understand Newton's Third Law.



The rocket's action is to push down out on its fuel with the force of its powerful engines, and the reaction is that the fuel pushes the rocket with an equal force.

Source: http://teachertech.rice.edu/Participants/louviere/Newton/

Types of Forces

Define the following terms in your own words and try to give examples.

- Gravity:

- Friction:

- Air Resistance:

Newton Scooters

Goal:

- Each team will build one Newton Scooter. It must move using Newton's 3rd Law of Motion: For every action, there is an equal and opposite reaction.
- **Your team's scooter must:**
  -Travel 3 meters across a track and stay within a 1 meter width boundary. Basically, it should travel pretty straight.
  -Be built from scratch. Your team is responsible for bringing materials from home. You may use everyday things such as a matchbox, soda cans, Gatorade bottles, CDs, thread spindles, string, straws, balloons, rubber bands, pencils.
  Ask your team:
  - What can we use for the body?
  - What can we use for wheels?
  - What can we use for axles?
  - How is it going to be held together?
  - What will make it go?

Materials:

<u>Newton Scooter Sketch</u>
- Drawing paper
- Colored Pencils

<u>Newton Scooter</u>
- Any materials decided upon by each team

Instructions:

<u>Scooter Sketch</u>

10. Design your scooter with your team.
11. Draw your sketch on the drawing paper provided by your advisor. Use colored pencils.
12. Your drawing must show what types of materials are being used in your car.
13. Your drawing must show how friction is acting on your scooter.
14. Your drawing must show how gravity is acting on your scooter.
15. Your drawing must show how air resistance is acting on your scooter.
16. Get final approval from your advisor.

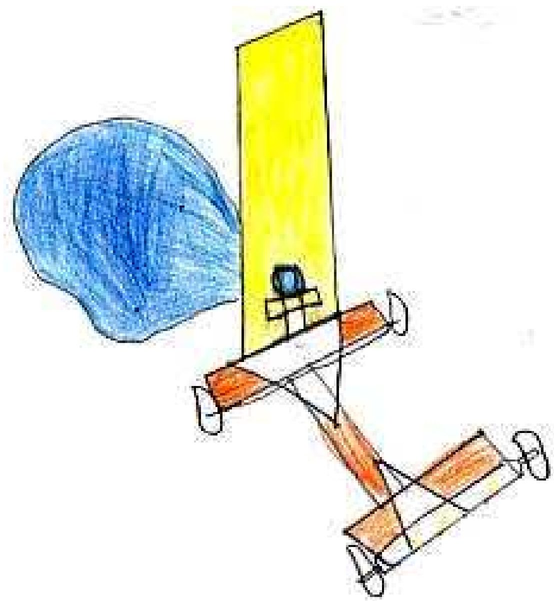
<u>Scooter Construction</u>

1. Check to make sure your team has all the materials needed for your car. If not, you need to modify your drawing.
2. Build your scooter with your team.
3. Test your scooter if time permits.

Rules:

- Scooter must be teacher-approved before construction begins.
- Scooter must move forward by pushing backward on the floor, another object or the air.
- Scooter must be built from scrap materials. No pre-made vehicles or "kits" allowed.
- You cannot interfere with your scooter once it leaves the starting line. You cannot give it a push as you launch it, and you cannot make adjustments after it is launched.
- You may not power your scooter with any form of electricity, fire, explosions, burning fuel or gravity.
- You may use a "track" to keep your vehicle within the 1 meter wide area. You must supply the track yourself, and can use pre-made parts, like a toy car track, or make your own.
- Your scooter does not have to move on the ground. It may travel through the air. A string or fishing line stretched between 2 chairs could be used as an air "track."
- Your class presentation must include a sketch of your scooter that illustrates the forces that act upon it. You should be able to explain any modifications that you made to your scooter to improve its performance.

Good Luck and Have Fun!



Lesson Activity

Title	On-Site Design Challenge: Paper Tower (60-80 Minutes)
ID Number	MS-E-OS2
Sequence and Duration	• Lead In: 10-15 Minutes • Activity: 40-50 Minutes • Closure: 10-15 Minutes
Age Level	Middle School
Essential Question	**What have I learned about on-site engineering challenges?**
Learning Objectives	• TSW design and build a tower to specs. • TSW reflect on and evaluate their approach to the problem and the strategies they used to address it. • TSW evaluate their comfort level with on-site design challenges. • TSW continue brainstorming strategies to help them be successful at on-site design challenges in the future.
Other Objectives	• TSW develop a working plan with their group to develop a cooperative environment. • TSW communicate with their group by contributing their vocal input. • TSW develop critical reading skills by finding relevant information in given materials. • TSW listen to their peers discuss their approaches to the problem. • TSW contribute to a group discussion about being successful in on-site design challenges.
Key Terms	• On-site design challenge • Approach • Strategy
Materials Needed	Per Class: • Meter stick • On-Site Engineering Design Data Collection Sheet • Scratch paper (different from paper in the building materials) Per Group: • Handout: On-Site Engineering Design specs • 1 sheet of paper • 12 inches clear tape • 1 pair of scissors • 1 ruler
Lead In	26. Remind the students that for the on-site challenge, teams will receive their mission and the specs only when they arrive "on site", and they must design, build and test their structure within the given time period and with the given materials. So they will essentially be "designing under pressure", relying on their ability to address the mission quickly by drawing on their prior knowledge and being strategic about their decisions and process. 27. Ask students to think about when they last practiced with an on-site design challenge. Allow time for discussion, using prompts such as the following: What did they learn from the on-site challenge? What kinds of skills and knowledge did they need to use to be successful with it? What did they think they might do differently next time to help them do better? 28. If they are available, have students review what they wrote in their MESA Notebooks for that challenge, in response to the question: "How should I

	approach an on-site engineering challenge?" 29. Tell students they will be doing a practice on-site design challenge today. Once they have their materials, they will have exactly 30 minutes to complete the mission. Remind them to consider the skills and strategies they discussed that will help them to be successful.
Activity	58. Separate students into groups of two and hand out the supplies to each pair. When all supplies have been distributed, hand out the specs face down, instructing students not to turn them over until you tell them to. Tell them they may raise their hands if they need clarification about the rules, but to think of you as the judge, not their advisor. 59. Call out "begin!" and start the 30 minute count-down. 60. After 30 minutes are up, call time and have students clean up their areas and bring their towers and any remaining tape to the testing area. 61. For each tower, measure the perpendicular distance from the testing surface to the highest point. Try to measure to the nearest millimeter. Record the heights on the Data Collection Sheet. 62. Declare the team with the highest tower to be the winners. In the case of a tie, the group that used the *least* amount of tape (i.e. has the most amount of tape remaining) is the winner. 63. Clean up the materials and testing area and have students return to their seats.
Closure	20. Give students time to reflect on their approaches and strategies with this challenge, first with their groups and then reporting out to the whole class. Were they better prepared to approach this challenge after trying an on-site challenge once before? What did they learn from the first challenge that helped them be successful with this one? What did they do differently? What did they do similarly? 21. Ask students what knowledge they used for this challenge, e.g. previous experiences with tower-building; knowledge of structural elements; knowledge of team work strategies; knowledge of the engineering process, etc. 22. Ask students to reflect on their level of anxiety when approaching this challenge. Did trying out two on-site challenges help them feel more comfortable about doing on-site design in the future? 23. In their MESA Notebooks, have students respond to the following conclusion question: *What have I learned about on-site engineering challenges?* They can use the remaining time to complete their Notebooks or finish them as homework.
Informal Assessment	30. Monitor students' participation in the activity. 31. Monitor students' participation in the discussion.
Formal Assessment	• Completed MESA Notebook. • Completed tower.
Trouble Shooting	• Separate out each team's materials and place them in baggies or boxes prior to students' arrival to class. • You can have students build towers with whatever materials you happen to have on hand. Feel free to improvise to create your own challenge.

SEI Strategies Used

Preparation	Scaffolding	Grouping Options
☐ Adaptation of Content	☐ Modeling	☒ Whole class
☐ Links to Background	☐ Guided practice	☐ Small groups
☒ Links to Past Learning	☒ Independent practice	☒ Partners
☒ Strategies incorporated	☐ Comprehensible input	☐ Independent

Integration of Processes ☒ Reading ☐ Writing ☒ Speaking ☒ Listening Application ☒ Hands-on ☒ Meaningful ☒ Linked to objectives ☒ Promotes engagement Assessment ☐ Individual ☒ Group ☐ Written ☒ Oral	
Arizona Math Standards Addressed	(none)
Arizona Science Standards Addressed	• S3C2: TSW develop viable solutions to a need or problem.

ON-SITE ENGINEERING DESIGN
Middle School Level
Paper Tower

OBJECTIVE:

Your challenge is to design and build the tallest tower out of the given materials. Your team shall compete with other teams in a head-to-head competition.

MATERIALS:

1 – Sheet of paper
12 – inches clear tape

Other materials available for use but not included in the design:

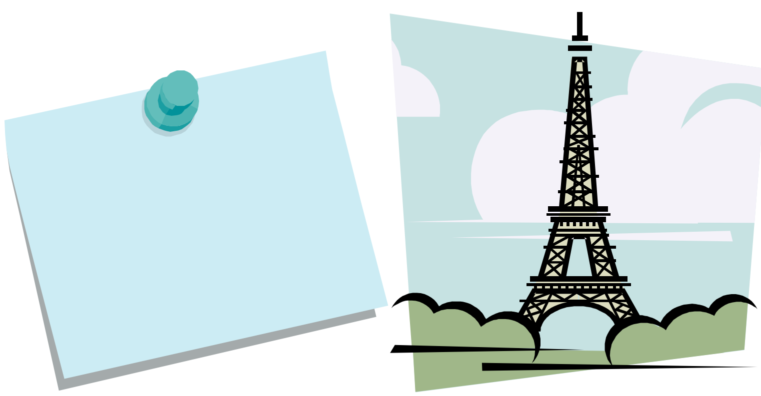
Scissors Ruler Pencil Scratch Paper

RESTRICTIONS and INSTRUCTIONS:

- Each tower must be made out of only the supplied paper and tape. No other materials, including other paper, can be used.
- Each tower must be free-standing. It must not be attached to or leaning against any other surface.
- After thirty minutes, towers must be moved to a judging area. No contact between team members and tower may be made after the tower is moved.

SCORING:

- Towers must stand for 10 seconds.
- All towers, whether straight, curved or sagging, will be measured from the surface of the judging area to their highest vertical point. Neither the judge nor team members may straighten towers.
- The highest tower will be declared the winner.
- In the event of a tie, the team that used the least tape in their design will be declared the winners.



ON-SITE ENGINEERING DESIGN
Middle School Level
Paper Tower

Data Collection Sheet

Group Members	Tower Height (cm)	Remaining Tape (mm)

MESA Mathematics Engineering Science Achievement

Lesson Activity

Title	**Design a Payload Delivery Device (70-80 minutes)**
ID Number	MS-E-OS1
Sequence and Duration	• Lead In: 10-15 Minutes • Activity: 50-60 Minutes • Closure: 10-20 Minutes
Age Level	Middle School
Essential Question	**How should I approach an on-site engineering challenge?**
Learning Objectives	• TSW design and build a payload delivery device to specs. • TSW reflect on and evaluate their approach to the problem and the strategies they used to address it. • TSW evaluate their ability to design and construct under pressure. • TSW brainstorm strategies to help them be successful at on-site design challenges in the future.
Other Objectives	• TSW develop a working plan with their group to develop a cooperative environment. • TSW communicate with their group by contributing their vocal input. • TSW develop critical reading skills by finding relevant information in given materials. • TSW listen to their peers discuss their approaches to the problem. • TSW contribute to a group discussion about being successful in on-site design challenges.
Key Terms	• On-site design challenge • Approach • Strategy
Materials Needed	Per Class: • An obstacle, e.g. a shallow dish of water or an area rug • A small payload, e.g. a marble, pencil, or paper clip • A payload receptacle, e.g. a paper cup or small bowl • Stopwatch • Ruler or tape measure • On-Site Engineering Design Data Collection Sheet Per Student: • Handout: MESA Notebook • Handout: MESA Day On-Site Engineering Design Event Specifications Per Team: • Handout: On-Site Engineering Design specs • 4 clothes pins • 3 feet of twine or yarn • 1 mousetrap • 10 popsicle sticks • 1 foot of masking tape • 6 inches of duct tape • 2 small washers • 2 binder clips • 2 Styrofoam cups • 2 pairs of scissors • Scratch paper for drawing

	• Other materials of your choice, such as cardboard, rubber bands, cardstock, etc., ensuring that all teams have identical supplies
Lead In	30. Tell students you will be talking about preparing for one particular MESA Day competition today: the On-Site Design challenge. Hand out the MESA Day On-Site Engineering Design event specs and read through them with the students. 31. If there are students in the class who have participated in previous MESA Day events, allow them to comment on the On-Site challenge. If there are no students with previous experience, solicit students' ideas about what the on-site design challenge will be like. 32. If it has not already been discussed, tell students that for the on-site challenge, teams will receive their mission and the specs only when they arrive "on site", and they must design, build and test their structure within the given time period and with the given materials. So they will essentially be "designing under pressure", relying on their ability to address the mission quickly by drawing on their prior knowledge and being strategic about their decisions and process. 33. Ask students what kinds of skills and strategies might be useful for this kind of challenge. Possible skills include: the ability to work under pressure; patience; ability to apply previous learning to the task; having a solid understanding of the mission; ability to work well with your team members. Strategies include: reading the specs carefully; reviewing what you know about the science behind the mission; taking the time to design prior to building; working efficiently so you have time to test and modify prior to competing.
Activity	64. Tell students they will be doing a practice on-site design challenge today. Once they have their materials, they will have exactly 30 minutes to complete the mission. Remind them to consider the skills and strategies they discussed that will help them to be successful. 65. Separate students into groups of three or four and hand out the specs face down, instructing students not to turn them over until you tell them to. When all groups have a copy, have them flip the specs over and read their mission. Point out the obstacle, payload and payload receptacle, and let them know if there is anything specific to them that they need to know about (e.g. where distances will be measured from). Inform them that they are only allowed to control their device from ONE side of the obstacle (the "departure" side), and all team members must remain on that side. Remind them that their objective will be to get their payload as close as possible to the receptacle. In the case of a tie (teams getting equally close or into the receptacle), the fastest delivery will win. 66. Tell students that at any time they may raise their hands if they need clarification about the rules, but to think of you as the judge, not their advisor. 67. Hand out the supplies to each group, instructing students not to touch them until all groups have their supplies. 68. Call out "begin!" and start the 30 minute count-down. 69. After 30 minutes are up, call time and have students clean up their areas and bring their devices to the testing area. 70. Begin the competition. Call teams up one by one, allowing two minutes for them to set up their device and place the payload. Call out "go" and start the time on the stopwatch. Monitor the team's actions as they deliver the payload. When the payload drops, stop the watch and record the time on the Data Collection Sheet. Measure the distance from the payload to the point on the receptacle and record this distance on the Data Collection Sheet. 71. Ensure that all students are attentive to other groups' deliveries. 72. Do not allow last-minute adjustments to the design of the devices above and beyond setting it up for initiation.

	73. When all teams have completed their deliveries, declare the winner of the mission.
Closure	24. Initiate a discussion of students' strategies in approaching the challenge, and their experiences as they were engaged in designing and constructing. Were all students able to build successful devices? Why or why not? 25. For teams that were successful, what helped them figure out how to design their devices? What else helped them succeed? 26. Ask how many students thought of other challenges they've participated in when they were designing their device. How did what they learned from those experiences help them make decisions about their designs? For students who did not have previous experiences, what did they think about as they were designing? Did they have other knowledge that helped them design their devices? 27. If students did not know how to proceed, discuss some possibilities. Students could try experimenting with different designs quickly, thinking of examples of things they've seen that move things from place to place, thinking back over other scientific knowledge they have that might relate to the mission, etc. 28. Ask students, for future on-site design challenges, how might you approach the problem? What strategies will you use? How will you make the best use of your time? 29. In their MESA Notebooks, have students respond to the following conclusion question: *How should I approach an on-site engineering challenge?* They can use the remaining time to complete their Notebooks or finish them as homework.
Informal Assessment	32. Monitor students' participation in the activity. 33. Monitor students' participation in the discussion.
Formal Assessment	• Completed MESA Notebook. • Completed device.
Trouble Shooting	• Separate out each team's materials and place them in baggies or boxes prior to students' arrival to class. • What materials the groups receive to create their designs is not as important as the fact that all groups have the same materials. Feel free to improvise with materials you have on hand. • You may have students who freeze under time constraints; urge these students to relax and take one step at a time. Encourage them to just begin talking or designing and do the best they can with the time they have. • If students are asking questions during the design time, be sure to answer the questions loudly and make sure that all groups receive the information. Feel free to improvise with the rules (e.g. the payload must be placed, not dropped; disqualification if the payload gets wet, etc.) so long as all students have this information when they are designing. • You may want to have a bell or other signal for getting all students' attention when you are about to make a clarification of the rules. • Make sure the "departure-side border of the obstacle" referred to in the specs is clear, e.g. the departure-side wall of a basin of water. Mark off the border if it is not readily apparent. Point out the border to the students when you are reviewing the specs. • Prior to the competition, identify a standard location on the receptacle to measure from when measuring the distance from the payload to the receptacle, and point out this location to the students when explaining the rules.
SEI Strategies Used	

Preparation ☐ Adaptation of Content ☐ Links to Background ☒ Links to Past Learning ☒ Strategies incorporated	Scaffolding ☐ Modeling ☐ Guided practice ☒ Independent practice ☐ Comprehensible input	Grouping Options ☒ Whole class ☒ Small groups ☐ Partners ☐ Independent
Integration of Processes ☒ Reading ☒ Writing ☒ Speaking ☒ Listening	Application ☒ Hands-on ☒ Meaningful ☒ Linked to objectives ☒ Promotes engagement	Assessment ☐ Individual ☒ Group ☒ Written ☒ Oral

Arizona Math Standards Addressed	(none)
Arizona Science Standards Addressed	• S3C2: TSW develop viable solutions to a need or problem.

ON-SITE ENGINEERING DESIGN
Middle School Level
Payload Delivery Device

OBJECTIVE:

Your engineering team has been hired to design and build a device that will safely deliver a payload from one side of an obstacle to the other and place it in a payload receptacle. The team shall compete with other teams in a head-to-head competition. The team who gets the payload closest to the receptacle in the fastest time wins.

MATERIALS:

4 – clothes pins
3 – feet of twine or yarn
1 – mousetrap
10 – popsicle sticks
1 – foot of masking tape
6 – inches of duct tape
2 – small washers
2 – binder clips
2 – Styrofoam cups

Other materials available for use but not included in the design:

Scissors Pencil Paper

RESTRICTIONS and INSTRUCTIONS:

1. All team members must remain on the "departure" side of the obstacle. Any contact with the device must be restricted to this side. Team members' hands (and other body parts) cannot extend beyond the departure-side border of the obstacle.
2. The payload must begin its journey on the departure side of the obstacle, before the departure-side border.
3. The payload may be placed into the device by hand, but no other physical contact can be made with the payload after this point.
4. The payload must travel completely across the obstacle. Teams will be penalized if the payload does not complete the journey.
5. When time is called, all devices must be brought to the judge. When it is your team's turn to compete, you will have two minutes to assemble your device before initiation.

SCORING:

- Distance from the receptacle will be measured by judge(s) using a ruler or tape measure.
- Each team's payload delivery will be timed from the point the judge says "go" to the point the payload is delivered, using a standard digital stopwatch.

Distance ties will be broken by using the fastest device!

ON-SITE ENGINEERING DESIGN
High School Level
Glider

Data Collection Sheet

Group Members	Distance from Receptacle (cm)	Time (s)

Last updated 7/30/2008

Mathematics Engineering Science Achievement

Lesson Activity

Title	**Seeing the Wind (45-60 minutes)**
ID Number	MS-S-A7
Sequence and Duration	• Lead In: 10-15 minutes • Activity: 20-25 minutes • Closure: 15-20 minutes
Age Level	Middle School
Essential Question	**How does the wind differ at different heights above the Earth?**
Learning Objectives	• TSW describe how the wind varies with height above the ground. • TSW explain how height and obstructions affect the wind in a certain area. • TSW extend their learning to consider how wind speed and turbulence can affect wind turbines and wind farms.
Other Objectives	• TSW contribute to a group discussion about wind and wind speed. • TSW communicate with their group by contributing their vocal input. • TSW collaborate with their group to develop a cooperative environment.
Key Terms	• Wind speed • Turbulence • Windmills and wind turbines
Materials Needed	Per Class: • One or two large, sturdy kites or several large helium balloons • Kite string, at least 100-150 feet • 15 3-4 foot streamers – e.g. caution tape, crepe paper • Wind speed meters (optional) • Handout: Seeing the Wind Set-Up Per Student or Pair: • Handout: Seeing the Wind worksheet
Lead In	34. Get students talking about the wind. Ask them questions such as, where is the windiest place they've ever been? What are the windiest places in the world? Is it windier in the summer or winter? Is it windier in the desert, on a mountain, near the ocean, in the city, in a field? Where do you go if you want to get away from the wind? Why? Have students ever seen a windmill or turbine? How do they work? Are they located in some places and not others? Why? Are they usually tall or short? Why? Give students a chance to talk about and mull over these questions.
Activity	74. Tell the students that their activity today will be "looking" at the wind in different places. Ask them to brainstorm ways they might do this, and why. 75. If it has not already been suggested, let the students know that they will be looking at the effect the wind has on objects in different places. Namely, they will be looking at the wind's effect on objects at different heights, and in different locations. They will be tying streamers of a light, bright substance (such as caution tape or crepe paper) to the string of a high-flying kite or balloon to see how the streamers are affected by the wind. 76. Show the students what the set-up will look like and have them help put it together. Students can be measuring and cutting streamers, spacing out and tying streamers to the string, and maybe siting locations for the kite/balloons to go up. 77. Ask the students to think about what this set-up will show them. How does it allow them to "see" the wind? [The streamers will blow out in the direction of the wind; the straighter out the streamer is, the stronger the wind, and the

	more flapping the streamer does, the more variable the wind.] 78. Have the students predict what they will see when the kite or balloons go up. Will all the streamers look the same? Does it matter where the kite/balloons are placed? How would streamers on a kite near a building compare to streamers on a kite in the middle of a field? Allow students to discuss their predictions briefly. 79. Hand out the Seeing the Wind worksheet to students individually or in or pairs. Direct their attention to the questions they will be asked to answer after their make their observations. Make sure they complete a drawing of their prediction and explain why they made this prediction. 80. Bring the students and materials outdoors and set the kite or balloons aloft. When the kite/balloons are as high as you like, anchor the string to the ground and give the students 5-10 minutes to make observations. 81. If you have more than one set-up, place them in different areas with different conditions; if you have only one set-up, try to place it in an open area bordered on one side by obstructions such as trees or buildings. The obstructions will cause turbulence in the wind at lower altitudes, resulting in a greater variability among streamers at differing heights. 82. [Optional: If you have wind speed meters, take readings at the ground level and attach them to the kite or balloons to get a reading at a higher altitude. Have the students predict the results and analyze the outcome.] 83. After students have completed their drawings, have them all lie on the ground. Ask if they can feel the wind. Is it strong or weak? How does it compare to what they felt when they were standing? 84. Gather the materials and return to the classroom.
Closure	30. Give the students a few minutes to discuss their observations and respond to the questions on the worksheet. Ask them what it means if the streamers at different heights were moving differently. [Streamers blowing at different angles mean the wind is blowing at different velocities; shallow angles mean weak winds while 90 degree angles mean strong winds. Streamers flapping wildly mean the wind is irregular, or *turbulent*; streamers whose motion is steady mean the wind is fairly constant.] 31. Ask the students to come up with explanations for why the wind is different at different heights above the ground. Did they see a pattern? [The air nearer to the ground is more turbulent and slower than air higher up.] Why might this be? Allow students to brainstorm, accepting all answers. Ask students follow-up questions to probe their thinking, especially if they talk about friction from, or interference with, the ground and structures on the ground (hills, buildings, trees, etc.). [The friction between the air and the ground slows the wind down, and air swirls around objects in its way, making winds in different directions, resulting in turbulence. At higher elevations, the air is further from the ground and only experiences friction from other air, and there are fewer obstructions, so the air smoothes out and speeds up.] 32. Refer the students back to the question about whether they have ever seen windmills or wind turbines. How do these machines work? [They use the wind's power to do work or to create electricity.] Why would engineers be interested in wind speed and turbulence when they choose sites for windmills and turbines? [The greater the wind speed, the more power the mill or turbine will have to do its job, so engineers choose locations with high wind speeds. Turbulent air can damage windmills and turbines, however, so they also need to choose areas where turbulence is minimal.]
Informal Assessment	34. Monitor students' participation in group discussion. 35. Monitor students' participation in making observations. 36. Monitor students' contribution to group work.

Formal Assessment	• Completed worksheet.
Trouble Shooting	• Choose a fairly windy day for this activity. • The more streamers you hang, the more data students can collect, but the heavier the setup becomes. Make sure you have a large kite or sufficient number of helium balloons to hold up the streamers' weight. You may also want to bring scissors with you when you bring the students outside, in case you need to prune some streamers in order to get the setup aloft. • The kite string with all its streamers can quickly become a tangled mess. Before bringing it outdoors, try wrapping the string and streamers around a cylinder (e.g. a bucket, paper towel roll) for easier transportation. When pulling the strings down from the sky, have the students help assemble them neatly by re-wrapping them.
Citation	• KidWind Project, http://www.kidwind.org

SEI Strategies Used

Preparation
- ☐ Adaptation of Content
- ☒ Links to Background
- ☐ Links to Past Learning
- ☒ Strategies incorporated

Scaffolding
- ☐ Modeling
- ☒ Guided practice
- ☐ Independent practice
- ☐ Comprehensible input

Grouping Options
- ☒ Whole class
- ☐ Small groups
- ☒ Partners
- ☒ Independent

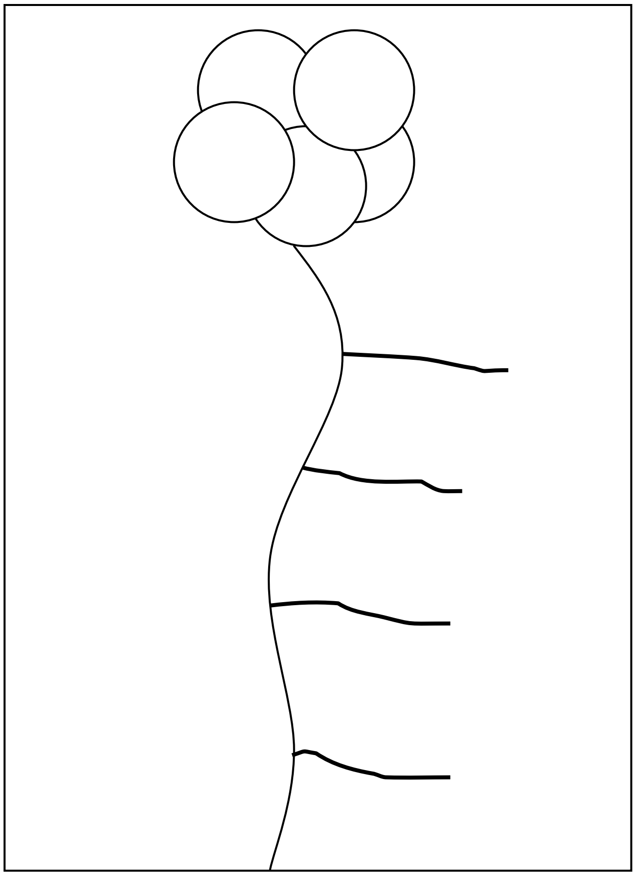
Integration of Processes
- ☒ Reading
- ☒ Writing
- ☒ Speaking
- ☒ Listening

Application
- ☒ Hands-on
- ☒ Meaningful
- ☒ Linked to objectives
- ☒ Promotes engagement

Assessment
- ☒ Individual
- ☐ Group
- ☒ Written
- ☐ Oral

Arizona Math Standards Addressed	(none)
Arizona Science Standards Addressed	• S1C1: TSW formulate predictions, questions or hypotheses based on observations. • S1C3: TSW analyze and interpret data to explain correlations and results. • S6C3: TSW understand characteristics of weather conditions and climate.

Seeing the Wind Set-Up



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Kite string: 100-150 feet

Streamers: 3-4 feet

Space streamers about 10 feet apart

You may need to use fewer streamers if they are heavy; your kite or balloons will not be able to fly as high with a lot of weight.

Seeing the Wind – Worksheet

Prediction **Data**

Draw a picture of what you expect the string and streamers will look like when they are set up outside.

Why do you predict that this will happen?

____

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Draw a picture of what you see when the string and streamers are set up.

What is happening?

____

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Does your data match your prediction?

How can you explain any differences between what you see and what you predicted?

Seeing the Wind – Worksheet

Compare the lower streamers with the higher streamers. How are they different?

Which streamers are flapping wildly?

Which streamers are almost motionless?

Why would the streamers move differently?

Where do you think the highest wind speeds are located? Give evidence to support your answer.

Where are the smoothest winds? Give evidence to support your answer.

What do you think affects the wind's speed? Give evidence to support your answer.

Lesson Activity

Title	On-Site Design Challenge: Skyscrapers & Earthquakes (40-55 minutes)
ID Number	MS-E-OS4
Sequence and Duration	• Lead In: 5 minutes • Activity: 30-40 minutes • Closure: 5-10 minutes
Age Level	Middle School
Essential Question	How can very tall buildings be engineered to withstand earthquakes?
Learning Objectives	• TSW design and build a model skyscraper that will remain intact when exposed to earthquake-like conditions. • TSW identify structural designs and strategies that were the most effective at protecting the skyscrapers during the "earthquake." • TSW identify similarities and differences between their approaches to and strategies for this challenge and other on-site design challenges.
Other Objectives	• TSW develop a working plan with their group to develop a cooperative environment. • TSW communicate with their group by contributing their vocal input. • TSW listen to their peers discuss their design choices. • TSW contribute to a group discussion about their approaches to the challenge.
Key Terms	• On-site design challenge • Skyscraper • Stability
Materials Needed	Per Class: • Non-stick cooking spray • 1 packet of gelatin per group, prepared prior to activity • Water for preparing gelatin • Meter stick • Timer Per Group: • Handout: On-site Engineering Design Specs • Bowl • Disposable plate • Roll of clear tape • 20 drinking straws • 2 pairs of scissors • 1 ruler • Other materials of your choice, such as paper clips, masking tape, paper, pipe cleaners, etc., ensuring that all teams have identical supplies
Preparation	35. Prior to class, prepare one batch of gelatin per group of 2-3 students. Pour each batch of gelatin into a soup bowl that has been sprayed with non-stick cooking spray, and refrigerate and allow to set. For consistency, use similarly-shaped bowls for each group. You may be able to split one packet of gelatin between two groups. Once set and removed from the bowls, the gelatin domes should be deep enough for a straw to be stuck into securely, and wide enough around that students will be able to build a foundation for a "building" on top. 36. When the gelatin is set, overturn each bowl onto a plate to distribute to each group. Or, have the students complete this step in the classroom.

Lead In	37. Initiate a discussion about students' experience and knowledge of earthquakes. Have they ever felt an earthquake? Do they know anyone who has been through a very strong earthquake? What do they know about current events related to earthquakes? What are the dangers associated with earthquakes? 38. Ask the students if they would rather be in a very large, tall building, or a small, low building during an earthquake. Why? What factors might influence their decision? 39. Ask the students to think about what architectural engineers have to consider about the impacts of earthquakes on the buildings they design. How do earthquakes affect the stability of structures, and what can engineers do to prepare for earthquakes and reduce the amount of damage they do to buildings? 40. Tell the students that today they will be doing an on-site design challenge that will require them to address this issue.
Activity	85. Separate students into groups of two or three and hand out the supplies. When all supplies have been distributed, hand out the specs face down, instructing students not to turn them over until you tell them to. Tell them they may raise their hands if they need clarification about the rules, but to think of you as the judge, not their advisor. They will have 20 minutes to complete the challenge. Remind them to consider the skills and strategies for on-site design challenges they learned about already that will help them to be successful. 86. Call out "begin!" and start the 20 minute count-down. 87. After 20 minutes are up, call time and have students clean up their areas and bring their skyscrapers to a table that will serve as the testing area. 88. For each skyscraper, measure the distance from the "ground" (the table and floor) and the highest point of the structure. Try to measure to the nearest millimeter. Record the heights on the Data Collection Sheet. The tallest building (or buildings, in case of a tie) receives 50 points, the 2nd tallest receives 40 points, the 3rd receives 30 points, 4th receives 20, and 5th receives 10. All others receive zero points for height. 89. Subject all skyscrapers to an earthquake by shaking the table on which the structures are sitting for ten seconds. If any building begins to break or collapse in any way during the earthquake, give these structures zero points for earthquake readiness. Continue subjecting the structures to ten-second earthquakes until all buildings have been destroyed. Structures receive 10 points for every earthquake they survive. If, after five earthquakes, any building is still standing, this structure receives 50 points. 90. Declare the winner to be the group with the most points. In the event of a tie, the taller structure wins.
Closure	33. Ask the students to reflect with their groups about the knowledge they used when they designed their buildings, and the things they tried to do to counteract the effects of an earthquake. When they have had time to discuss, have them report out to the whole class. Which building strategies and/or structural designs seemed to work the best? How did the groups choose these strategies/designs? [If students have done previous "tower"-type challenges, ask them to talk about what they learned from doing those activities that helped them with this one.] 34. Have the students discuss their approaches and strategies with this challenge. How was their approach different with this activity than with other on-site design challenges they've tried? How was it similar? 35. In their MESA Notebooks, have students respond to the following conclusion question: *How can very tall buildings be engineered to withstand earthquakes?*
Informal Assessment	37. Monitor students' participation in the activity. 38. Monitor students' participation in the discussions.

Formal Assessment	• Completed MESA Notebook. • Completed exercise machine.
Trouble Shooting	• Separate out each team's materials and place them in baggies or boxes prior to students' arrival to class. • What materials the groups receive to create their designs is not as important as the fact that all groups have the same materials. Feel free to improvise with materials you have on hand. • If the students will be eating the gelatin after the activity, wrap the domes in plastic wrap until the activity is over (straws can be punched through the wrap).
Citation	• Adapted from: Raytheon Company. (2006). Jello-mounted skyscraper. Raytheon Classroom Projects – Elementary [CD].

SEI Strategies Used

Preparation
- ☐ Adaptation of Content
- ☒ Links to Background
- ☒ Links to Past Learning
- ☒ Strategies incorporated

Scaffolding
- ☐ Modeling
- ☐ Guided practice
- ☒ Independent practice
- ☐ Comprehensible input

Grouping Options
- ☒ Whole class
- ☒ Small groups
- ☐ Partners
- ☐ Independent

Integration of Processes
- ☒ Reading
- ☐ Writing
- ☒ Speaking
- ☒ Listening

Application
- ☒ Hands-on
- ☒ Meaningful
- ☒ Linked to objectives
- ☒ Promotes engagement

Assessment
- ☐ Individual
- ☒ Group
- ☐ Written
- ☒ Oral

Arizona Science Standards Addressed	• S3C2: TSW develop viable solutions to a need or problem.

Data Collection Sheet

Group Members	Height (cm) Circle 1st, 2nd, 3rd, 4th, and 5th tallest	Points for Height	Number of Earthquakes Survived	Points for Earthquake Readiness

ON-SITE ENGINEERING DESIGN
Middle School Level
Skyscraper

OBJECTIVE:

Today's engineers envision that in the 22^{nd} century, buildings will be up to 300 stories high. As buildings grow taller, the ground beneath them becomes a less dependable anchor, resulting in a serious stability problem. Your team's objective is to design and build a skyscraper with the given materials that is as tall as possible and able to withstand earthquake-like conditions.

MATERIALS:

1 – Gelatin dome
1 – Roll of clear tape
20 – Drinking straws

Other materials available for use but not included in the design:

Scissors Ruler Pencil Paper

RESTRICTIONS and INSTRUCTIONS:

6. All skyscrapers must be anchored in the gelatin.
7. Skyscrapers may be built in any shape and to any height with the given materials.
8. No assistance and no physical contact can be made with your skyscraper once the earthquake is initiated.
9. The judge will subject all skyscrapers to five 10-second earthquakes by shaking the table on which all skyscrapers are standing.

SCORING:

- Skyscrapers will receive points for height based on the following:

Tallest:	50 points
2^{nd} Tallest:	40 points
3^{rd} Tallest:	30 points
4^{th} Tallest:	20 points
5^{th} Tallest:	10 points
All others:	0 points

- Skyscrapers will receive ten points for each earthquake they survive.

In the event of a tie, the taller building wins.

Lesson Activity

Title	**Solar Water Still (40-50 minutes)**
ID Number	MS-S-A8
Sequence and Duration	• Lead In: 5-10 minutes • Activity: 25-35 minutes • Closure: 5-10 minutes
Age Level	Middle School
Essential Question	**How is a solar water still similar to the water cycle?**

Learning Objectives	• TSW identify and describe the following terms:
	  ◦ Evaporation
	  ◦ Condensation
	  ◦ Precipitation
	• TSW compare the water cycle process to the solar water still and distinguish the similarities and differences.
	• TSW construct a simple water still using given materials.
	• TSW identify and explain the features of their water still and describe how it works.
	• TSW evaluate the strengths and weaknesses of their solar water still.

Other Objectives	• TSW read the directions for constructing the solar water still and discuss their clarification with their group and/or their MESA Advisor. • TSW communicate with their group by contributing their vocal input. • TSW listen as their peers discuss the construction of their solar water still. • TSW write down the procedure in their MESA Notebook.
Key Terms	• Evaporation: change of a liquid to a gas. • Condensation: change of a gas to a liquid. • Precipitation: moisture that falls from the air to the ground.
Materials Needed	Per student • Handout: MESA Notebook • Handout: Survival on a Desert Island • Handout: Solar Water Still Per Team • Large Bowl • Small cup • Tape • Plastic wrap • Small weight (ex. Rock) • Water • Salt • Long spoon for stirring • Colored pencils
Lead In	1. Pass out MESA Notebook. 2. Pass out Handout: Survival on a Desert Island. 3. Have students form teams of 3-4 students. 4. Read handout with students. Check for understanding. 5. Discuss dehydration in detail. Make references to the local area and how important hydration is in the Southwest. 6. If students ask questions like ‘what are we building’, ‘how does it work’, etc.,

	let them know that they will understand as the lesson progresses. [Note: The students are building a solar water still, not knowing its purpose or function.]
Activity	1. Let students build their mini solar still. Check for student participation. 2. Allow 10-15 minutes for construction of still. 3. When teams finish, have students put solar still bowls in a warm place to speed up condensation. (E.g. near a heater, outside in full sunlight, under a heat lamp.) 4. Read each item from 'Questions for Thought', followed by discussion, and try to formulate a class answer for each. Encourage discussion and lead students to make connections to their solar water stills. 5. When discussing the water cycle, you may want to illustrate it on the board or pass out a supplemental diagram. Some students may have background/prior knowledge of this natural occurrence. Encourage students to draw their understanding of the water cycle onto their paper using colored pencils. Check drawings to check for understanding. 6. When discussing the similarities between the solar water still and the water cycle, guide students to point out where evaporation, condensation, and precipitation occur in each. Refer to their drawing of the water cycle and make connections between each cycle. 7. Wrap up 'Questions for Thought' by asking students if they can explain how their solar water still uses the same concepts as the water cycle. Call on students at random to explain the phenomenon, soliciting help from the class where needed. 8. Allow students to check their solar water stills. Water has probably not collected in the cup yet, but students may be able to see the condensation on the bottom of the plastic wrap. Ask students: • If we were to let this sit overnight, what would we probably find tomorrow? Why? *There will probably be water in the cup. More water droplets are going to form overnight.* • Why did we put the weight right above the cup? *The weight provides the angle for the water to drip into the cup.* • Is the water on the plastic that will drip into the cup pure, clean drinking water? Why do you think so? *Yes, it is. The salt water is evaporating and leaving the salt behind. Only pure clean water is forming on the plastic.* • Can you point out to me where evaporation, condensation, and precipitation are occurring on your bowl? *Students can point to specific places on the bowl.* • Why do you think the plastic wrap has to be closed tightly around the bowl so that no air gets in or out? *The plastic wrap is trapping heat in the bowl, thus speeding up the evaporation.* 9. Finish group discussion about their bowl construction. 10. Have group return to their teams and pass out Handout: Solar Water Still. 11. Read handout with students and refer to their bowl construction. 12. Discuss each question with group and encourage their input. Check for understanding. • Describe how the solar water still is similar to the water cycle. *Evaporation, condensation, and precipitation occur in each one. Fresh, clean water is the product of both.* • If you were stranded in the Arizona Sonoran Desert, could a solar water still be constructed using the same materials? What would be different? *Yes, a solar water still could be constructed using the same things, or even fewer materials could be used. The most important part of a solar water still is the clear covering, the plastic. Many hikers in Arizona carry a clear sheet of plastic covering with them all the time*

	in case they get lost and need to build a solar water still. In the desert, there is often no readily available water source like salt water. • List possible water sources in the Arizona Sonoran Desert. *Desert plants like cacti or even the dirt are sources of water in the desert. So, when you build a solar water still in the desert, you would put your plastic over dirt and desert plants. It takes longer to collect water, but it can be done.* • Modern engineers are trying to build a large scale solar water still. Why would this be important for our society? *Answers may vary.*
Closure	1. Have students complete their MESA Notebook. They may draw their solar water still bowl design on the back using colored pencils. 2. Have students answer the following conclusion question: How is a solar water still similar to the water cycle?
Informal Assessment	39. Check for literacy understanding. 40. Check for active student participation.
Formal Assessment	• Completed solar water still. • Completed MESA Notebook.
Trouble Shooting	• Students may get goofy with the water. • Have plenty of paper towels and rags available for clean-up. • Have a warm place in mind before doing this activity. • Check the weather report if you plan to put bowls outside.

SEI Strategies Used

Preparation	Scaffolding	Grouping Options
☒ Adaptation of Content	☐ Modeling	☒ Whole class
☒ Links to Background	☐ Guided practice	☒ Small groups
☒ Links to Past Learning	☒ Independent practice	☐ Partners
☒ Strategies incorporated	☒ Comprehensible input	☒ Independent

Integration of Processes	Application	Assessment
☒ Reading	☒ Hands-on	☒ Individual
☒ Writing	☒ Meaningful	☒ Group
☒ Speaking	☒ Linked to objectives	☒ Written
☒ Listening	☒ Promotes engagement	☒ Oral

Arizona Math Standards Addressed	• (none)
Arizona Science Standards Addressed	• S1C1: TSW formulate questions based on observations. • S1C2: TSW keep a record of observations, notes, sketches, questions, and ideas using written logs. • S1C3: TSW form a logical argument about a correlation between variables. • S1C4: TSW communicate the results and conclusions of the investigation. • S3C2: TSW develop a viable solution to a need or problem and construct a solution to that need or problem using simple materials. • S4C3: TSW describe how water quality affects the quality of life. • S6C1: TSW analyze the interactions between the earth's atmosphere and the earth's bodies of water (The Water Cycle).

Survival on a Desert Island

You have been shipwrecked on a desert island. Some of the contents of your cruise ship have washed ashore: a mixing bowl, a drinking cup, and a plastic covering for the life boats. Looking around your new environment, you know several things:

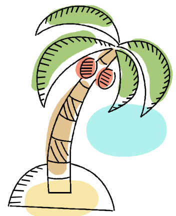
1. The human body can survive several days without food. As you look around the island, you think that there has got to be something you can eat from the land or from the sea.
2. The human body cannot survive longer than 3 days without water. There is water all around you, but it is salt water. You cannot drink it. You must think of a way to make fresh drinking water from the salt water.
3. You will be saved…it will just be a matter of days before help arrives.

Goal:

Your goal is to get drinking water as soon as possible. With the cruise ship contents that have washed ashore, it is possible to get fresh water. Dehydration is dangerous, especially in high temperatures. You know that if you do not get water soon, you will begin to get symptoms of dehydration:

- Nausea
- Headaches

- Muscle cramps
- Dizziness



Materials:

- Mixing bowl
- Drinking cup
- Plastic wrap
- Small weight (clay or a rock)
- Water
- Salt
- Spoon to stir

Instructions:

1. Get supplies from teacher for your team.
2. Fill your bowl half full of water.
3. Add 5 tablespoons of salt to the water and stir.
4. Put the drinking cup in the center of the bowl. Do not let it fill with any of the salt water.
5. Cover the bowl and the drinking cup with plastic wrap. Make sure the edges of the plastic wrap are sealing the edge of the bowl. There should be no air being let into the bowl. If you need, get some tape to tape down the plastic wrap.
6. Get your weight and put it in the middle of the plastic wrap right above the drinking cup.
7. Put your bowl in a warm spot for about 30 minutes.
8. Check your bowl to see what happened.

Questions for thought:

1. What is fresh water?

2. Where does fresh water come from?

3. Using the space below, draw the water cycle:

4. Explain how your bowl is acting like a miniature water cycle. Where is evaporation occurring? Where is condensation occurring? Where is precipitation occurring?

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Solar Water Still

Congratulations! You have constructed a Solar Water Still. Solar water stills are lifesaving devices that provide fresh water. Solar water stills use the energy from the sun to distill and purify contaminated water. Contaminated water is any water that is not drinkable.

<u>Post Activity Questions:</u>

1. Describe how a solar water still is similar to the water cycle:
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2. If you were stranded in the Arizona Sonoran Desert, could a solar water still be built using the same materials as this activity? What could be different?
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3. On the desert island, there was salt water all around that could be turned into freshwater. In the Arizona Sonoran Desert, any water is hard to find. List some possible water sources:
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4. Modern engineers are trying to construct a large scale solar water still. Why would this be important to our society?
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Lesson Activity

Title	**Spaghetti Beam Bridge (2 sessions, 50-70 minutes)**
ID Number	MS-E-C2
Duration	Session 1: Background and Design (50-70 minutes) Session 2: Building and Testing (50-70 minutes)
Age Level	Middle School
Essential Question	**How do engineering elements such as trusses address compression force and tension force on a bridge?** **How do they improve the strength and stability of a bridge?**
Learning Objectives	• TSW identify and recognize the 3 types of bridges: beam, arch, and suspension. • TSW describe the design features that classify the 3 types of bridges. • TSW define and apply the following terms: compression, tension, dissipate force, and transfer force. • TSW design and construct a spaghetti beam bridge using given materials. • TSW devise a spaghetti beam bridge design concept with their partner. • TSW modify their design as they begin to build to improve the overall structure. • TSW evaluate the strengths and weaknesses of their design and their constructed bridge. • TSW compare their design concept and their constructed bridge to those of their peers. • TSW describe the process they took to complete the spaghetti bridge project. • TSW explain how compression and tension is acting on their spaghetti beam bridge.
Other Objectives	• TSW develop a working plan with their group to develop a cooperative environment. • TSW communicate with their group by contributing their vocal input. • TSW listen as their peers discuss the design of their investigation. • TSW write down the procedure they used to design their project.
Key Terms	• Beam Bridge: a horizontal beam supported at both ends. • Arch Bridge: a bridge supported by curved structures. • Abutment: the end support of a bridge; in an arch bridge, the lower part of the arch that supports the arch. • Suspension Bridge: a bridge supported by cables anchored to towers. • Truss: triangular structure that helps support the load of bridges. • Compression: a force that acts to compress or shorten the thing it is acting on. • Tension: a force that acts to expand or lengthen the thing it is acting on. • Dissipate force: to spread out force over a greater area, so that no one spot has to bear the brunt of the concentrated force. An arch bridge is a good example of force dissipation. • Transfer force: to move it from an area of weakness to an area of strength, an area designed to handle the force. A suspension bridge is a good example of force transference.
Materials Needed	Session 1: For Teacher Demonstration • Meter stick • 2 chairs or 2 tables pulled close enough for the meter stick to span Per Student • Handout: Bridge

	• Handout: MESA Notebook Per Team (2-3 students) • Spaghetti Beam Bridge Challenge handout • Drawing paper • ½ pound of spaghetti • Glue Session 2: Per Group • Scale- Triple beam or Digital • Stopwatch Per Student • Handout: MESA Notebook Per Team (2-3 students) • Glue for repairs • 4 textbooks to suspend bridge across • 1 kg weight • Spaghetti Beam Bridge Challenge handout • My Bridge Design handout • Spaghetti Bridge Competition Data Sheet
Session 1	1. Pass out the Bridge handout. 2. Explain and give examples of the 3 types of bridges. You can use various sources to show examples: Bridge handout, overhead, internet, etc. (e.g. http://www.matsuo-bridge.co.jp/english/bridges/index.shtm) Discuss the positive and negative factors of each type of bridge. *For example:* *Beam Bridge: simple design, usually inexpensive, trusses can be added above or below the bridge to add support and strength, can only be built over short distances.* *Arch Bridge: very strong design, strength comes from arch structure that dissipates tension force to the abutments, old arch bridges from Roman times are still being used, can be built over longer distances than beam bridges, including over water.* *Suspension Bridge: can span very long distances, strength of design comes from the suspension structure, the towers and the anchorages of a suspension bridge absorb all the compression pressure, tension is relieved by cables suspended between the towers and the anchors, can span water, can be very expensive.* 3. Pass out the MESA Notebook handout. 4. Write the key terms on the board. *Teacher Demonstration:* *Take a meter stick and span it across 2 tables or 2 chairs – you have just created a crude beam bridge. Now, place a weight in the middle of the meter stick or put pressure on it. Notice how the meter stick bends. The top side is under compression (squeezing) and the bottom side is under tension (stretching). If you keep adding weight, eventually the meter stick will break: the top side will buckle and the bottom side will snap.* *Note: Any similar demonstration will work; you could use other objects.* 5. Discuss the meaning of each term and come up with simple student definitions that the class and you agree on. Write the student definitions on the board. Have students copy the student definitions into their MESA Notebook handout. 6. Tell students they will be constructing a beam bridge using spaghetti and glue. 7. Pass out Spaghetti Beam Bridge Challenge handout. Read and discuss instructions with students.

	8. Have students get in groups of 3 and pass out drawing paper and tell students to get out a pencil. 9. Give them 5 minutes to design their bridge on paper. Monitor students and occasionally ask, "How will your bridge look? Are you going to implement a truss design? Where is the compression going to be on your bridge? Where is the tension going to be? How can you lessen or spread out the compression and tension forces?" 10. After 5 minutes, pass out spaghetti and glue to each group. 11. Tell them they have 30-40 minutes to create their bridge. They must work together to complete it in time. 12. Monitor students to check for participation and understanding. 13. When time is up, have students carefully take their bridges to an area in your room where they will dry completely and store safely until the next meeting. 14. Have students clean up supplies. 15. Collect Spaghetti Beam Bridge Challenge handout and MESA Notebook handout from students and keep until next week.
Session 2	1. Tell students to get their bridge and check for repairs that need to be done. Allow them 5-10 minutes to re-glue any parts that may have fallen off. *Note: Inform students not to use too much glue. It will take longer to dry and it may not dry by the time group is ready to test.* 2. While students are making repairs, pass out Spaghetti Beam Bridge Challenge handout and MESA Notebook handout. 3. After time is up, gather student focus back on you. 4. Review Spaghetti Beam Bridge Challenge handout. Discuss challenge specifications. 5. Ask teams to present their design drawing to their peers. Give them 5 minutes to prepare for this mini presentation. Pass out the My Bridge Design handout or write the following components on the board that they need to cover: • How did you come up with your design? • Did you have to modify your design when you began to build your bridge? Why? How did you modify it? • Did you use trusses? If so, how is it strengthening your bridge? • Describe where compression forces are acting on your bridge. • Describe where tension forces are acting on your bridge. • What problems did you encounter in making your bridge? • What would you change about your bridge design if you were to do this again? 6. Each team will do a brief presentation of their bridge addressing the above mentioned components. 7. Pass out Spaghetti Bridge Competition Data Sheet handout to each team. 8. Have students fill in Team Names of each team. See sample for example. 9. Teams will bring their bridges up to the advisor to be weighed. Have each team record the mass of ALL the team's bridges in the space provided on the handout. Teacher can also write the mass of each team's bridge on the board. *While all masses of bridges are found, have other teams get 4 textbooks out. Their bridge will span across the textbooks during the competition.* 10. Have students place the textbooks in two stacks of two and lay their bridge

	across the textbooks. Use a stopwatch to time the event. 11. At the set start time, students will place the 1kg weight on their bridge. Remind students that their bridge should try to hold the weight for 10 minutes. 12. The students may keep watch over their bridge or they may wander to other teams to check out their design and construction. 13. As bridges break, note the time and have the teams record it on their Spaghetti Bridge Competition Data Sheet handout. 14. At the conclusion of 10 minutes, the bridges that remain will be noted. 15. The team with the most efficient bridge will be the team whose bridge held the 1kg weight for 10 minutes with the least amount of supplies (the bridge that weighed the least).
Closure	1. Discuss the design elements of bridges that lasted 10 minutes. What did they have in common? 2. Discuss the activity with the students. Address questions and guide students to reflect on how they could make their bridge better. 3. Have students complete the 'procedure' section of their MESA Notebook handout. 4. Write the following 'conclusion' question on the board and have students answer: How *do engineering elements such as trusses address compression force and tension force on a bridge, and how do they improve the strength and stability of a bridge?* **Note: Students may complete the 'Procedure' and 'Conclusion' section of the MESA Notebook at home before the next MESA meeting if time is an issue.* 5. Clean up and collect their handouts.
Informal Assessment	41. Monitor students to check for understanding. 42. Monitor students to check for participation. 43. Student oral presentation explaining their team's procedure.
Formal Assessment	• Completed Bridge Design. • Completed Bridge. • Completed MESA Notebook handout.
Trouble Shooting	• Keep an eye on the time. Don't linger too long over a single component or you will run out of time. • Have handouts printed before meetings. • Review bridge handout. • Have demonstration materials ready before meeting. • Keep an eye on the glue when students are constructing. • Have extra glue handy. • Keep completed bridges in a safe place between meetings. • If using a trip-beam, make sure it is balanced before weighing bridges. If you are using a digital scale, reset it before weighing the next bridge. • Have plenty of 1kg weights for students to use. You can use anything as a weight, as long as they all weigh around 1 kg and all weigh the same, e.g. textbooks.

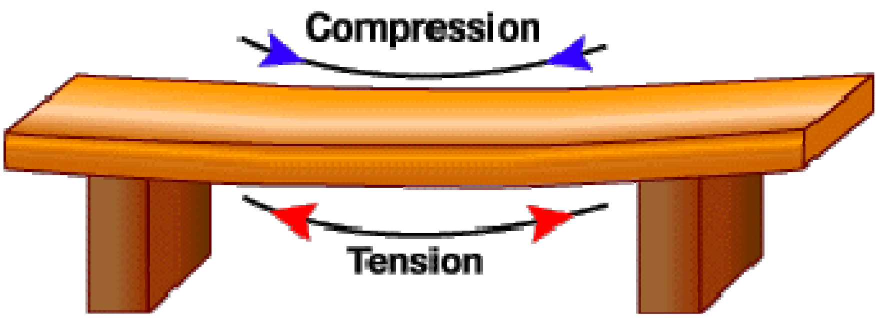
SEI Strategies Used

Preparation	Scaffolding	Grouping Options
☐ Adaptation of Content	☐ Modeling	☐ Whole class
☐ Links to Background	☒ Guided practice	☒ Small groups
☐ Links to Past Learning	☐ Independent practice	☐ Partners
☒ Strategies incorporated	☐ Comprehensible input	☐ Independent
Integration of Processes	**Application**	**Assessment**
☒ Reading	☒ Hands-on	☐ Individual
☒ Writing	☒ Meaningful	☒ Group

☒ Speaking ☒ Listening	☒ Linked to objectives ☒ Promotes engagement	☒ Written ☒ Oral

Arizona Science Standards Addressed	• S1C1: TSW formulate predictions and questions based on observations. • S1C2: TSW design and conduct an investigation demonstrating safe behavior and appropriate procedures while keeping a record of observations, notes, sketches, and questions. • S1C4: TSW communicate the results of their investigation. • S5C2: TSW understand the relationship between force and motion.

The Beam Bridge



A beam bridge is basically a rigid horizontal structure that is resting on two piers, one at each end. The weight of the bridge and any traffic on it is directly supported by the piers. The weight is traveling directly downward.

Compression
The force of compression manifests itself on the top side of the beam bridge's deck (or roadway). This causes the upper portion of the deck to shorten.

Tension
The result of the compression on the upper portion of the deck causes tension in the lower portion of the deck. This tension causes the lower portion of the beam to lengthen.

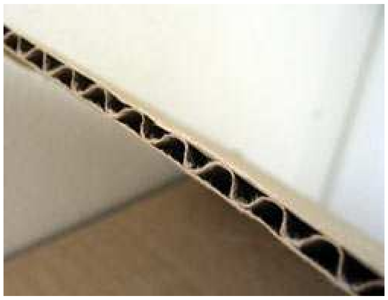
Beam Bridge in Battleground Creek Bridge in Texas

Beam bridge with trusses in Venango County, Pennsylvania

Source: http://science.howstuffworks.com/bridge3.htm

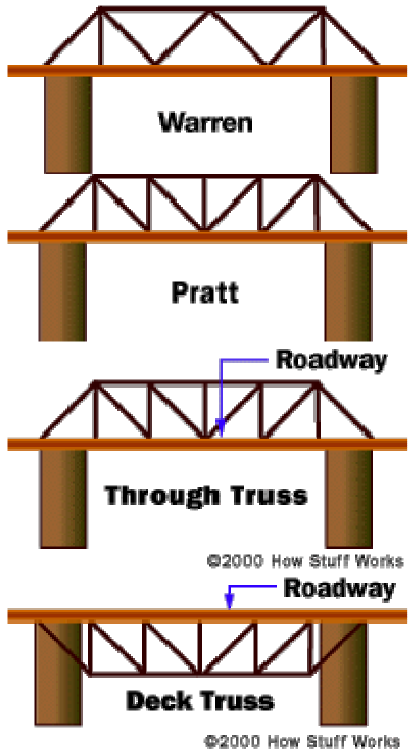
Trusses

What is a truss? A truss is a type of framework, usually comprising straight struts and ties, which is designed to be stiff, even if all the joints are considered to be pinned. The design of a truss, which is usually a variant of a triangle, creates both a very rigid structure and one that transfers the load from a single point to a considerably wider area.

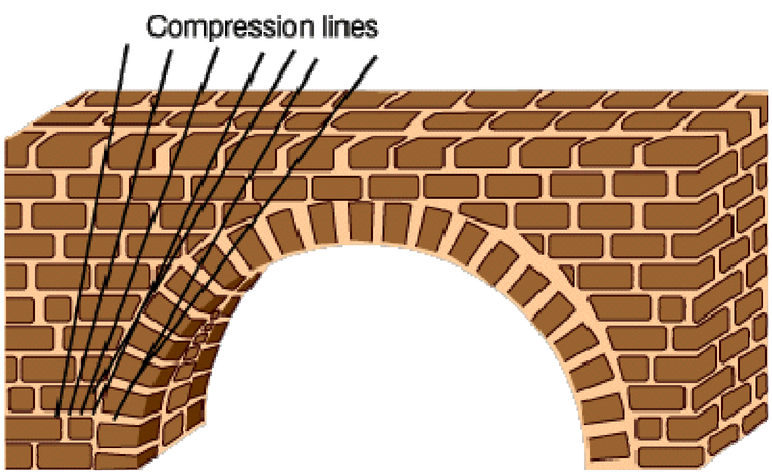


Corrugated cardboard is a good example of how a truss design makes the overall structure stronger.

Types of Bridge Trusses:



The Arch Bridge



An arch bridge is a semicircular structure with abutments on each end. The design of the arch, the semicircle, naturally diverts the weight from the bridge deck to the abutments.

Compression
Arch bridges are always under compression. The force of compression is pushed outward along the curve of the arch toward the abutments.

Tension
The tension in an arch is negligible. The natural curve of the arch and its ability to dissipate the force outward greatly reduces the effects of tension on the underside of the arch. The greater the degree of

curvature (the larger the semicircle of the arch), however, the greater the effects of tension on the underside.

As we just mentioned, the shape of the arch itself is all that is needed to effectively dissipate the weight from the center of the deck to the abutments. As with the beam bridge, the limits of size will eventually overtake the natural strength of the arch.

An Arch Bridge in Minnesota

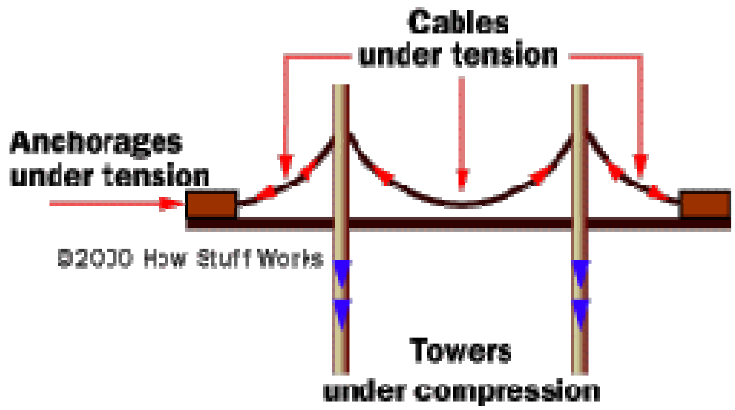
An Arch Bridge in Clements, Kansas

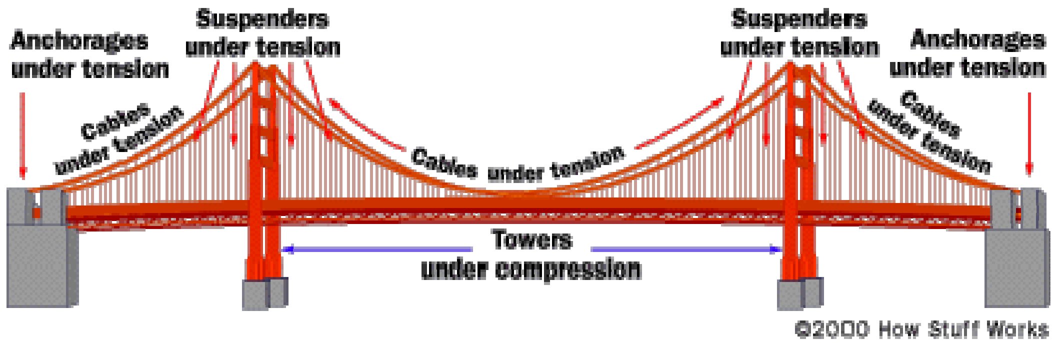
The Suspension Bridge

A suspension bridge is one where cables (or ropes or chains) are strung across the river (or whatever the obstacle happens to be) and the deck is suspended from these cables. Modern suspension bridges have two tall towers through which the cables are strung. Thus, the towers are supporting the majority of the roadway's weight.

Compression
The force of compression pushes down on the suspension bridge's deck, but because it is a suspended roadway, the cables transfer the compression to the towers, which dissipate the compression directly into the earth where they are firmly entrenched.

Tension
The supporting cables, running between the two anchorages, are the lucky recipients of the tension forces. The cables are literally stretched from the weight of the bridge and its traffic as they run from anchorage to anchorage. The anchorages are also under tension, but since they, like the towers, are held firmly to the earth, the tension they experience is dissipated.





Almost all suspension bridges have, in addition to the cables, a supporting truss system beneath the bridge deck (a **deck truss**). This helps to stiffen the deck and reduce the tendency of the roadway to sway and ripple.

Types of Suspension Bridges

Suspension bridges come in two different designs: the **suspension** bridge, recognized by the elongated 'M' shape, and the less-common **cable-stayed** design, which has more of an 'A' shape. The cable-stayed bridge does not require two towers and four anchorages as does the suspension bridge. Instead, the cables are run from the roadway up to a single tower where they are secured.

‘A’ Shape Bridge in Savannah, Georgia

‘M’ Shape Bridge in New York City

‘M’ Shape Clifton Suspension Bridge

Spaghetti Beam Bridge Challenge

Goal:

Your team will design and construct a beam bridge out of spaghetti and glue that will hold a 1kg weight for a minimum of 10 minutes.

The competition component is for teams to design and build a bridge that uses the least amount of supplies. The bridge that holds a 1kg weight for 10 minutes and has used the least amount of spaghetti and glue wins.

The bridge must weigh less than 200 g and be at least 50 cm long.

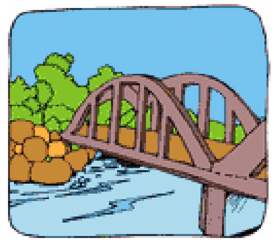
Team Materials:

- Drawing paper
- 200 g (½ pound) of spaghetti
- Glue

You do not have to use all your materials, but you cannot share them with another group.

Instructions:

1. Read Spaghetti Beam Bridge Challenge.
2. Get drawing paper from your advisor. With your team, come up with a design sketch for your bridge. On your sketch, note where compression forces and tension forces are acting.
3. Once your teacher approves your sketch, get spaghetti and glue.
4. You have 30-40 minutes to construct your bridge.
5. Put your bridge in the space designated by your advisor.
6. Clean up.



My Bridge Design Team Oral Presentation

Your team has designed and constructed a beam bridge out of spaghetti and glue. You achieved this goal in 2 steps:

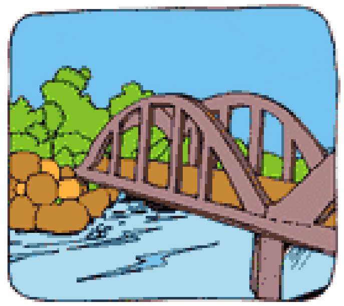
- Designed a bridge on paper
- Built your bridge according to the design

Your bridge had to address compression forces and tension forces. You labeled how these forces are acting on your bridge on your drawing.

Goal:
Your team will give a brief explanation of your bridge design drawing. In your brief presentation, please address the following components:

- How did you come up with your design?
- Did you have to modify your design when you began to build your bridge? Why? How did you modify it?
- Did you use trusses? If so, how is it strengthening your bridge?
- Describe where compression forces are acting on your bridge.
- Describe where tension forces are acting on your bridge.
- What problems did you encounter in making your bridge?
- What would you change about your bridge design if you were to do this again?

You have 5 minutes to plan your brief oral presentation



Spaghetti Bridge Competition Data Sheet

Directions:

Write the names of all the teams in the MESA group. Record the mass of each team's bridge. Once the competition begins, write down the time it took before the bridge collapsed under the 1kg weight. If a bridge holds for 10 minutes, write 10 minutes under time. Good Luck!

Team	Mass of Bridge in Grams	Time

MESA Mathematics Engineering Science Achievement

Lesson Activity

Title	**On-Site Design Challenge: Straw Bridge (60-80 Minutes)**
ID Number	MS-E-OS3
Sequence and Duration	• Lead In: 10-15 Minutes • Activity: 40-50 Minutes • Closure: 10-15 Minutes
Age Level	Middle School
Essential Question	**What have I learned about on-site engineering challenges?**
Learning Objectives	• TSW design and build a bridge to specs. • TSW reflect on and evaluate their approach to the problem and the strategies they used to address it. • TSW evaluate their comfort level with on-site design challenges. • TSW continue brainstorming strategies to help them be successful at on-site design challenges in the future.
Other Objectives	• TSW develop a working plan with their group to develop a cooperative environment. • TSW communicate with their group by contributing their vocal input. • TSW develop critical reading skills by finding relevant information in given materials. • TSW listen to their peers discuss their approaches to the problem. • TSW contribute to a group discussion about being successful in on-site design challenges.
Key Terms	• On-site design challenge • Approach • Strategy
Materials Needed	Per Class: • Stopwatch • Scale • Textbook (if possible, enough identical textbooks to have one for each group) • Additional weights, e.g. rocks, smaller books, 10 g masses, etc. • Two stable surfaces separated by 12 inches, such as two tables • Masking tape to mark off each group's testing area (optional) • On-Site Engineering Design Data Collection Sheet Per Group: • Handout: On-Site Engineering Design specs • 15 straws • 1 stapler filled with staples (e.g. one "bar" of staples per stapler, same number for each group) • 1 pair of scissors • 1 ruler
Lead In	41. This lesson plan is another option for practicing with on-site design challenges. You can use this activity in place of one of the previous activities (Payload Delivery Device: intro to on-site design; Paper Tower: review of on-site design) with more elaborate lesson plans. Or you can use this activity to continue practice with on-site design challenges. 42. Feel free to incorporate pre and post-activity discussions that meet your goals, such as having students reflect on their strategies for approaching

	on-site design challenges, their prior knowledge about the challenge, strategies for working together as a team, or their comfort level with designing under pressure.
Activity	91. Separate students into groups of two or three and hand out the supplies to each pair. When all supplies have been distributed, hand out the specs face down, instructing students not to turn them over until you tell them to. Tell them they have thirty minutes to complete the challenge. They may raise their hands if they need clarification about the rules, but they should think of you as the judge, not their advisor. 92. Call out "begin!" and start the 30 minute count-down. 93. After 30 minutes are up, call time and have students clean up their areas and bring their bridges to the testing area. 94. Test each bridge by placing a textbook across it and timing how long it can withstand the weight. In the case that more than one bridge can withstand the weight indefinitely, continue adding weight until the bridges break. Record the final weight each bridge was able to withstand. 95. Declare the team with the strongest tower to be the winners. 96. Clean up the materials and testing area and have students return to their seats.
Closure	36. Give students time to reflect on their approaches and strategies with this challenge, first with their groups and then reporting out to the whole class. 37. Guide the discussion to meet your objectives, having the students reflect on, for instance, how previous challenges prepared them for this one, what they did differently or similarly, what scientific knowledge they used in their design, etc.
Informal Assessment	44. Monitor students' participation in the activity. 45. Monitor students' participation in the discussion.
Formal Assessment	• Completed MESA Notebook (optional). • Completed bridge.
Trouble Shooting	• Separate out each team's materials and place them in baggies or boxes prior to students' arrival to class. • You can have students build their bridges with whatever materials you happen to have on hand. Feel free to improvise to create your own challenge. • You can test the bridges one at a time with the same textbook and same area to span, but if you have enough textbooks and a large enough area, you could test them all at once. In this case, you may want to mark off testing areas for each group and put the dimensions of this area into the students' specs.

SEI Strategies Used

Preparation	Scaffolding	Grouping Options
☐ Adaptation of Content	☐ Modeling	☒ Whole class
☐ Links to Background	☐ Guided practice	☐ Small groups
☒ Links to Past Learning	☒ Independent practice	☒ Partners
☒ Strategies incorporated	☐ Comprehensible input	☐ Independent

Integration of Processes	Application	Assessment
☒ Reading	☒ Hands-on	☐ Individual
☐ Writing	☒ Meaningful	☒ Group

☒ Speaking ☒ Listening	☒ Linked to objectives ☒ Promotes engagement	☐ Written ☒ Oral

Arizona Math Standards Addressed	(none)
Arizona Science Standards Addressed	• S3C2: TSW develop viable solutions to a need or problem.

ON-SITE ENGINEERING DESIGN

Middle School Level
Straw Bridge

OBJECTIVE:

Your challenge is to design and build the strongest possible bridge from the given materials. Your team shall compete with other teams in a head-to-head competition.

MATERIALS:

15 – Straws
Staples available in stapler

Other materials available for use but not included in the design:

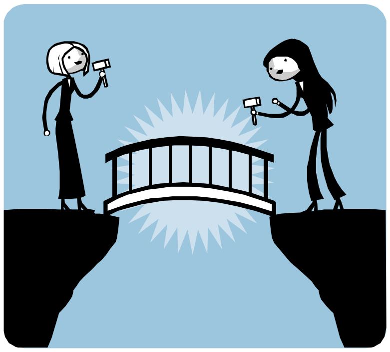
Scissors Stapler Ruler Pencil Paper

RESTRICTIONS and INSTRUCTIONS:

- Each bridge must be made out of only the supplied straws and staples. No other materials can be used.
- Each bridge must span the 12-inch distance and must be able to withstand the weight of one textbook.
- After thirty minutes, towers must be moved to a judging area. No contact between team members and tower may be made after the tower is moved.

SCORING:

- Bridge must withstand the weight of the textbook for at least 1 second.
- Time will begin when the textbook is placed on the bridge and end when the textbook hits the floor.
- The bridge that withstands the weight for the longest time is the winner.
- In the event that more than one bridge is able to withstand the weight of one textbook indefinitely (i.e. more than five minutes), additional weights will be added until the bridges give way. The bridge that withstands the greatest weight before breaking will be declared the winner.



ON-SITE ENGINEERING DESIGN
Middle School Level
Straw Bridge

Data Collection Sheet

Group Members	Lifespan of Bridge – 1 textbook	Tie Breaker: Total weight withstood before breaking

Last updated 7/30/2008

Mathematics Engineering Science Achievement

Lesson Activity

Title	**Straw Tower (60-70 minutes)**
ID Number	MS-E-C3
Sequence and Duration	• Lead In (10-15 minutes) • Activity (40-45 minutes) • Closure (10-15 minutes)
Age Level	Middle School
Essential Question	**What engineering design elements create the tallest and most stable tower?**
Learning Objectives	• TSW describe design elements in a tower that make the structure more stable as it gets taller. • TSW apply their understanding of design elements such as triangles and the joining of joints to construct a tall, stable tower. • TSW discuss, re-explain, and demonstrate how different engineering design elements make a tower more stable or unstable. • TSW apply their overall understanding of tower construction to design and construct a tower using the given materials in the given time. • TSW describe the construction process of their tower and evaluate its strengths and weaknesses by comparing it to other towers constructed by their peers.
Other Objectives	• TSW develop a working plan with their group to develop a cooperative environment. • TSW communicate with their group by contributing their vocal input.
Key Terms	• Tower: A tall man-made structure, always taller than it is wide, usually much taller. Towers are generally built to take advantage of their height and can stand alone or as part of a larger structure.
Materials Needed	Per Group • Images of towers from the Internet (sample images included) Per Student • MESA Notebook • Handout: Tower Building Challenge Per Team • Blank sheet of paper • Colored pencils • Straws • Paper clips • Masking tape
Lead In	1. Pass out MESA Notebook and Handout: Tower Building Challenge. 2. Tell students that they will be constructing a tower today. Have students define 'tower' as a group. Guide students to a communal definition and write it on the board. Write down given definition of 'tower' and compare both definitions. Discuss and come up with a new definition that incorporates both ideas. Have students write this in their MESA Notebook. 3. Ask, "How could you design a tower so that it is very high, but very stable so it doesn't fall over?" Discuss possible design strategies with class. 4. Show images of various towers around the world. Discuss engineering design with students and generate ideas about how they could incorporate some of the principles into their tower.

	19. Read through the handout with students. Ask them to retell the objective, rules, and materials to you. Call on students at random.
Activity	1. Have students break into teams of 2-3. Each team will assign the following tasks to its members: • Recorder: Records what materials have been purchased. • Manager: Keeps team on task and focused. • Materials Supervisor: Obtain materials for the team. 2. Have teams make a quick sketch of their proposed design. Ask, "Are you going to connect straws with paper clips or masking tape? Why?" 3. Ask Team Recorder to write down what supplies their team will be "purchasing". Remind them to only write down what they think they need. Once an item is purchased, it is purchased and cannot be returned. They can always submit a new supply request if they run out of supplies. 4. Ask Team Materials Supervisor to bring up supply request to fill order. 5. Once team gets their supplies, they may begin building their tower. 6. Monitor teams as they construct their towers. Allow about 20-25 minutes for tower construction. 7. Have each team clean up their area. Tell the Team Recorder to add up their total supply cost. Check this as students clean up. 8. Tell students to bring their towers to a communal table. 9. Have students compare and contrast their tower design with their peers'. 10. Hypothesize about which tower looks the most stable in design. What engineering elements were used in this tower? 11. Measure each tower from the base to the top. 12. Tallest tower gets to deduct $5 from their total supply cost. 13. Second tallest tower gets to deduct $4 from their total supply cost. 14. Third tallest tower gets to deduct $3 from their total supply cost. 15. Fourth tallest tower gets to deduct $2 from their total supply cost. 16. Fifth tallest tower gets to deduct $1 from their total supply cost. 17. Have Team Recorders calculate new deductions into their total supply cost if applicable. 18. The tower that was the tallest AND the most economical wins the design contest.
Closure	1. Ask each team to describe the most difficult part of their tower construction. 2. Ask each team to describe what they would do differently if they were to construct another tower. 3. Ask students to complete their MESA Notebook and to answer the following conclusion question, "What engineering design elements create the tallest and most stable tower?" 4. Have students complete their MESA Notebook.
Informal Assessment	46. Monitor students as they sketch their design. 47. Monitor students as they construct their tower.
Formal Assessment	• MESA Notebook • Completed Tower • Team Record Sheet
Trouble Shooting	• Make sure each Recorder is keeping an accurate record of their supply purchases. • Make sure Materials Supervisor is filling supply request correctly. • Make sure Manager is keeping team on task.

SEI Strategies Used

Preparation	Scaffolding	Grouping Options
☒ Adaptation of Content	☐ Modeling	☐ Whole class
☒ Links to Background	☐ Guided practice	☒ Small groups

Last updated 7/30/2008

☐ Links to Past Learning ☒ Strategies incorporated	☒ Independent practice ☐ Comprehensible input	☐ Partners ☐ Independent
Integration of Processes ☒ Reading ☒ Writing ☒ Speaking ☒ Listening	Application ☒ Hands-on ☒ Meaningful ☒ Linked to objectives ☒ Promotes engagement	Assessment ☒ Individual ☒ Group ☒ Written ☒ Oral

Arizona Math Standards Addressed	• (none)
Arizona Science Standards Addressed	• S1C1: TSW formulate predictions, questions, or hypotheses based on observations of their tower and their peers'. • S1C2: TSW design a controlled investigation of tower building and keep a record of their observations, notes, sketches, questions, and ideas in their MESA Notebook. • S1C4: TSW communicate the results of their investigation and share their conclusions. • S3C2: TSW develop a viable solution to a need or problem and design and construct a solution to the identified need using simple classroom materials.

Tower Images

Toronto's CN Tower

Paris's Eiffel Tower

Moscow's Shukhov Tower

Medieval Siege Tower

Tower Building Challenge

Goal:

Each team will attempt to build the tallest free-standing tower on the smallest budget.

Materials and Material Cost:

- Straws- $1.00 each
- Paper Clip- $0.25 each
- Masking Tape- $0.10 per/cm
- Design Drawing
  - Blank sheet of paper
  - Colored Pencils

Job Descriptions for Team

- Manager: This student is responsible for keeping their team on task while they design and construct their tower.
  Student: ___________________________

- Recorder: This student is responsible for recording what materials have been purchased.
  Student: ___________________________

- Materials Supervisor: This student is responsible for getting the materials for the team.
  Student: ___________________________

Rules:

1. Use only the materials provided.
2. Follow the instructions carefully.
3. All members of the team must participate in the design and construction of the tower.
4. If you purchase a material, it is non-refundable. You have to pay for it even if you don't use it.
5. If you need more materials, the Team Recorder can request more supplies. The Team Materials Supervisor needs to tell the advisor that your team is putting in another supply request.
6. Keep accurate records of your total supply cost.

Good Luck and Have Fun!

Team Record Sheet

Team Members: ____

Quantity	Supply	Cost	Total Cost
	Straws	$1.00 each	
	Paper Clip	$0.25 each	
	Masking Tape	$0.10 per cm	
		Subtotal:	

Height of Structure (in cm): ____

Bonus for Height	
Highest	Subtract $5.00 from sub-total
Second Highest	Subtract $4.00 from sub-total
Third Highest	Subtract $3.00 from sub-total
Fourth Highest	Subtract $2.00 from sub-total
Fifth Highest	Subtract $1.00 from sub-total

Final Cost of Tower: ____

Additional Supply Request:

Quantity	*Supply*	*Cost*	*Total Cost*
	Straws	*$1.00 each*	
	Paper Clip	*$0.25 each*	
	Masking Tape	*$0.10 per cm*	
		Subtotal:	

Follow Up Questions:

1. What was the most difficult part of building the tower?

2. What problems did your team have?

3. What changes did you make from your sketch? Why?

4. If you could do it again, what would you do differently?

5. What geometric shapes are found in your tower?

6. What kind of angles did your team use in your tower?

MESA Mathematics Engineering Science Achievement

Lesson Activity

Title	**The Strongest Link**
ID Number	MS-E-C4
Sequence and Duration	Lead In: 5-10 minutes Activity: 25-30 minutes Closure: 5-10 minutes
Age Level	Middle School
Essential Question	**What design elements make my paper chain stronger?**
Learning Objectives	• TSW design a chain link made out of paper • TSW construct a paper chain using given materials • TSW compare their chain design to other students' • TSW evaluate the strengths and weaknesses of their paper chain
Other Objectives	• TSW discuss their design element
Key Terms	• Force • Motion • Tension
Materials Needed	Per Class: • 2 Ropes to pull chains • Metal caribiners to link paper chains to rope and other chains Per Team: • Per Student: • Handout: MESA Notebook • 1 sheet of copy paper • 6 inches of masking tape • 1 rubberband
Lead In	1. Advisor will write the word 'force' on the board. 2. Discuss what 'force' is. Simple definition: push or pull. 3. Discuss how 'force' affects an object. It moves. 4. Ask what happens when too much force acts on a object from all directions. Its structure will be compromised. 5. Have students visualize a chain link fence. Ask what would happen if a chain link fence were pulled apart. It will break.
Activity	1. Tell students that they will be designing and constructing one chain link. 2. Show them the rope and caribiners. Explain that their chains will be put between the caribiners and pulled from both sides. 3. Hold up the materials that each student will get to make their chain. This is the paper, the masking tape, and a rubber band. 4. Pass out the supplies. 5. Tell students they have 15 minutes to construct their chain. When they are done constructing their chain, they will write their name on it. 6. Collect all paper chains at the front at the end of 15 minutes. 7. Hold up all the paper chains. 8. Have students describe characteristics about each paper chain. 9. Tell students to predict which paper chain will be the strongest. Ask why, what design elements make one chain look stronger than another. 10. Ask for 2 student volunteers. Use caribeners to link several chains to the rope. 11. Have students pull the chain at the same time to eliminate weak chains. Ask where force is acting on the chain and what kind of force it is. How is the

	force a variable? (students are pulling at different strengths.) 12. Repeat until one chain remains. In the interval, discuss that design elements make a chain weak.
Closure	1. Hold up the winning chain. 2. Ask student to describe their design process and why they constructed it in a particular way. 3. Have class list specific design elements that make strong chains: small, think, tightly constructed.
Informal Assessment	• Monitor students to make sure they are participating • Ask students to explain their design process while they are constructing
Formal Assessment	• Chain pull
Trouble Shooting	• Do not use scotch tape • Make sure rubber bands are similar in size • Tell students they only get 1 set of materials and if they mess up, they cannot get more

SEI Strategies Used

Preparation	Scaffolding	Grouping Options
☒ Adaptation of Content	☐ Modeling	☒ Whole class
☐ Links to Background	☐ Guided practice	☐ Small groups
☐ Links to Past Learning	☐ Independent practice	☐ Partners
☒ Strategies incorporated	☐ Comprehensible input	☒ Independent
Integration of Processes	**Application**	**Assessment**
☐ Reading	☒ Hands-on	☒ Individual
☐ Writing	☒ Meaningful	☐ Group
☒ Speaking	☒ Linked to objectives	☐ Written
☒ Listening	☒ Promotes engagement	☐ Oral

Arizona Math Standards Addressed	• S5C2PO4: TSW describe forces as interactions between bodies
Arizona Science Standards Addressed	•

Lesson Activity

Title	**Toothpick Dome (60 minutes)**
ID Number	MS-E-C1
Sequence and Duration	• Lead In (20 minutes) • Activity (20 minutes) • Closure (20 minutes)
Age Level	Middle School
Essential Question	**What makes a geodesic dome strong?**
Learning Objectives	• TSW identify the triangle as a very stable shape used in engineering and construction. • TSW describe qualities that make a triangle very stable. • TSW identify the weak point in a triangle (joint area). • TSW apply their understanding of triangular strength to the engineering of a geodesic dome. • TSW discuss, re-explain, and demonstrate how a geodesic dome distributes the weight load over all the different triangles that compose it. • TSW apply their overall understanding of geodesic domes to design and construct one using the given materials in the given time. • TSW describe the construction process of their dome and evaluate its strengths and weaknesses by comparing it to other domes constructed by their peers.
Other Objectives	• TSW develop a working plan with their group to develop a cooperative environment. • TSW communicate with their group by contributing their vocal input.
Key Terms	• Geodesic dome • Polygon • Triangle • Compression • Tension • Weight distribution
Materials Needed	Per Group • Pictures of geodesic domes: Epcot, Biosphere Per student • Handout: MESA Notebook Per team (2-3 students) • 100 round toothpicks • 30-40 small marshmallows or gum drops
Lead In	20. Pass out the MESA Notebook handout. (If necessary, tell them that they will be completing this handout for each MESA activity. Tell them you will guide them through the handout today.) 21. Show the students images of some geodesic domes. 22. Ask them to point out similarities. Write these on the board. 23. Ask them to point out differences. Write these on the board. 24. Guide students to identify the types of shapes used in geodesic dome design, specifically triangles. 25. Write the term 'Geodesic Dome' on the board. Instruct them to write it in the 'key term' section of the MESA Notebook Handout. 26. Ask one student to find the definition in a dictionary and read it aloud. Write this

definition on the board but instruct them not to write it on their handout. Simplify the definition into grade-appropriate terminology using the images as teaching tools. Students will create a communal oral definition, write this on the board, and have them copy this into their handout.

Example of a Dictionary Definition: A domed or vaulted structure of lightweight straight elements that form interlocking polygons.
Example of Student Definition: A structure made of connected polygons.

27. Write the term 'polygon' on the board and have them follow the same procedure as above. When they come to writing their own definition, one suggestion is to have them draw types of polygons next to the definition instead of using vocabulary.

Example of a Dictionary Definition: A closed plane figure bounded by 3 or more line segments.
Example of a Student Definition: A shape made of straight lines. (drawn polygon shapes)

28. Write the term 'triangle' on the board and follow the same steps as for 'polygon'. They will draw the definition on the handout.
29. Show students a toothpick square. Ask them to identify what makes it a square. Discuss.
30. Ask students to point out where they think the weakest area/point of the square is. Most students will point to the joint area at the marshmallows.
31. Show the students a toothpick triangle. Ask them to identify what makes it a triangle. Discuss.
32. Ask students to point out where they think the weakest area/point of the triangle is. Most students will point to the joint area at the marshmallows.
33. Hold up both the toothpick square and the toothpick triangle. Point out obvious shape differences.
34. Ask, "Which of these two toothpick structures is more stable or stronger?" Solicit answers, write them on the board, and discuss.

A dome must support its own dead load as well as the live load of wind, rain, snow, or ice. The geodesic dome's strength is due to the fact that triangles are very stable shapes. It is difficult to distort a triangle; compression at one joint is balanced by tension along the opposite side. The geodesic dome's design distributes loads over all the different triangles that comprise it.

35. Have one student come up to apply pressure to both toothpick structures. The square toothpick structure should collapse easily. You may also choose to do this part of the demonstration yourself to ensure it does.
36. Ask students, "Why is the triangle toothpick structure more stable?" Solicit answers and discuss.
37. Put the following terms on the board: 'compression' and 'tension'
38. Use the demonstration to help the students define these terms or use the dictionary as a starting point and the students can come up with their own definition again. Have students write the definition on their handout.
39. Show students pictures of geodesic domes again and ask them to describe how they would build one using toothpicks and marshmallows. Point to the toothpick triangle as a starting off point. Discuss and draw on the board or model for them by adding to the triangle.
40.

Activity	1. Tell students that they will be engineering and constructing a geodesic dome using the concepts they just learned. 2. Pass out supplies to each group. 3. Tell students to write what materials they are using under the 'Materials Used' section of their MESA Notebook handout. 4. Students will begin activity. 5. Monitor student progress. Check to make sure the base of the geodesic dome is reasonable. Some may try to make a very large base and not complete their dome in the remaining time. 6. As groups finish, instruct them to begin the 'Procedure' section of the MESA Notebook handout. They will write down all the steps they took to build their geodesic dome. 7. Allow time for clean up.
Closure	1. Put pressure on top of each group's dome with books to check the strength and stability. Use one group's dome as a class model. 2. Ask students to describe how the whole structural design makes it strong. Discuss. Mention how the dome design gives even weight distribution and briefly explain what weight distribution means by going back to the book support model. 3. Have student groups hold up and demonstrate their constructed domes. 4. Each group will describe what difficulties they had in constructing their domes. 5. Point to the MESA Notebook Handout. 6. Instruct students to complete the 'Procedure' section if they did not complete it. 7. Write the following question on the board: 'What makes a geodesic dome strong?' Instruct students to answer this question on the 'Conclusion' section of the MESA Notebook handout. 8. Point out the back of the handout. It is up to you whether or not to have them draw a picture of their completed dome before the next meeting. They can label it, pointing out joints, tension, and compression. **Note: Students may complete the 'Procedure' and 'Conclusion' section of the MESA Notebook at home before the next MESA meeting if time is an issue.*
Informal Assessment	48. Monitor students to check for understanding. 49. Monitor students to check for participation.
Formal Assessment	• Completed Geodesic Dome. • Completed MESA Notebook Handout (They may complete this before the next MESA meeting).
Trouble Shooting	• Keep an eye on the time. Don't linger too long over a single component or you will run out of time. • Have additional supplies ready for groups that work quickly. They can add to the base of their dome. • Make sure all students participate in clean up.

SEI Strategies Used

Preparation	Scaffolding	Grouping Options
☒ Adaptation of Content	☒ Modeling	☐ Whole class
☐ Links to Background	☒ Guided practice	☒ Small groups
☐ Links to Past Learning	☐ Independent practice	☐ Partners
☒ Strategies incorporated	☒ Comprehensible input	☐ Independent
Integration of Processes	**Application**	**Assessment**
☒ Reading	☒ Hands-on	☐ Individual
☒ Writing	☒ Meaningful	☒ Group
☒ Speaking	☒ Linked to objectives	☒ Written
☒ Listening	☒ Promotes engagement	☒ Oral

Arizona Science Standards Addressed	• S1C1: TSW formulate predictions and questions based on observations. • S1C2: TSW design a controlled investigation and keep a record of their observations, notes, and sketches. • S1C4: TSW communicate the results of their investigation and create a list of instructions that others can follow. • S2C2: TSW understand how science is a process for generating knowledge and apply scientific processes to problem solving situations.

Skill Set 2:
Math and Math Puzzles

Lesson Activity

Title	**Math Puzzle: Climbing Snail**
ID Number	MS-MP-1
Duration	10 Minutes
Age Level	Middle School
Learning Objectives	• TSW solve a logical mathematical word problem using grade-appropriate problem-solving strategies. • TSW solve a multi-step word problem by applying various numerical operations.
Other Objectives	• TSW communicate with their peers to solve a problem. • TSW listen as their peers discuss their strategies. • TSW participate in a group discussion about problem solving.
Key Terms	• Problem solving: process of coming up with a solution to a problem.
Materials Needed	• Handout: Climbing Snail
Lead In	• Pass math problem out to students. • Inform students they may work in pairs to solve the puzzle.
Activity	• After 5 minutes, discuss the problem. • Have one student model a possible solution on the board.
Closure	• Discuss the process of problem solving with class and ask for other ways to solve the problem.
Informal Assessment	50. Monitor students to check for engagement. 51. Monitor students to check for participation.
Formal Assessment	• Solution to Climbing Snail question.

SEI Strategies Used

Preparation
- ☐ Adaptation of Content
- ☐ Links to Background
- ☐ Links to Past Learning
- ☒ Strategies incorporated

Scaffolding
- ☐ Modeling
- ☐ Guided practice
- ☒ Independent practice
- ☒ Comprehensible input

Grouping Options
- ☐ Whole class
- ☐ Small groups
- ☒ Partners
- ☐ Independent

Integration of Processes
- ☒ Reading
- ☒ Writing
- ☒ Speaking
- ☒ Listening

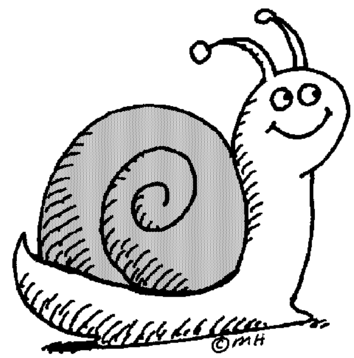
Application
- ☐ Hands-on
- ☒ Meaningful
- ☒ Linked to objectives
- ☒ Promotes engagement

Assessment
- ☒ Individual
- ☒ Group
- ☒ Written
- ☒ Oral

Arizona Math Standards Addressed	• S1C2: TSW understand and apply numerical operations such as solving grade level appropriate word problems using appropriate operations and numbers.

Climbing Snail

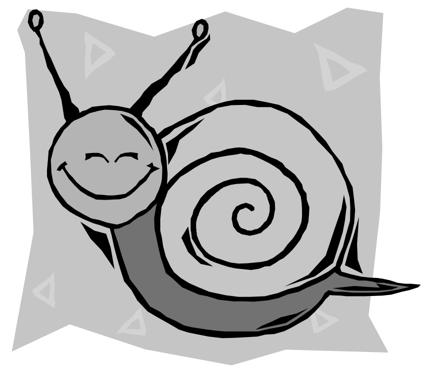
A snail is at the bottom of a 20 meter deep pit. Every day the snail climbs 5 meters upward, but at night it slides 4 meters back downwards.



The Question: How many days does it take before the snail reaches the top of the pit?

Climbing Snail

A snail is at the bottom of a 20 meter deep pit. Every day the snail climbs 5 meters upward, but at night it slides 4 meters back downwards.



The Question: How many days does it take before the snail reaches the top of the pit?

On the first day, the snail reaches a height of 5 meters and slides down 4 meters at night, and thus ends at a height of 1 meter.
On the second day, he reaches 6 meters, but slides back to 2 meters.
On the third day, he reaches 7 meters, but slides back to 3 meters.
...
On the fifteenth day, he reaches 19 meters, but slides back to 15 meters.
On the sixteenth day, he reaches 20 meters, so *now* he is at the top of the pit!
Conclusion: The snail reaches the top of the pit on the 16th day!...

Lesson Activity

Title	**Math Puzzle: Designing an Inlaid Table**
ID Number	MS-MP-2
Duration	20-25 Minutes
Age Level	Middle School
Learning Objectives	• TSW identify patterns and apply pattern recognition to solve grade level-appropriate pattern problems. • TSW manipulate various pattern combinations to solve a mathematical pattern puzzle.
Other Objectives	• TSW communicate the results of their efforts to their peers. • TSW listen as their peers discuss their strategies.
Key Terms	• Pattern: a repeating design.
Materials Needed	Per student • Designing an Inlaid Table Top handout • Table Top Grid handout • Construction paper in the following colors: red, blue, green, yellow, and brown • Scissors
Lead In	1. Pass out Design an Inlaid Table Top handout. 2. Call on a student to read the instructions, and have students tell you in their own words what they will be doing. 3. Tell students that they will be using the Table Top handout for testing their pattern designs. 4. Instruct students to get scissors and construction paper to cut 5 pieces of each color. 5. Model for them how they can use the colored paper manipulatives to solve the problem.
Activity	1. When the students have one pattern solved, tell them to write the pattern on their Design an Inlaid Table Top handout. 2. Allow them 15-20 minutes to solve 2 possible patterns. 3. Monitor their progress. 1. When time is up, have students share their patterns with each other. There will be different pattern possibilities. 4. Have students check other student work.
Informal Assessment	52. Monitor students to check for engagement. 53. Monitor students to check for understanding.
Formal Assessment	• Completed Design an Inlaid Table handout.

SEI Strategies Used

Preparation
- ☐ Adaptation of Content
- ☐ Links to Background
- ☐ Links to Past Learning
- ☒ Strategies incorporated

Scaffolding
- ☒ Modeling
- ☐ Guided practice
- ☒ Independent practice
- ☒ Comprehensible input

Grouping Options
- ☐ Whole class
- ☐ Small groups
- ☐ Partners
- ☒ Independent

Integration of Processes
- ☒ Reading
- ☐ Writing

Application
- ☒ Hands-on
- ☒ Meaningful

Assessment
- ☒ Individual
- ☐ Group

☐ Speaking ☒ Listening	☒ Linked to objectives ☐ Promotes engagement	☐ Written ☐ Oral
Arizona Math Standards Addressed	• S3C1: TSW identify patterns and apply pattern recognition to reason mathematically.	

Designing an Inlaid Table
Student Worksheet

Red	Blue	Green	Yellow	Brown

Students:
Use this worksheet to manipulate the 5 squares of red, blue, green, yellow, and brown construction paper to help you solve the puzzle. When you think you have a pattern, raise your hand and your advisor will check it for you. Then, write the color patterns on your worksheet.

Lesson Activity

Title	**Eight Cube Picture Puzzle**
ID Number	MS-M-A2
Sequence and Duration	• Lead In: 5 minutes • Activity: 40-45 minutes • Closure: 10 minutes
Age Level	Middle School
Essential Question	**How does changing the shape of an object affect its volume?**
Learning Objectives	• TSW construct a geometric cube • TSW analyze how the cube makes different shapes • TSW manipulate the cube to expose different shapes • TSW calculate different volumes depending on the shape of the object • TSW explain how shape affects volume
Other Objectives	• TSW listen to the step by step explanation of how to construct the cube • TSW discuss the construction of their cube with their classmates
Key Terms	• Cube • Area • Volume • Shape • Horizontal • Vertical
Materials Needed	Per Class: • Visual drawings of each step on large post it paper Per Team: • Scissors • Scotch Tape • Glue • Construction paper • Assorted Magazines Per Student: • 8 Handouts: Cube Cut-Out
Lead In	1. Hold up one cube and ask students to describe it. 2. Guide the discussion to include size, shape, and volume. 3. Hold up another cube and tape them together. Ask how the size, shape and volume change. 4. Hold up a completed picture puzzle cube and ask them to describe the size, shape, and volume. 5. Flip the picture puzzle to make a different shape and ask them if the volume is the same. Discuss. Use the picture puzzle to make varying shapes. Guide students to determine that the volume of an object changes if the shape changes.
Activity	1. Pass out the handouts to the students. Give them 15-20 minutes to make 8 cubes from the cut out handout. 2. Model for them how to connect the cubes using the attached teacher handout. 3. Use the large post it to draw colored diagrams to make it more visual for them. 4. Monitor students to see that they are following the instructions clearly. 5. Once the puzzle cubes are constructed, have students cut out large pictures from a magazine or draw their own to paste onto the puzzle cubes. This may take some time because the students may be picky about their pictures.

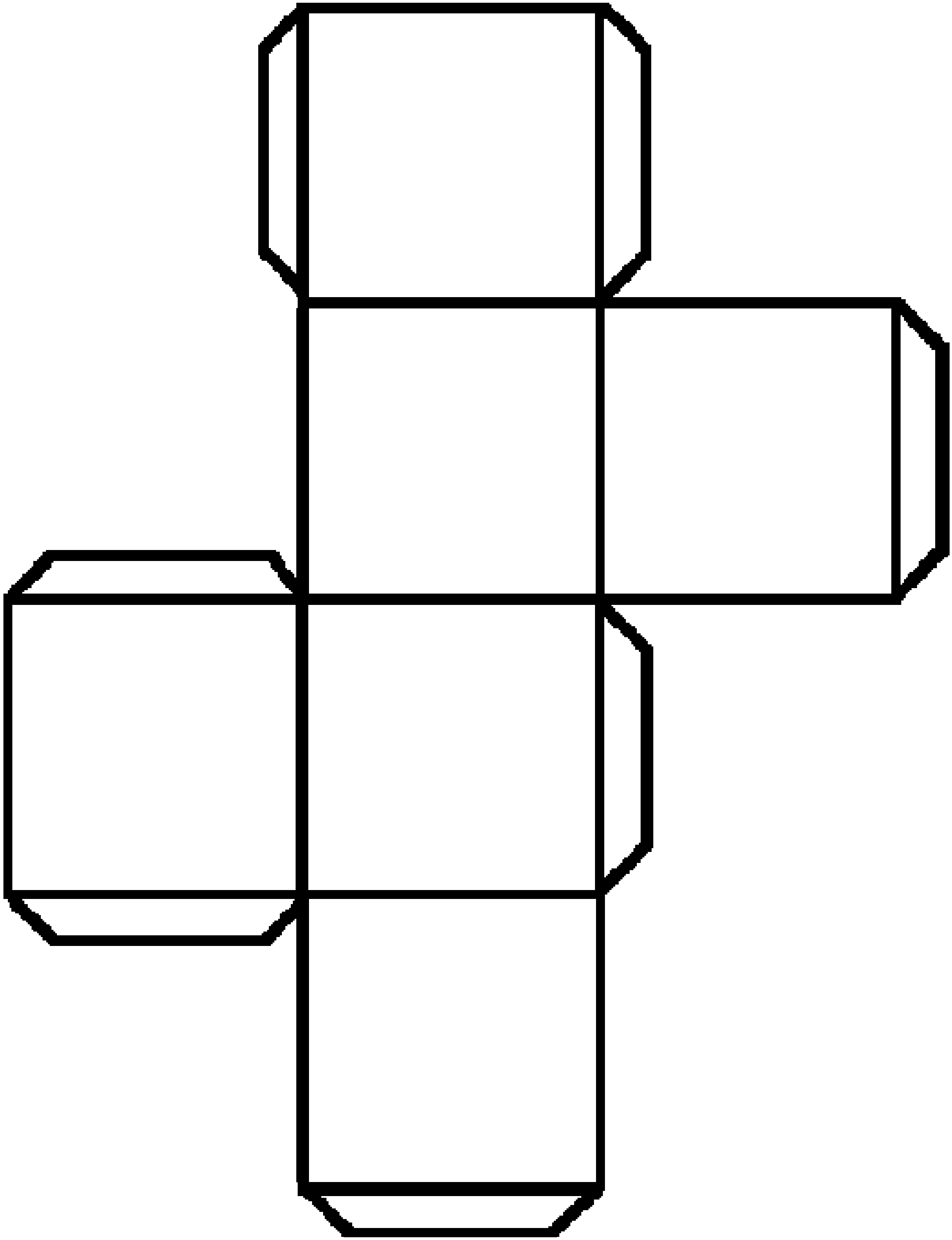
	6. Once the puzzles are completed, have the students clean up their areas
Closure	1. Have students share their puzzle cubes with each other. Have them make different shapes based on the pictures that they put together. 2. Students can discuss why they picked certain pictures for their cube sides.
Informal Assessment	• Monitor students to make sure they are all participating.
Formal Assessment	• Completed cube with pictures on various sides.
Extensions	• Students can decorate the cubes using a theme. • The cube can be used as a book report, students can paste different reading concepts for a book on different sides. • More information can be found at: http://www.mathematicsche-bastelieien.de/magiccube.htm • Lesson plan courtesy of RAFT
Trouble Shooting	• Step 7 and 9 are tricky, you may want to practice this several times before modeling it for students. • The constructed boxes may be flimsy if they are using regular paper. Thick cardstock or thicker paper may be a better choice if possible.

SEI Strategies Used

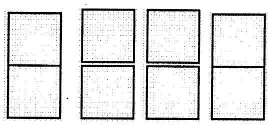
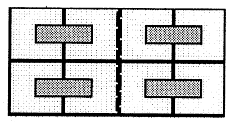
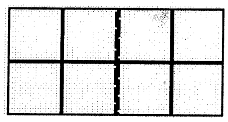
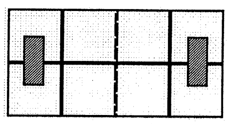
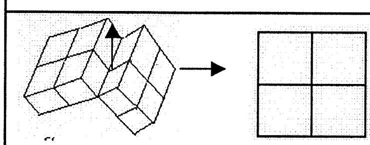
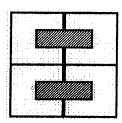
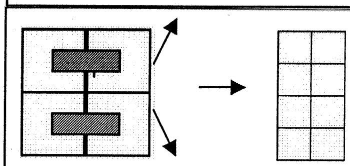
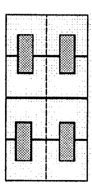
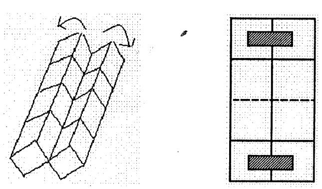
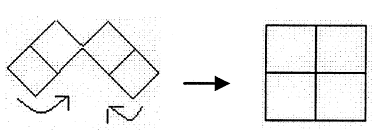
Preparation	Scaffolding	Grouping Options
☒ Adaptation of Content	☒ Modeling	☒ Whole class
☒ Links to Background	☒ Guided practice	☐ Small groups
☒ Links to Past Learning	☒ Independent practice	☐ Partners
☒ Strategies incorporated	☒ Comprehensible input	☒ Independent

Integration of Processes	Application	Assessment
☐ Reading	☒ Hands-on	☒ Individual
☐ Writing	☒ Meaningful	☐ Group
☒ Speaking	☒ Linked to objectives	☐ Written
☒ Listening	☒ Promotes engagement	☐ Oral

Arizona Math Standards Addressed	• S4C1PO4: TSW classify 3-D figures by their attributes and distinguish between length, area, and volumes using these 3-D figures • Opt. S4C4PO1: TSW identify the appropriate unit of measure for the volume of an object
Arizona Science Standards Addressed	•



A. Building the Cube:

	1. Lay four cubes as shown and tape in pairs
	2. Flip each pair over
	3. Put other four cubes in between taped pairs
	4. Tape cubes across in pairs as shown
	5. Roll top row up and bottom row down to open up center. [*Note*: The middle block pairs are not yet connected]
	6. Tape end pairs
	7. Hold with two hands on top and turn towards you so middle pops out
	8. Tape horizontal pairs [*Note*: All block pieces are interconnected at this point]
	9. Roll top row away from you and bottom row towards you so you see all eight cubes
	10. Tape vertical pairs
	11. Open out middle one more time and tape horizontal pair on top and on bottom
	12. Bend back top and bottom to expose middle – this gives you the right starting face for gluing on pictures.

MESA Mathematics Engineering Science Achievement

Lesson Activity

Title	**Math Puzzle: Folding Up Boxes**
ID Number	MS-M-P3
Duration	10-15 minutes
Age Level	Middle School
Learning Objectives	• TSW solve a logical mathematical word problem using grade-appropriate problem-solving strategies. • TSW solve a multi-step word problem by applying various numerical operations.
Other Objectives	• TSW communicate with their peers to solve a problem. • TSW listen as their peers discuss their strategies. • TSW participate in a group discussion about problem solving.
Materials Needed	• Handout: Folding Up Boxes 3
Activity	1. Pass out Math Puzzle: Folding Up Boxes 3. Tell students they have 10 minutes to solve and may work together. 2. After 10 minutes, discuss problems and answers. Ask students to describe the strategies they used to solve the problem. What worked for them?
Informal Assessment	54. Monitor students for engagement. 55. Monitor students for participation.
Formal Assessment	• Completed solutions to problems.

SEI Strategies Used

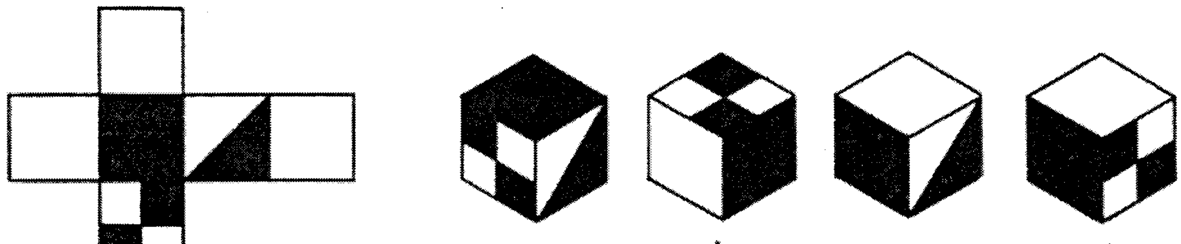
Preparation	Scaffolding	Grouping Options
☐ Adaptation of Content	☐ Modeling	☐ Whole class
☐ Links to Background	☐ Guided practice	☒ Small groups
☐ Links to Past Learning	☒ Independent practice	☒ Partners
☒ Strategies incorporated	☐ Comprehensible input	☐ Independent
Integration of Processes	**Application**	**Assessment**
☐ Reading	☐ Hands-on	☒ Individual
☐ Writing	☐ Meaningful	☒ Group
☒ Speaking	☒ Linked to objectives	☐ Written
☒ Listening	☒ Promotes engagement	☒ Oral

Arizona Math Standards Addressed	• S1C2: TSW understand and apply numerical operations such as solving grade level appropriate word problems using appropriate operations and numbers.

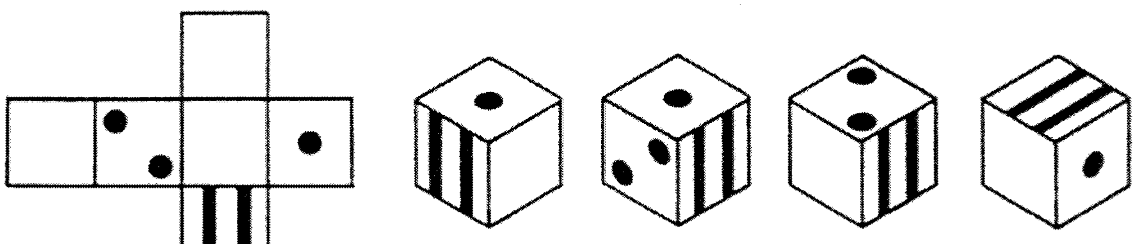
Name ______________________________

Folding Up Boxes 3

Look at each flattened box. One of the four boxes to the right shows the flattened box folded up. Circle this box.

1 

a b c d

2 

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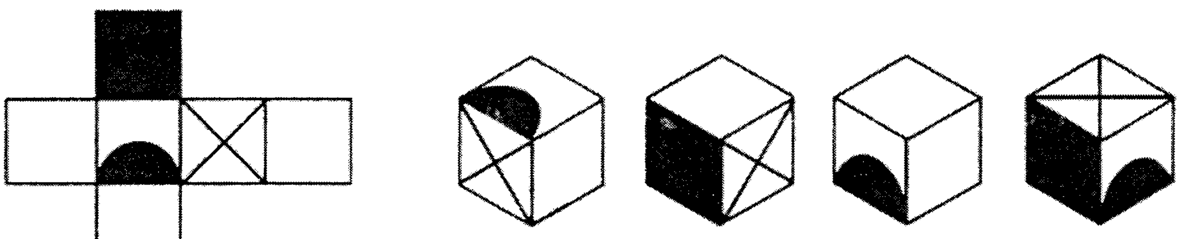
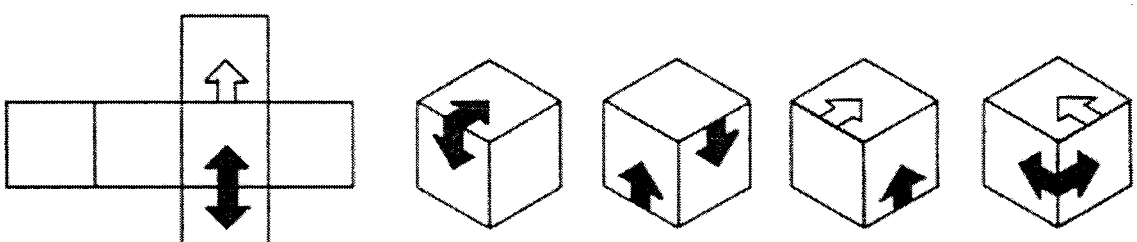
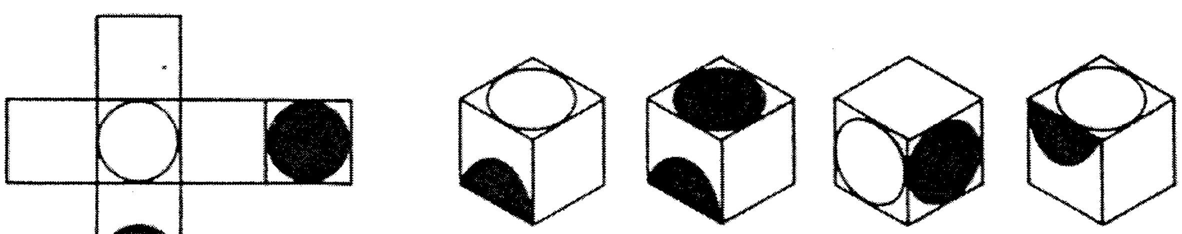
3 

a b c d

4 

a b c d

5 

a b c d

MESA Mathematics Engineering Science Achievement

Lesson Activity

Title	**Math Puzzles: Hans and Gerrie, Birthday Cake**
ID Number	MS-MP-4
Duration	15 minutes
Age Level	Middle School
Learning Objectives	• TSW solve higher order math logic puzzles using grade level-appropriate problem-solving strategies. • TSW use reasoning to solve mathematical logic puzzles using given information.
Other Objectives	• TSW develop a working plan with their group to develop a cooperative environment. • TSW communicate with their group by contributing their vocal input.
Key Terms	• Logical thinking: using reasoning to solve a problem or come to a conclusion.
Materials Needed	• Handout: Hans and Gerrie, Birthday Cake
Activity	• Pass puzzles out to students. • Inform students that they may work individually or in groups of two. Instruct them not to give the answer if they solve it before time is up. • Monitor and guide students to the solution.
Closure	• After 10-15 minutes, discuss each puzzle, its solution, and the logical reasoning student used to solve it. Call on students at random or have them volunteer to explain their problem-solving strategies.
Informal Assessment	56. Monitor students to check for participation. 57. Student oral presentation explaining their strategy.

SEI Strategies Used

Preparation
- ☐ Adaptation of Content
- ☒ Links to Background
- ☐ Links to Past Learning
- ☒ Strategies incorporated

Scaffolding
- ☐ Modeling
- ☐ Guided practice
- ☒ Independent practice
- ☐ Comprehensible input

Grouping Options
- ☐ Whole class
- ☐ Small groups
- ☒ Partners
- ☒ Independent

Integration of Processes
- ☒ Reading
- ☐ Writing
- ☒ Speaking
- ☒ Listening

Application
- ☐ Hands-on
- ☒ Meaningful
- ☒ Linked to objectives
- ☒ Promotes engagement

Assessment
- ☐ Individual
- ☒ Group
- ☒ Written
- ☒ Oral

Arizona Math Standards Addressed	• S5C1: TSW use reasoning to solve mathematical problems in contextual situations.

Birthday Cake

The birthday cake on the picture must be cut into eight equally sized pieces. However, you are allowed to make only 3 straight cuts.

The Question: How can the cake be cut into eight pieces with only 3 straight cuts?

Hans & Gerrie

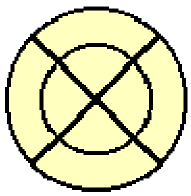
Hans is standing behind Gerrie and at the same time Gerrie is standing behind Hans.

The Question: How is this possible?

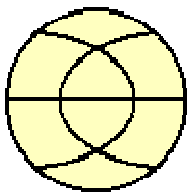
Birthday Cake

The birthday cake on the picture must be cut into eight equally sized pieces. However, you are allowed to make only 3 straight cuts.

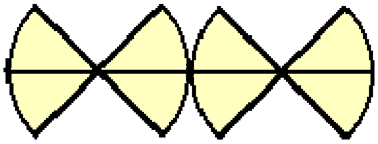
The Question: How can the cake be cut into eight pieces with only 3 straight cuts?
This is how the cake could be cut (seen from above), if we would prefer to have both top and bottom parts in each piece:



Note however that this is not a real solution, since it has non-straight cuts. In this way, we could think of many other 'solutions', like:



Finally, an alternative solution that requires some rearrangement of the pieces after the first two cuts, is the following: like before, make the first two cuts cross-wise, then arrange all four pieces in a row, and make the third straight cut like this:



Hans & Gerrie

Hans is standing behind Gerrie and at the same time Gerrie is standing behind Hans.

The Question: How is this possible?
Hans and Gerrie are standing with their backs towards each other!

Puzzles courtesy of: http://www.puzzle.dse.nl/index_us.html

Lesson Activity

Title	**Math Puzzle: Horse Trade**
ID Number	MS-MP-5
Duration	10 Minutes
Age Level	Middle School
Learning Objectives	• TSW solve a logical mathematical word problem using grade-appropriate problem-solving strategies. • TSW solve a multi-step word problem by applying various numerical operations.
Other Objectives	• TSW communicate with their peers to solve a problem. • TSW listen as their peers discuss their strategies. • TSW participate in a group discussion about problem solving.
Key Terms	• Problem solving: process of coming up with a solution to a problem.
Materials Needed	• Handout: Horse Trade
Activity	1. Pass math puzzle out to students. 2. Inform students they may work in pairs to solve the puzzle. 3. After 5 minutes, discuss problem and have one student model possible solution on the board. 4. Discuss process of problem solving with class and ask for other ways to solve the problem.
Informal Assessment	58. Monitor students to check for engagement. 59. Monitor students to check for participation.
Formal Assessment	• Solution to problem.

SEI Strategies Used

Preparation
- ☐ Adaptation of Content
- ☐ Links to Background
- ☐ Links to Past Learning
- ☒ Strategies incorporated

Scaffolding
- ☐ Modeling
- ☐ Guided practice
- ☒ Independent practice
- ☒ Comprehensible input

Grouping Options
- ☐ Whole class
- ☐ Small groups
- ☒ Partners
- ☐ Independent

Integration of Processes
- ☒ Reading
- ☒ Writing
- ☒ Speaking
- ☒ Listening

Application
- ☐ Hands-on
- ☒ Meaningful
- ☒ Linked to objectives
- ☒ Promotes engagement

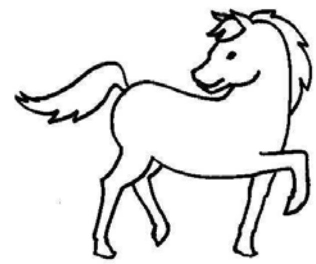
Assessment
- ☒ Individual
- ☒ Group
- ☒ Written
- ☒ Oral

Arizona Math Standards Addressed	• S1C2: TSW understand and apply numerical operations such as solving grade level appropriate word problems using appropriate operations and numbers.

Last updated 7/30/2008

Horse Trade

A man decides to buy a nice horse. He pays $60 for it, and he is very content with this strong animal. After a year, the value of the horse has increased to $70 and he decides to sell the horse. But, already a few days later, he regrets his decision to sell the beautiful horse and he buys it back. Unfortunately, he has to pay $80 to get it back, so he loses $10. After another year of owning the horse, he finally decides to sell the horse for $90.



The Question: What is the overall profit the man makes?

Horse Trade

A man decides to buy a nice horse. He pays $60 for it, and he is very content with this strong animal. After a year, the value of the horse has increased to $70 and he decides to sell the horse. But, already a few days later, he regrets his decision to sell the beautiful horse and he buys it back. Unfortunately, he has to pay $80 to get it back, so he loses $10. After another year of owning the horse, he finally decides to sell the horse for $90.

The Question: What is the overall profit the man makes?

Consider the trade-story as if it describes two separate trades, where:

> In the first trade, the man buys something for $60 and sells it again for $70, so he makes a profit of $10.
> In the second trade, the man buys something for $80 and sells it again for $90, so he makes again a profit of $10.

Conclusion: The man makes an overall profit of $10 + $10 = **$20**.

You can also look at the problem as follows: the total expenses are $60 + $80 = $140 and the total earnings are $70 + $90 = $160. The overall profit is therefore $160 - $140 = $20.

Lesson Activity

Title	**Horse Race Probabilities (40-50 minutes)**
ID Number	MS-M-A2
Sequence and Duration	• Lead In (10-15 minutes) • Activity (15-20 minutes) • Closure (10-15 minutes)
Age Level	Middle School
Essential Question	**In the MESA Horse Race, what determines whether my horse will win?**
Learning Objectives	• TSW discuss the possible outcomes for a probability activity. • TSW predict the outcome for a probability activity. • TSW hypothesize outcomes for a probability activity using dice. • TSW compare the statistical results of two identical activities to analyze the frequency of probability. • TSW record and analyze the data from the probability activity.
Other Objectives	• TSW listen to the class discussion and use this to generate their own ideas and hypotheses. • TSW contribute to the class discussion. • TSW write down the data from the activity on their record sheets.
Key Terms	• Probability: a measure of how likely something is. • Outcome: the end result.
Materials Needed	Per Group • Images of Race Horses Per Team • Handout: MESA Day at the Races! *(optional: 2 copies for team if you want to duplicate the activity to compare data)*
Lead In	41. Tell students that today is MESA Race Day. 42. Explain that MESA is having a horse race and they have 11 horses to choose from. 43. Tell students that they will be in teams of 2-3, depending on how many students it takes to make 11 teams. 44. Show pictures of the race horses. Hold up each picture, give their name, and discuss physical strengths of each horse. As you are showing the pictures, tell teams to think about which horse they want to pick. 45. Lay pictures of horses out on a table. *46.* Have teams select their horse. *You may want to use some sort of lottery pick for this because some teams are very aggressive in making sure they get the horse they want.* 47. Pass out Handout: MESA Day at the Races! to each team. Tell them to put their names on it and have one student responsible for keeping data. 48. Tell students that the race is ready to start. 49. Explain to students that a horse 'runs' when his number is thrown by a pair of dice. 50. Show students the following chart on the board: (You need to make sure this chart is on the board before the students arrive or have an alternate 'track'.)

Name of Horse	Track Position										
2- Winnie											Finish Line
3- Jet											
4- Kentucky King											
5- Oreo Dream											
6- Georgia Rules											
7- Sonoran Snow											
8- Lickity Split											
9- Joe											
10- Midnight Runner											
11- Starfire Sweet											
12- Beauty											

Note: Track can be extended to make for a longer race. As a horse's number is thrown, move the horse forward by placing a check next to their name. The first horse to reach the finish line wins.

51. Demonstrate for the students how the race works: Roll a pair of dice and whatever the sum of the numbers is that show up, that is the horse that moves ahead 1 space.
52. Ask if all teams are ready: "Are your horses warmed up?"
53. Before beginning the race, ask students to make predictions. Which horse do they think will win? Why? Ask them to explain their logic.

Activity

1. Begin playing the game.
2. Record the progress of each horse as you roll the dice.
3. At intervals, check the progress of each horse and ask questions like:
   - Why are these particular horses in the lead?
   - Why are these horses still way in the back?
   - What about the dice is determining a horse's progress?
4. At the conclusion of the race, discuss why certain horses made more progress than others. The horses that dominate the race will be 6, 7, and 8, because the probability of throwing those sums is higher.
5. If you want, you can duplicate the race to compare probability outcomes. The result will be similar.

Closure

1. Ask students to look at their data.
2. Have students answer the post-race questions on their handout. They may work together in teams to answer them.
3. Discuss the groups' answers to come up with a general statement about probable outcomes using dice.
4. Discuss the terms 'probability' and 'outcome' and relate the terms to the activity. Have the group come up with a general definition for each term using examples from the activity.
5. You can relate this to the common term 'lucky sevens'.

Informal Assessment

60. Monitor to make sure each student is participating.
61. Make sure each team is keeping accurate data.
62. Frequently check for understanding.

Formal Assessment

- Completed MESA Day at the Races handout.

Trouble Shooting

- Make sure 'race track' is prepared before activity. You can use the chart on the board; some teachers have made actual tracks to put on the table or on a handout, etc.

Extension

- Have students work out the number of possible ways to roll each number and compare (e.g. there are six possible ways to roll a seven, three possible ways to roll a four, and one possible way to roll a twelve). If students also work out

	the total number of possible combinations (36), this can lead to a lesson about using fractions to measure probabilities. [For instance, you have six out of thirty-six chances to roll a seven (6/36) versus one out of thirty-six chances to roll a twelve (1/36). How much more likely are you to roll a seven than a twelve? (6/36 divided by 1/36 = 6 times more likely)]

SEI Strategies Used

Preparation
- ☐ Adaptation of Content
- ☒ Links to Background
- ☐ Links to Past Learning
- ☒ Strategies incorporated

Scaffolding
- ☒ Modeling
- ☐ Guided practice
- ☐ Independent practice
- ☐ Comprehensible input

Grouping Options
- ☒ Whole class
- ☒ Small groups
- ☐ Partners
- ☐ Independent

Integration of Processes
- ☒ Reading
- ☒ Writing
- ☒ Speaking
- ☒ Listening

Application
- ☒ Hands-on
- ☒ Meaningful
- ☒ Linked to objectives
- ☒ Promotes engagement

Assessment
- ☐ Individual
- ☒ Group
- ☒ Written
- ☒ Oral

Arizona Math Standards Addressed	• S2C2: TSW understand and apply the basic concepts of probability.
Arizona Science Standards Addressed	• None

MESA Day at the Races!

Today is MESA Race Day! Your team will choose a horse to bet on. Look at each horse carefully; study its size and age. There are 11 horses to choose from. Good Luck!

Goal:

Each team will select a race horse for the MESA Horse Race. The MESA Advisor will roll 2 dice and the combined total of the roll determines which horse moves ahead one place on the track. For example, if the MESA advisor rolls a 3 and a 1, horse number 4 will move ahead one space. Choose wisely!

Team:

____

____

____

____

Number and Name of Selected Horse:

____

____

____

____

Post Activity Questions:

1. Which horse won the race?

   ____

2. Based on your observations, why did the winning horse finish first?

   ____

   ____

   ____

   ____

3. What are the chances that the winning horse will win again? Low or high? Explain your answer.

   ____

   ____

   ____

   ____

4. If you were to pick 3 horses for another race, which numbers would you pick and why?

5. Why is there not a Horse #1? Explain.

Horse # 2

Winnie

Horse #3

Jet Li

Horse #4

Kentucky King

Horse #5

Oreo Dream

Horse #6

Georgia Rules

Horse #7

Sonoran Snow

Horse #8

Lickity Split

Horse #9

Joe

Horse #10

Dexie's Midnight Runner

Horse #11

Starfire Sweet

Horse #12

Blanca

MESA Mathematics Engineering Science Achievement

Lesson Activity

Title	**Math Problem: Perimeter Matters**
ID Number	MS-MP-6
Duration	10-15 Minutes
Age Level	Middle School
Learning Objectives	• TSW solve a multi-step word problem using age-appropriate problem-solving strategies. • TSW apply their previous knowledge of measurement, computation, and geometric properties to find the perimeter of a given problem. • TSW write their answer with proper unit of measure.
Other Objectives	• TSW develop a working plan with their group to develop a cooperative environment. • TSW communicate with their group by contributing their vocal input.
Key Terms	• Perimeter: the distance around a geometrical figure.
Materials Needed	• Handout: Perimeter Matters
Activity	• Pass math problem out to students. • Inform students that they may work individually or in groups of two. Instruct them not to give the answer if they solve it before time is up. • Monitor and guide students to the solution.
Closure	• After 10-15 minutes, have one student model each problem on the board to explain how they arrived at their answer. Discuss alternate methods of problem-solving with students.
Informal Assessment	63. Monitor students to check for participation. 64. Student oral presentation explaining their strategy.

SEI Strategies Used

Preparation	Scaffolding	Grouping Options
☐ Adaptation of Content	☐ Modeling	☐ Whole class
☒ Links to Background	☐ Guided practice	☐ Small groups
☐ Links to Past Learning	☒ Independent practice	☒ Partners
☒ Strategies incorporated	☐ Comprehensible input	☒ Independent

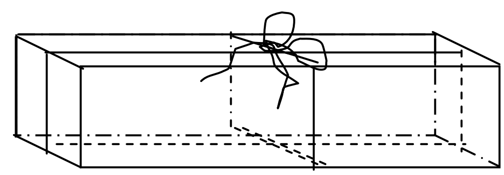
Integration of Processes	Application	Assessment
☒ Reading	☐ Hands-on	☐ Individual
☐ Writing	☒ Meaningful	☒ Group
☒ Speaking	☒ Linked to objectives	☒ Written
☒ Listening	☒ Promotes engagement	☒ Oral

Arizona Math Standards Addressed	• S1C2: TSW understand and apply numerical operations and their relationship to one another by solving word problems using grade-level appropriate operations and numbers. • S4C4: TSW understand and apply appropriate units of measure, measurement techniques, and formulas to determine measurement. Specifically, to distinguish between perimeter and area in given contextual situation.

Perimeter Matters

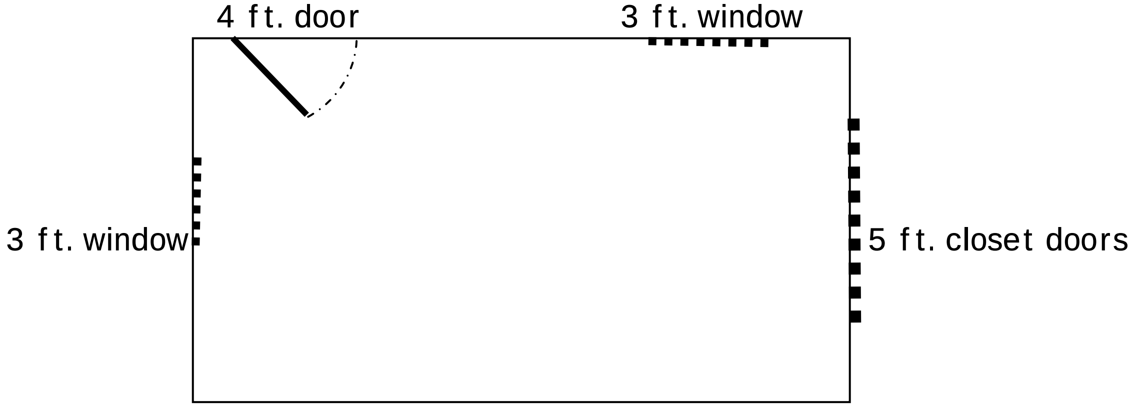
1. Marta wants to tie a ribbon around the sides of a hexagonal box and then tie a bow. Each side of the box is 4 inches long. She needs 14 inches for the bow. Is one yard of ribbon enough? Explain. Then state exactly how long the ribbon must be.

2. Caryn needs to ship a box that is 14" high, 12 inches deep and 24 inches long. After sealing the box, she tied it with twine as shown:



How much twine does she need if the bow uses 12 inches of twine?

2. Shawndolyn is remodeling her daughter's room. She plans to put a border around the room at waist height and another border around the ceiling. The diagram shows the layout of the 12' X 8' room. There will be no gaps in the ceiling border. How many feet of border does Shawndolyn need?



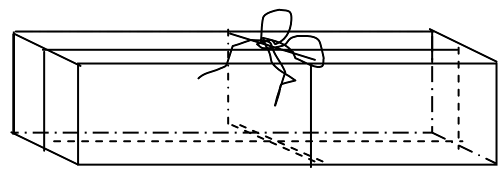
Written by Nancy R. Johnson
2002

Perimeter Matters (answers)

1. Marta wants to tie a ribbon around the sides of a hexagonal box and then tie a bow. Each side of the box is 4 inches long. She needs 14 inches for the bow. Is one yard of ribbon enough? Explain. Then state exactly how long the ribbon must be.

The box has six sides, each 4 inches long. Therefore, Marta needs 6 X 4 = 24 inches of ribbon to go around the box. The bow takes 14 inches. So, Marta needs 24 + 14 = 38 inches. One yard or 36 inches of ribbon is not enough. Marta must have at least 38 inches.

2. Caryn needs to ship a box that is 14" high, 12 inches deep and 24 inches long. After sealing the box, she tied it with twine as shown:

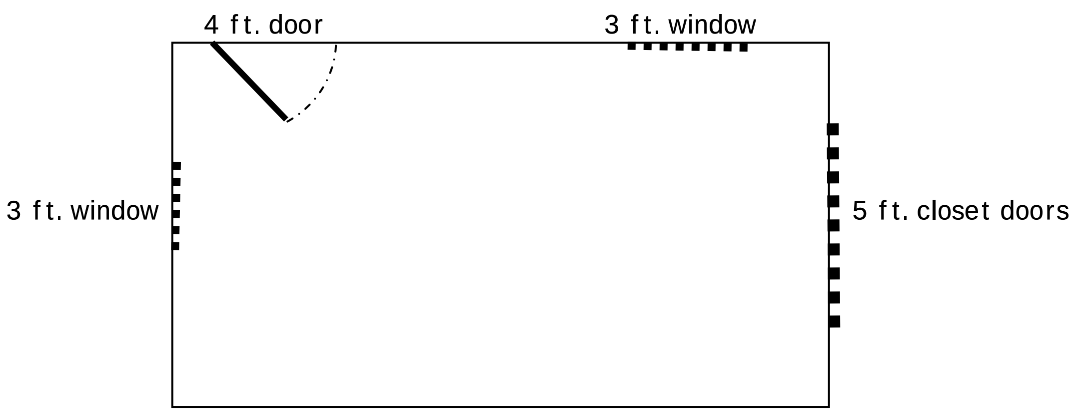


How much twine does she need if the bow uses 12 inches of twine?

She needs 140 inches of twine. The twine is used along the height 4 times, along the depth 2 times, and along the length 2 times. The box takes 12 inches. The amount of twine needed = 4(14)+ 2(12) + 2(24) + 12 = 140

2. Shawndolyn is remodeling her daughter's room. She plans to put a border around the room at waist height and another border around the ceiling. The diagram shows the layout of the 12' X 8' room. There will be no gaps in the ceiling border. How many feet of border does Shawndolyn need?

The border around the ceiling takes 2(12) + 2(8) = 24 + 16 = 40 feet.
The waist high border takes 12 + (8 – 5) + (12 – 3 – 4) + (8 – 3) = 12 + 3 + 5 + 5 = 25 feet.
Shawdolyn needs 40 + 25 or 65 feet of the border.

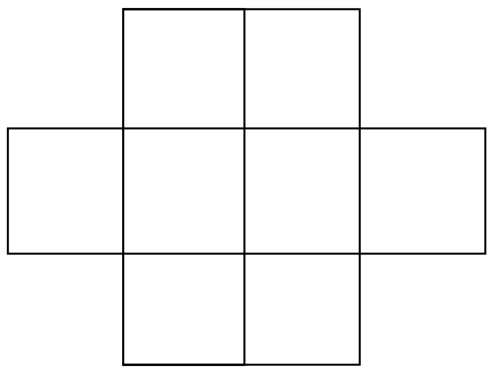


Written by Nancy R. Johnson
2002

Critical thinking Puzzles

Letters in the Mailboxes

The mailboxes for the residents of Sunny Side Apartments are mounted as the drawing below shows.



The residents' last names start with consecutive letters of the alphabet:

Abbott	Baker
Czaia	Duiski
Enzio	Francavilla
Gilbert	Honore

Their mailboxes are arranged so that the letters identifying the owner of the mail in the box, A, B, C, D, E, F, G, and H, do not touch side to side, up and down, or corner to corner.

Label the mailboxes.

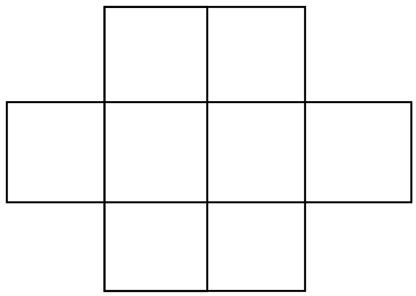
Is it possible to label the mailboxes another way or will the postmaster be sure to deliver mail to the correct resident?

Written by Nancy R. Johnson
2002

Critical thinking Puzzles

Letters in the Mailboxes (answer)

The mailboxes for the residents of Sunny Side Apartments are mounted as the drawing below shows.



The residents' last names start with consecutive letters of the alphabet:

Abbott	Baker
Czaia	Duiski
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Gilbert	Honore

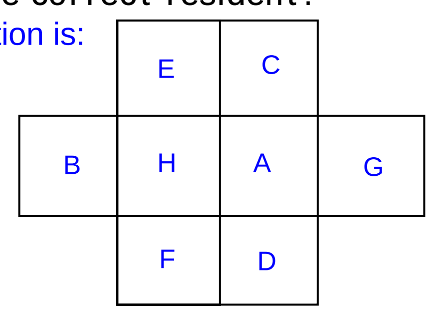
Their mailboxes are arranged so that the letters identifying the owner of the mail in the box, A, B, C, D, E, F, G, and H, do not touch side to side, up and down, or corner to corner.

Label the mailboxes.

Hint: Use eight lettered cards to arrange instead of writing and erasing. Be sure to skip over both before and after each letter is placed. Students who have practice with logic puzzles should use the first and last in the middle boxes

Is it possible to label the mailboxes another way or will the postmaster be sure to deliver mail to the correct resident?

One possible solution is:



Others exist, so the boxes must be labeled for the postmaster to deliver mail to the correct resident.

Written by Nancy R. Johnson
2002

Designing an Inlaid Table Top

Lavarus is building an accent table that will have a square top with inlaid ceramic tiles. He has 5 tiles in each of 5 different colors, red, blue, green, yellow and brown.

His instructor challenged him to arrange the tiles in a design so that each row and column contains exactly one tile of each color and so that two tiles of the same color do not touch diagonally. The first row he laid was red, blue, green, yellow, and brown.

Show two different ways he could arrange the rest of the design. Color them. Is there another way?

TabLE Top 1

RED	BLUE	GREEN	YELLOW	BROWN

TabLE Top 2

RED	BLUE	GREEN	YELLOW	BROWN

TabLE Top 3

RED	BLUE	GREEN	YELLOW	BROWN

Written by Nancy R. Johnson
2002

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Show two different ways he could arrange the rest of the design. Color them. Is there another way?

TabLE Top 1

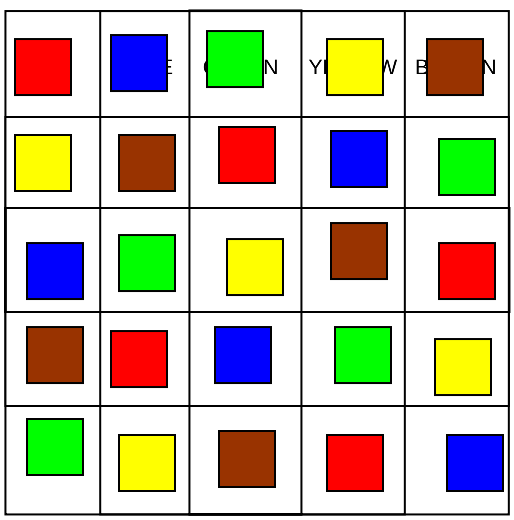


TabLE Top 2

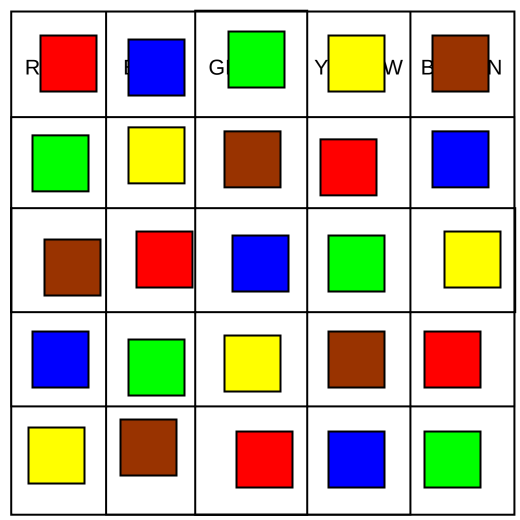
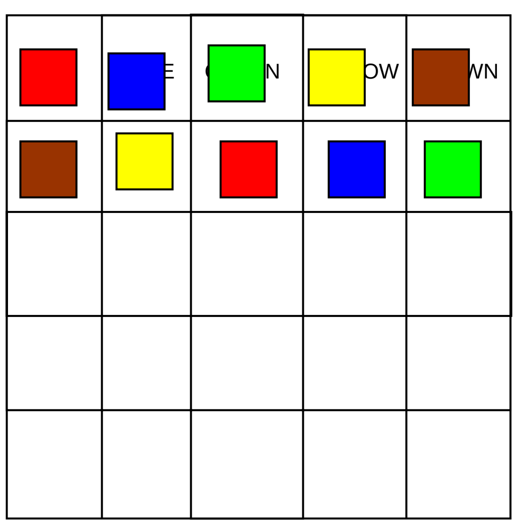


TabLE Top 3



I did not find another way.

Written by Nancy R. Johnson
2002

Lesson Activity

Title	**Math Puzzle: Sudoku for Kids!**
ID Number	MS-M-P7
Duration	20 minutes
Age Level	Middle School
Learning Objectives	• TSW solve a logical mathematical problem using grade-appropriate problem-solving strategies. • TSW solve a multi-step problem by applying various numerical operations.
Other Objectives	• TSW communicate with their peers to solve a problem. • TSW listen as their peers discuss their strategies. • TSW participate in a group discussion about problem solving.
Materials Needed	• Handout: Sudoku for Kids!
Activity	54. Pass puzzle out to students. 55. Inform students that they may work individually or in groups of two. Instruct them not to give the answer if they solve it before time is up. 56. Monitor and guide students to the solution. 3. After 15 minutes, discuss the puzzle, its solution, and the logical reasoning students used to solve it.
Informal Assessment	65. Monitor students for engagement. 66. Monitor students for participation.
Formal Assessment	• Completed solution to puzzle.

SEI Strategies Used

Preparation
- ☐ Adaptation of Content
- ☐ Links to Background
- ☐ Links to Past Learning
- ☒ Strategies incorporated

Scaffolding
- ☐ Modeling
- ☐ Guided practice
- ☒ Independent practice
- ☐ Comprehensible input

Grouping Options
- ☐ Whole class
- ☐ Small groups
- ☒ Partners
- ☐ Independent

Integration of Processes
- ☒ Reading
- ☐ Writing
- ☒ Speaking
- ☒ Listening

Application
- ☐ Hands-on
- ☐ Meaningful
- ☒ Linked to objectives
- ☒ Promotes engagement

Assessment
- ☒ Individual
- ☒ Group
- ☐ Written
- ☒ Oral

Arizona Math Standards Addressed	• S1C2: TSW understand and apply numerical operations such as solving grade level appropriate word problems using appropriate operations and numbers.

Sudoku for Kids!

Every row, column and mini-grid must contain the numbers 1 through 9. Don't guess – use logic!

	7			6			2	
		3	2	9	7	5		
		6	5		4	3		
	6	8				7	1	
1		7				9		5
	9	5				2	8	
		4	8		2	1		
		1	3	5	6	4		
	5			1			3	

Good Luck and Have Fun!

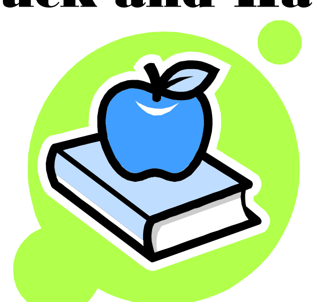
Last updated 7/30/2008

Sudoku for Kids!

Every row, column and mini-grid must contain the numbers 1 through 9. Don't guess – use logic!

5	7	9	1	6	3	8	2	4
8	4	3	2	9	7	5	6	1
2	1	6	5	8	4	3	9	7
4	6	8	9	2	5	7	1	3
1	2	7	6	3	8	9	4	5
3	9	5	7	4	1	2	8	6
6	3	4	8	7	2	1	5	9
9	8	1	3	5	6	4	7	2
7	5	2	4	1	9	6	3	8

Good Luck and Have Fun!



MESA Mathematics Engineering Science Achievement

Lesson Activity

Title	**Math Puzzle: Tapestry Squares**
ID Number	MS-M-P8
Duration	20-30 minutes
Age Level	Middle School
Learning Objectives	• TSW solve a logical mathematical word problem using grade-appropriate problem-solving strategies. • TSW solve a multi-step word problem by applying various numerical operations.
Other Objectives	• TSW communicate with their peers to solve a problem. • TSW listen as their peers discuss their strategies. • TSW participate in a group discussion about problem solving.
Materials Needed	• Handout: Tapestry Squares • Colored pencils
Activity	4. Pass out math puzzle. 5. Tell students they have 20-25 minutes to work on the puzzle. 6. Collect math puzzles and discuss problems that were most difficult. Review difficult concepts on the board.
Informal Assessment	67. Monitor students for engagement. 68. Monitor students for participation.
Formal Assessment	• Completed solution to puzzle.

SEI Strategies Used

Preparation
- ☐ Adaptation of Content
- ☐ Links to Background
- ☒ Links to Past Learning
- ☐ Strategies incorporated

Scaffolding
- ☐ Modeling
- ☐ Guided practice
- ☒ Independent practice
- ☐ Comprehensible input

Grouping Options
- ☐ Whole class
- ☐ Small groups
- ☐ Partners
- ☒ Independent

Integration of Processes
- ☐ Reading
- ☐ Writing
- ☒ Speaking
- ☒ Listening

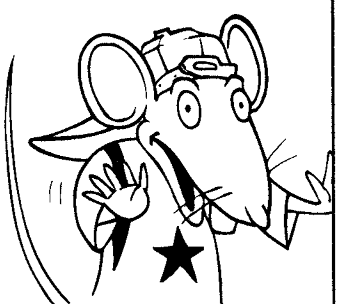
Application
- ☐ Hands-on
- ☐ Meaningful
- ☒ Linked to objectives
- ☒ Promotes engagement

Assessment
- ☒ Individual
- ☒ Group
- ☐ Written
- ☒ Oral

Arizona Math Standards Addressed	• S1C2: TSW understand and apply numerical operations such as solving grade level appropriate word problems using appropriate operations and numbers.

Activity 22: Tapestry squares

Multiplication



2, 3, 4	light blue
5, 6, 7	green
8, 9, 10	red
11, 12, 13, 14	orange
15, 16, 17	gray
18, 19, 20	black
25, 36, 49, 64	dark blue

Find the answer in each square and use the key to color in the grid. Give your picture a title.

Title

$\sqrt{9}$	16 ÷ 8	$\frac{1}{2}$ x 4	$\sqrt{16}$	18 ÷ 9	5 − 3	2^2	20 ÷ 10	$\frac{1}{2}$ x 8	6 − 4	1 + 1	12 ÷ 6	1 + 1	2 + 1	3 + 1	$\sqrt{36}$	$\sqrt{25}$	3 x 6	13 + 6	6 x 3	2^2	$\frac{1}{2}$ x 4
$\frac{1}{2}$ x 6	14 ÷ 7	$\sqrt{4}$	2 x 9	9 + 10	4 x 5	14 + 6	6 x 3	$\sqrt{9}$	6 x 3	11 + 9	20 − 1	3 x 6	8 + 12	3 x 6	4 x 5	2 x 10	5 x 4	20 − 2	5 x 4	$\sqrt{9}$	16 + 4
5 − 3	$\sqrt{16}$	6 x 3	10 x 2	3 x 6	2 x 10	2 x 9	9 + 10	20 − 1	4 x 5	8 + 11	20 − 2	5 x 4	$\sqrt{9}$	6 x 1	3 + 2	2 + 3	$\sqrt{49}$	20 − 1	2 x 10	8 + 10	5 x 4
18 ÷ 6	2 x 2	6 x 3	4 x 5	5 x 4	3 x 6	$\sqrt{4}$	$\sqrt{9}$	$\sqrt{16}$	17 + 3	4 + 16	16 ÷ 4	2^2	20 ÷ 5	11 − 5	4 + 2	2 + 4	3 + 4	2 x 10	4 x 5	11 + 8	$\sqrt{9}$
6 − 2	3 + 4	25 ÷ 5	12 ÷ 2	11 + 9	3 + 3	4 + 3	9 − 7	8 − 6	11 + 8	7 − 5	7 − 4	7 − 3	9 − 4	10 − 3	2 x 3	3 + 4	$\sqrt{36}$	10 − 3	3 + 2	$\sqrt{16}$	$\sqrt{4}$
6 − 4	10 − 4	7 − 2	9 x 2	2 x 9	5 + 2	3 + 4	9 − 2	3 x 2	$\sqrt{4}$	$\sqrt{9}$	$\sqrt{25}$	$\sqrt{36}$	$\sqrt{49}$	10 − 3	$\sqrt{25}$	4 + 3	3 x 2	11 − 4	1 + 4	4 + 8	4 + 7
$\sqrt{25}$	9 − 3	8 − 3	6 x 3	10 − 3	10 − 5	10 − 4	6 x 1	$\sqrt{64}$	4 x 2	$\sqrt{81}$	3^2	$\sqrt{100}$	17 − 7	$\sqrt{36}$	3 x 2	3 + 2	5 x 1	9 − 2	3 + 4	4 + 9	7 + 10
$\sqrt{49}$	9 − 4	4 + 4	4 + 5	4 + 6	7 − 2	7 − 1	7 − 0	9 + 0	8 − 0	4^2	3 x 5	4 x 4	19 − 2	8 − 1	4 + 1	10 x 2	$\sqrt{25}$	10 − 4	3 + 3	4 + 10	4^2
9 − 3	10 − 3	9 − 2	7 + 1	$\sqrt{25}$	$\sqrt{36}$	$\sqrt{81}$	$\sqrt{49}$	7 + 1	8 + 1	3 x 5	4^2	2 x 8	4 x 4	$\sqrt{25}$	20 − 1	20 − 2	6 x 3	4 + 2	2 + 4	3 + 8	3 x 5
$\sqrt{36}$	3^2	7 + 1	8 + 1	$\sqrt{64}$	2 x 4	3 x 3	$\sqrt{81}$	5 x 2	24 ÷ 3	$\sqrt{100}$	27 ÷ 3	9 ÷ 1	3^2	20 − 1	6 x 3	3 x 6	4 x 5	17 + 3	7 − 1	3 + 9	5 + 6
9 − 4	$\sqrt{100}$	4^2	5 x 3	4^2	$\sqrt{100}$	18 − 1	5 x 3	4^2	3^2	17 − 2	19 − 2	4^2	$\sqrt{81}$	20 − 3	3 x 5	5 x 3	$\sqrt{64}$	10 − 1	3 + 4	3 + 10	9 + 5
5 + 3	$\sqrt{64}$	3^2	20 − 3	2 x 5	3 x 3	4^2	3^2	4 x 4	$\sqrt{100}$	5 x 3	$\sqrt{81}$	3 x 5	3^2	11 − 1	4^2	5 x 2	$\sqrt{81}$	4 x 2	7 − 2	3 + 11	5 + 7
1 x 5	5 + 4	5 x 2	8 x 2	6 + 2	7 + 2	3 x 5	4^2	10 + 7	$\sqrt{64}$	9 + 8	11 + 6	8 + 9	2 x 4	3^2	8 + 9	4 + 5	$\sqrt{100}$	3^2	2 x 3	6 + 5	8 + 3
6^2	$\sqrt{81}$	20 − 12	13 − 5	16 − 8	9 − 1	15 − 7	12 − 4	19 − 11	14 − 6	11 − 3	18 − 10	10 − 2	17 − 9	4 x 2	2 x 4	2 x 5	5 x 2	3 x 3	15 + 5	5 + 6	5 + 8
5^2	3 x 2	3^2	6 + 3	$\sqrt{25}$	$\sqrt{49}$	2 x 4	3 + 5	$\sqrt{25}$	$\sqrt{49}$	5 x 2	6 + 4	$\sqrt{25}$	$\sqrt{49}$	3^2	5 x 2	3 + 2	4 + 2	5 + 2	4 + 1	5 + 1	3^2
7^2	3 + 2	3 x 3	5 + 4	$\sqrt{36}$	4 + 3	5 + 3	4 x 2	$\sqrt{36}$	3 + 4	$\frac{1}{2}$ x 20	2 x 5	$\sqrt{36}$	3 + 4	2 x 4	4 + 6	3 + 4	0 + 7	0 + 6	0 + 5	6 + 1	$\sqrt{100}$
6 x 3	7 + 12	13 + 7	9 x 2	20 − 1	6 + 14	2 x 9	6 x 3	18 x 1	5 + 13	20 − 1	28 − 10	20 − 2	1 x 18	6 x 3	2 x 10	9 + 9	3 x 6	10 x 2	8 + 11	5 x 4	4 x 5
$\sqrt{36}$	15 − 8	1 x 5	16 − 9	11 − 5	20 ÷ 4	11 − 6	$\sqrt{25}$	12 − 7	$\frac{1}{2}$ x 10	25 ÷ 5	13 − 6	13 − 8	3 + 3	30 ÷ 6	$\sqrt{49}$	4 + 3	45 ÷ 9	4 + 3	20 − 14	3 + 4	3 x 2

MESA Mathematics Engineering Science Achievement

Lesson Activity

Title	**Math Puzzle: Ten Trees**
ID Number	MS-M-P9
Duration	15-20 minutes
Age Level	Middle School
Learning Objectives	• TSW solve a logical mathematical word problem using grade-appropriate problem-solving strategies. • TSW solve a multi-step word problem by applying various numerical operations.
Other Objectives	• TSW communicate with their peers to solve a problem. • TSW listen as their peers discuss their strategies. • TSW participate in a group discussion about problem solving.
Materials Needed	• Handout: Ten Trees
Activity	57. Pass puzzles out to students. 58. Inform students that they may work individually or in groups of two. Instruct them not to give the answer if they solve it before time is up. 59. Monitor and guide students to the solution. 60. After 10-15 minutes, discuss each puzzle, its solution, and the logical reasoning students used to solve it. Call on students at random or have them volunteer to explain their problem-solving strategies.
Informal Assessment	69. Monitor students for engagement. 70. Monitor students for participation.
Formal Assessment	• Completed solution to problem.

SEI Strategies Used

Preparation
- ☐ Adaptation of Content
- ☐ Links to Background
- ☐ Links to Past Learning
- ☒ Strategies incorporated

Scaffolding
- ☐ Modeling
- ☐ Guided practice
- ☒ Independent practice
- ☐ Comprehensible input

Grouping Options
- ☐ Whole class
- ☐ Small groups
- ☒ Partners
- ☐ Independent

Integration of Processes
- ☒ Reading
- ☐ Writing
- ☒ Speaking
- ☒ Listening

Application
- ☐ Hands-on
- ☐ Meaningful
- ☒ Linked to objectives
- ☒ Promotes engagement

Assessment
- ☒ Individual
- ☒ Group
- ☐ Written
- ☒ Oral

Arizona Math Standards Addressed	• S5C1: TSW use reasoning to solve mathematical problems in contextual situations to solve a simple logic problem from given information.

Ten Trees

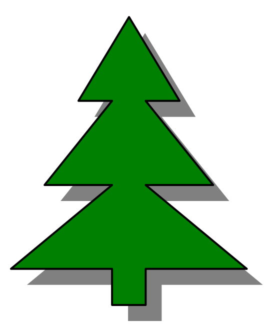
Joyce has bought ten trees for her garden. She wants to plant these trees in five rows, with four trees in each row.

The Question: How must Joyce plant the trees**?**

The Answer:

Another Question: Joyce's neighbor George has bought nine trees for his garden. How can he plant these nine trees in ten rows, with three trees in each row**?**

Another Answer:



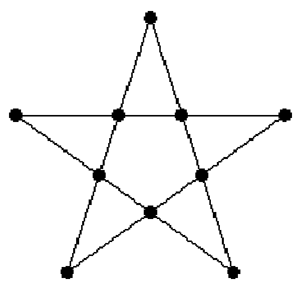
Ten Trees

Joyce has bought ten trees for her garden. She wants to plant these trees in five rows, with four trees in each row.

The Question: How must Joyce plant the trees**?**

The Answer:

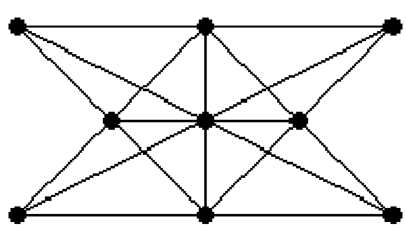
The trees must be planted on the edges of a five pointed star:



Another Question: Joyce's neighbor George has bought nine trees for his garden. How can he plant these nine trees in ten rows, with three trees in each row**?**

Another Answer:

The nine trees must be planted as follows:



Source: http://www.puzzle.dse.nl/basic/index_us.html#ten_trees

MESA Mathematics Engineering Science Achievement

Lesson Activity

Title	**Math Puzzle: Which Wright is Right?**
ID Number	MS-M-P10
Duration	10-15 minutes
Age Level	Middle School
Learning Objectives	• TSW solve a logical mathematical word problem using grade-appropriate problem-solving strategies. • TSW solve a multi-step word problem by applying various numerical operations.
Other Objectives	• TSW communicate with their peers to solve a problem. • TSW listen as their peers discuss their strategies. • TSW participate in a group discussion about problem solving.
Materials Needed	• Handout: Which Wright is Right?
Activity	7. Pass puzzles out to students. 8. Inform students that they may work individually or in groups of two. Instruct them not to give the answer if they solve it before time is up. 9. Monitor and guide students to the solution. 7. After 10-15 minutes, discuss each puzzle, its solution, and the logical reasoning student used to solve it. Call on students at random or have them volunteer to explain their problem-solving strategies.
Informal Assessment	71. Monitor students for engagement. 72. Monitor students for participation.
Formal Assessment	• Completed solution to problem.

SEI Strategies Used

Preparation
- ☐ Adaptation of Content
- ☐ Links to Background
- ☒ Links to Past Learning
- ☒ Strategies incorporated

Scaffolding
- ☐ Modeling
- ☐ Guided practice
- ☒ Independent practice
- ☐ Comprehensible input

Grouping Options
- ☐ Whole class
- ☐ Small groups
- ☒ Partners
- ☐ Independent

Integration of Processes
- ☒ Reading
- ☐ Writing
- ☒ Speaking
- ☒ Listening

Application
- ☐ Hands-on
- ☐ Meaningful
- ☒ Linked to objectives
- ☒ Promotes engagement

Assessment
- ☒ Individual
- ☒ Group
- ☐ Written
- ☒ Oral

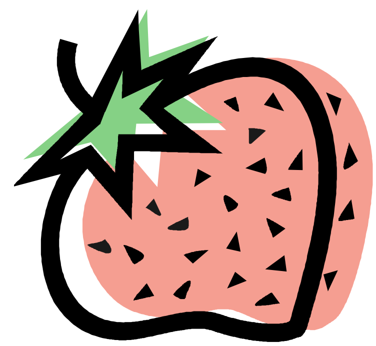
Arizona Math Standards Addressed	• S1C2: TSW select the grade level appropriate operation to solve a word problem.

Which Wright Is Right?

Dave Wright said that he put up a fence around his strawberry patch. He also said that the fence forms a right triangle, has sides of 12 yards, 25 yards, and 40 yards, and encloses an area of 150 square yards. Jason Wright, his brother, said that Dave is making up this story. Jason said that there is no such fence, and there could never be such a fence around the strawberry patch. Then, Dave Wright said that Jason never tells the truth and tries to show him up all the time.

Which brother is right?

Hint: What do you know about the sides of a right triangle?



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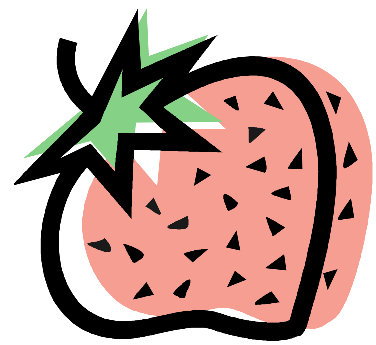
Which brother is right?

Hint: What do you know about the sides of a right triangle?



Solution:

Jason is right. Dave could not have built a fence in the form of a right triangle with sides measuring 12 yards, 25 yards, and 40 yards.

By using the Pythagorean theorem, you can determine that a right triangle with legs measuring 12 yards and 25 yards must have a hypotenuse equal to the square root of ($12^2 + 25^2$), which is approximately 27.7 yards, not 40 yards.

Skill Set 3:
College Prep Activities

Lesson Activity

Title	**CPW Activity: Study Skills (60-80 minutes)**
ID Number	MS-CPW-1
Sequence and Duration	• Lead In: Master Students Outside the Classroom (5 minutes) • Activity: "How Am I Doing?" Study Habits Questionnaire (15 minutes) • Activity: Study Habits Charades (35-45 minutes) • Closure (5-10 minutes)
Age Level	Middle School
Essential Question	**What study skills do I need to work on to be a Master Student?**
Learning Objectives	• TSW identify study habit strengths and weaknesses. • TSW increase awareness of good study habits.
Other Objectives	• Help students realize that they are natural learners • Help students identify tools that they already possess
Key Terms	• Master Student • Study Habits
Materials Needed	Per student • Copies of MESA Notebook • Copies of "How Am I Doing" Study Habits Questionnaire • Copy of 25 Practical Study Habits
Lead In	**Master Students outside the classroom** 1. Pass out the MESA Notebook and have the students fill in their name, date and write Study Skills as the title. 2. Have the students write the term Master Student in their MESA Notebook. 3. Ask them for their definition of Master Student. Write down their responses and then form a definition based on those responses. It should read similar to "one who is an expert at applying effective study habits to achieve maximum results" 4. Do the same process for the term Study Habits 5. Tell the students that each of them is already a Master Student and that you are going to prove it. 6. Ask the students "How many of you could sing every word of your favorite song right now?" 7. Ask "How many of you can quote your favorite movies accurately?" 8. Ask "How many of you know all the details about your favorite celebrity, artist or athlete?" 9. Now ask "How many of you have trouble doing your homework because you can't remember how the teacher did it?" 10. Ask "How many of you have trouble remembering important information for your tests?" 11. Now ask "Why is it that you can remember songs, movies, and sports and not your school work?" 12. Write down their responses on the board. 13. Now with the students help pick out key words (i.e. interesting, fun, talking about it with friends) and ask them to write them in the procedure portion of their MESA Notebooks under the heading "Keys to Effective Studying & Learning" 14. Tell the students that these responses show that they are already Master Students. They are natural learners and already have some good study habits but they need to figure out how to apply them to all school subjects

Activity	**"How Am I Doing?" Study Habits Questionnaire** 1. Distribute the questionnaire and tell the students that they are going to assess their study habits. 2. Tell the students to read the direction and then answer their questions and score themselves. 3. Remind students to be honest and that the information will be private. Let them know that this will help them accurately determine their strengths and weaknesses in their study habits. 4. When everyone is done have them break up into groups based on their strongest category, then even out the groups. **Study Habits Charades** 1. Tell the students that being a Master Student starts by having better study habits. Once you have mastered the art of studying you can do well in tests and turn in homework with more confidence. Studying isn't as difficult as it seems, but it is very important for student success. 2. Distribute the handout titled "25 practical study habits". 3. Ask the students if they have ever played the game charades. If there are students who have not, demonstrate it using students who have played and simple examples (i.e. peeling and eating an orange, reading a funny book) 4. Tell the students that they are going to teach each other some of the tips on this handout by playing Study Habits Charades! 5. Assign each group a set of tips. 6. Example: If you have 5 groups, Group #1 will be assigned numbers 1-5 and Group #2 will get numbers 6-10. Tell the students that they should pick at least 3 tips to teach to the class (it will be impossible to cover all 25 tips at once). 7. Ask each group to pick the three most important tips from their assigned numbers and act out those tips to the class. Students should not talk but you can allow it if you feel it is necessary. The can also use any items in the classroom for their skits. For each skit, the rest of the class (using the handout), guesses the study skill they think their classmates are demonstrating. For example: #3 could be demonstrated by a student pretending to be waiting at the bus stop, and musing to him/herself, "Ah, why don't I use this opportunity to review the notes I took in algebra today!" 8. Give them about 10-15 minutes to work on their presentations. When all the groups have finished, have them present their skits. Incentives (optional) can be given to students who guess a study skill correctly. 9. If there is time left, go over some tips that may be hard to understand, or important tips which were not presented in class.
Closure	1. Have the students return to their seats. 2. Ask them "How many of you learned more about yourself and your study habits today?" 3. Next ask them "How many of you identified at least two study habits you need to improve, and how to do it?" 4. Next ask them to write those things down in their MESA Notebook under conclusion. 5. Tell the students that it takes time to improve study habits and grades but that it is possible. Tell the students that if they are not sure how to improve then they should ask for help whether it be from a teacher, counselor, or fellow student.
Informal Assessment	73. Monitor students to check for engagement. 74. Monitor students to check for understanding.
Formal Assessment	• Completed MESA Notebook. • Completed Study Habits Questionnaire.
Trouble Shooting	• If working with large groups have them split into smaller groups with each group

	doing one of the study habits. • If time is a concern you can handout the questionnaire the week before and have the students complete it and bring it for this week. • Have students assist you in passing out handouts to save time. • If running out of time, have students answer closure questions on their own rather than in a group. • If you feel charades will not work with your students, you can have them sketch the tips in a “Win, Lose, or Draw” type format.

SEI Strategies Used

Preparation
- ☐ Adaptation of Content
- ☒ Links to Background
- ☒ Links to Past Learning
- ☐ Strategies incorporated

Scaffolding
- ☒ Modeling
- ☐ Guided practice
- ☐ Independent practice
- ☒ Comprehensible input

Grouping Options
- ☒ Whole class
- ☒ Small groups
- ☐ Partners
- ☒ Independent

Integration of Processes
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- ☒ Listening

Application
- ☒ Hands-on
- ☒ Meaningful
- ☒ Linked to objectives
- ☒ Promotes engagement

Assessment
- ☒ Individual
- ☐ Group
- ☒ Written
- ☒ Oral

HOW AM I DOING?

(Study Habits Questionnaire)

The purpose of this questionnaire is to help you get information about how you study. As you examine the results, you will discover your areas of strength and weakness. The results will have meaning only if you are honest and respond as accurately as possible. If the statement is true about you, circle **Y** for **YES**. If the statement is false as it applies to you, circle **N** for **NO**. Be sure to circle **Y** or **N** for each statement. Answer carefully so you can get accurate information.

1. I have trouble finishing tests on time.	Y	N
2. I set aside a regular time for studying every day.	Y	N
3. I study best with the radio or TV on.	Y	N
4. I don't have much luck following a definite study schedule.	Y	N
5. I give up if an assignment is difficult.	Y	N
6. I have difficulty determining important points in class discussions.	Y	N
7. Before class starts, I try to remember yesterday's lesson.	Y	N
8. I waste time because I am not organized.	Y	N
9. I focus entirely on my work when I study.	Y	N
10. I don't feel comfortable reading a chapter until I've read all the headings first.	Y	N
11. I don't bother taking notes about what the teacher says.	Y	N
12. I get sleepy when I study.	Y	N
13. I check my assignments to make sure I understand the directions.	Y	N
14. I seldom listen when the teacher is giving an assignment.	Y	N
15. I enjoy learning.	Y	N
16. Before I begin an assignment, I estimate how long it will take me and then try to beat the clock.	Y	N
17. Before answering an essay question, I organize what I am going to write.	Y	N
18. I have difficulty keeping my mind from wandering when I study.	Y	N
19. Using classroom notes and the textbook, I can usually predict 80-90% of the questions on a test.	Y	N

20. I could get better grades.	Y	N
21. I do my studying before I do anything else.	Y	N
22. I try to record everything a teacher says in a class presentation.	Y	N
23. I set a time to review for each course every week.	Y	N
24. I should use my time better, but it’s too much trouble to get organized.	Y	N
25. I’d rather get through fast than have a perfect paper.	Y	N
26. I usually lose points on my exams because of careless mistakes.	Y	N
27. I usually seek a quiet place to study.	Y	N
28. Before I leave class, I make sure that I know what homework to do and how to do it.	Y	N
29. I have a hard time getting interested in some of my courses.	Y	N
30. Good grades are important to me.	Y	N
31. I stop to check what I remember at the end of each section in a chapter.	Y	N
32. I know what time of day I do my best studying.	Y	N
33. I don’t study unless I feel like it.	Y	N
34. I don’t bother reading the questions at the end of the chapter before I begin reading the chapter.	Y	N
35. I often have trouble finding enough time to study.	Y	N
36. I don’t remember much of what I study.	Y	N
37. I tend to put off studying.	Y	N
38. To remember better, I check main headings and the summary before I read the article or chapter.	Y	N
39. I don’t do my best on tests because I am so nervous.	Y	N
40. I don’t review lecture notes until the night before a test.	Y	N
41. I listen carefully to a lecture instead of taking notes.	Y	N
42. I take time to review the chapter right after I read it.	Y	N
43. I really “dig in” when I study.	Y	N
44. Before starting a test, I plan how much time to use on each section of the test.	Y	N
45. I spend too much time on some things and not enough on others.	Y	N

ANSWER KEY: Circle the questions you answered correctly.

1. N	11. N	21. Y	31. Y	41. N
2. Y	12. N	22. N	32. Y	42. Y
3. N	13. Y	23. Y	33. N	43. Y
4. N	14. N	24. N	34. N	44. Y
5. N	15. Y	25. N	35. N	45. N
6. N	16. Y	26. N	36. N	
7. Y	17. Y	27. Y	37. N	
8. N	18. N	28. Y	38. Y	
9. Y	19. Y	29. N	39. N	
10. Y	20. Y	30. Y	40. N	

WHAT ARE MY STRENGTHS AND WEAKNESSES? After scoring your answer sheet, look for the questions you answered correctly and circle the numbers below.

CONCENTRATION	3	9	12	18	27	33			
REMEMBERING	29	23	38	40	36				
ORGANIZING TIME	2	4	8	16	35	24	32	45	21
STUDYING A CHAPTER	10	31	34	42					
LISTENING AND TAKING NOTES	6	11	41	13	14	7	22		
TAKING TESTS	1	17	19	26	39	44			
MOTIVATION	5	15	25	28	30	37	43		

Strengths = Where do you have the most correct answers? ____

Weaknesses = Where do you have the least correct answers? ____

MESA Mathematics Engineering Science Achievement

25 Practical Study Habits

When to Study

1. **Study difficult (or boring) subjects first.**
   If there is a subject that tends to put you to sleep, study that first while you are fresh and you can use your concentration on that. When you reach the other more interesting subjects it will be easier for you to stay involved on your own.
2. **Be aware of your best time of day.**
   Find out when you are comfortable studying. Experiment and see when you learn best. Pay attention to your concentration level and make sure that you are being productive.
3. **Use waiting time.**
   Whether you are waiting for a bus, have time before class, or waiting for a doctor's appointment, all that adds up to extra time. Use that time to study small portions of information. You might even prepare index cards with definitions or math formulas you need to remember. Use every moment you have free to be productive.

Where to Study

4. **Use regular study area.**
   Find a location that you can set aside for doing nothing but studying. Your body will become accustomed to your study area and will increase your focus. Avoid doing any other type of activity there so that it can retain its focal aspect.
5. **Study where you'll be alert.**
   Try to avoid comfortable places like beds and couches when studying. These areas may make you too comfortable and will increase your desire to sleep. Find somewhere that will be comfortable but will also increase your energy level.
6. **Use a library.**
   If all else fails, use the library. Libraries can signal quiet and focus. They can be a great resource for learning.

25 Practical Study Habits – page 2

How to Handle the Rest of the World

7. Pay attention to your attention.

Observe what distractions you may have inside your body. Are you thinking about getting something else done? If so try to take care of that task now, or if you can, write a note so that you know you won't forget, then return your attention to studying. Try to focus solely on what you are studying if you are having trouble try to reduce some of the clutter in your head.

8. Agree with living mates about study time.

Make an arrangement with your parents and siblings that you would like to study and need a distraction-free and quiet environment.

9. Get off the phone.

The phone can be one of the worst distractions because it is unexpected and can't necessarily be prevented. Turn off your cell phone. Let your parents and siblings know that you are studying and have them take a message if someone calls you at home. Make sure that they hold on to your messages to keep from distracting you. When you are done studying you can call back whoever called you as a mini-reward.

10. Learn to say no.

It is a hard thing to do, but learning how to say no is an important life skill. Making your education a priority will help you in the long run. Telling friends that you are studying and can't hang out is understandable and they should understand. You can always hang out another time.

11. Hang a "do not disturb" sign on your door.

Let everyone know that you are studying and don't want to be disturbed and hang the reminder on the door.

12. Get ready the night before.

Getting your clothes ready and making sure your backpack is ready to go can save you some rushed time in the morning. Prepare anything that you can the night before and save some time.

13. Call ahead.

If you are going to study with someone make sure and phone ahead and see if they are still available. You don't want to walk to your friend's house and find out that they don't have time to study…you just wasted all that time.

14. Avoid noise distractions.

Try to study in a place that promotes concentration. Get away from the TV or turn off the radio. Try to also set aside a time when your house is the quietest to study.

15. Notice how others misuse your time.

If there are a few people that continually interrupt your study time, try to work a schedule out with them that promotes your study time and their time with you productively.

25 Practical Study Habits – page 3

Things You Can Ask Yourself When You Get Stuck

16. Ask: What is one task I can accomplish towards my goal.
If you have a big task with many parts, break it down into smaller tasks. It is easier to get the small things done then sitting down and trying to finish it all at once.

17. Ask: Am I being too hard on myself?
Have confidence in your ability to finish your tasks. If you speak to yourself with negative comments like "How will I ever get this done?", you will find yourself stuck trying to dig yourself out of a hole you created. Be positive and find out where your real problem is. It is much easier to tackle a problem that is recognized.

18. Ask: Is this a piano?
Carpenters usually ask this question when they are telling themselves does this have to be perfect? Ask yourself the same question. Do you have to read the entire reading assignment? Can you get the main points by skimming? Try to save as much time by keeping yourself from doing useless studying.

19. Ask: Would I pay myself for what I'm doing right now?
Are you doing your best work? Have you been working hard and taking deserved breaks or are you taking 3 breaks in 30 minutes.

20. Ask: Can I do just one more thing?
Are you stopping your studying before you have to? Can you do just one more thing before you have to really stop for the day? Even getting in a tiny bit more can help you.

21. Ask: Am I making time for things that are important but not urgent?
Even when we are trying to get all the studying out of the way we forget what is important to us. You still have to remember to do things like have fun and relax, which are important, when you are studying for a few days. Make sure that your personal importance has a place within your academic goals.

22. Ask: Can I delegate this?
Instead of always working alone while studying maybe it might help you to study with another person. You might break up the study material and teach each other what you have learned. Beware of slackers…Make sure that each person has an equal amount of work and everyone is working hard to learn all of the information.

23. Ask: How did I just waste time?
Make sure that each moment is productive. Make sure that you are covering at least one aspect of the information throughout each study time.

24. Ask: Could I find the time if I really wanted to?
Studying isn't exactly the most exciting activity in the world, but it needs to be done. Even if you are busy it is an important part of your academics and there needs to be time for it. Search your schedule for study time each week and make it a routine.

25. Ask: Am I willing to promise it?
Promise yourself that you will study all the material for the upcoming test. Make a promise to yourself that you will work hard and do whatever it takes to get it all done. If you put the expectation on yourself, you can develop the motivation to be a great student!

MESA Mathematics Engineering Science Achievement

Lesson Activity

Title	**MESA CPW: Time Management (50-60 minutes)**
ID Number	MS-CPW-2
Sequence and Duration	• Lead In (15 minutes) • Activity (30-40 minutes) • Closure (5-10 minutes)
Age Level	Middle School
Essential Question	**How does time management make me a master learner?**
Learning Objectives	• TSW identify 'have-to' time blocks in their daily schedule. • TSW identify 'want-to' time blocks in their daily schedule. • TSW identify and schedule short term goals into their daily/weekly/monthly schedule. • TSW identify and schedule long term goals into their daily/weekly/monthly schedule. • TSW create a time budget allocating specific periods of time to identified activities. • TSW evaluate the priorities of different activities in their schedule. • TSW create a daily schedule using their identified time budget. • TSW create a weekly schedule using their identified daily schedules. • TSW recognize the following activities as students and fit them into their schedules: chores, schoolwork, sports and activities.
Other Objectives	• TSW participate and contribute to class discussion. • TSW write their time management goals and apply this to making a schedule. • TSW listen to the ideas of other students.
Key Terms	• Budget • Time Management • Have to's • Want to's • Short term goals • Long term goals • Consequences (as related to not budgeting time) • Daily schedule • Weekly schedule • Monthly schedule
Materials Needed	• Handout: Have to's vs. Want to's • Handout: Budgeting Activity Time Block • Handout: Budgeting Activity Time Pie • Handout: Weekly Planner • Handout: Time Management Crossword Puzzle
Lead In	1. Ask students to describe their typical day. Call on students at random. 2. Compare a couple of student schedules on the board. 3. Find gaps in time for them: ex. When do you study? What time do you eat dinner? Where do you shower and get ready for school? 4. Tell students that a Master Learner is a student who is successful because of their choices. Every student has a choice about their day, their week, etc. 5. Ask students to describe their study time at home. Call on students at random. Have them describe the time they study, the duration, and what often distracts or interrupts them. Write some of their descriptions on the board.

	6. Ask students if they understand what the term 'budget' means. Discuss term and solicit answers. They may vary from 'a plan on how to spend money' to 'making sure we have enough money for everything'. Expand on their description to describe budgeting time. Explain that a Master Learner budgets their time to make sure they have time to accomplish all their goals.
Activity	1. Pass out the Handout: Have to's vs. Want to's 2. Explain to students that before they can start budgeting their time to make a successful time schedule, they need to figure out how they spend their time. 3. Complete the Have to's vs. Want to's handout with students. Make sure they account for all the activities in their day to day life. (sleep, eating, school, homework, MESA meeting, sports, chores, TV, phone time, video game time, reading, etc.) 4. Now, pass out the handout: Budgeting Activity Time block. Tell them that this particular handout is for a particular day, perhaps tomorrow or the following Monday. Some student's schedules change day to day depending on after school activities, early release days, or home obligations on certain days of the week. Have them put all their Have to's and Want to's on this handout, estimating how much time it takes to complete each activity. Monitor students to make sure they are putting in all their activities. 5. Once the handout is completed, have students add up all the times to find out how much time they need to complete all their tasks. Now, tell them to compare this to the time in a given day: 24 hours. Remind them not to forget sleep time! 6. Ask students if this daily schedule works for every day of the school week. It probably does not, but for some students, their schedule is the same day to day. They may make another daily schedule for another day that is different. Allow students time to cater their schedule to fit their needs. 7. When their daily schedules are complete, have them fit their daily schedule into their weekly schedule. You may want to model this for them on an overhead or on the board. Use a student's daily schedule to help you. Ask questions like, "You scheduled 1 hour for homework on Tuesday; do you have to start your homework at a specific time, or can you fit it in where it is convenient?" Show students how to prioritize their activities. If dinner is always served at 6pm, homework can't be put in that time slot. If MESA always starts at 2:45 on Friday, they cannot schedule another activity during that time. Explain the difference between flexible and inflexible time. 8. Monitor students as they make their weekly schedules. 9. Discuss with students how to plan short term or long term goals into their schedule. For example, if they have a project in science due in one week, show them how to budget in 30 extra minutes of study time every day to make sure they complete the project on time. 10. Ask students to follow their schedule for the following week. Then, challenge them to make a similar schedule for the next week after that. Encourage them to use this tool to become master learners.
Closure	1. Pass out Time Management crossword puzzle. 2. Have students work on puzzle together.
Informal Assessment	75. Monitor students to make sure they are engaged.
Formal Assessment	• Completed weekly schedule.
Trouble Shooting	• Have copies ready before meeting.

SEI Strategies Used

Preparation	Scaffolding	Grouping Options
☐ Adaptation of Content	☒ Modeling	☐ Whole class
☒ Links to Background	☐ Guided practice	☐ Small groups
☐ Links to Past Learning	☒ Independent practice	☐ Partners
☐ Strategies incorporated	☐ Comprehensible input	☒ Independent
Integration of Processes	**Application**	**Assessment**
☐ Reading	☐ Hands-on	☒ Individual
☒ Writing	☒ Meaningful	☐ Group
☒ Speaking	☒ Linked to objectives	☐ Written
☒ Listening	☐ Promotes engagement	☐ Oral

Have to's vs. Want to's

Day of the Week: ____

Activities I have to do	Activities I want to do

Possible ideas: Sleep, Eating, School, Chores, MESA Meeting, Sports Practice, TV Time, Reading Time, Band Practice, Babysitting, etc.

Step 1: Budgeting Activity Time

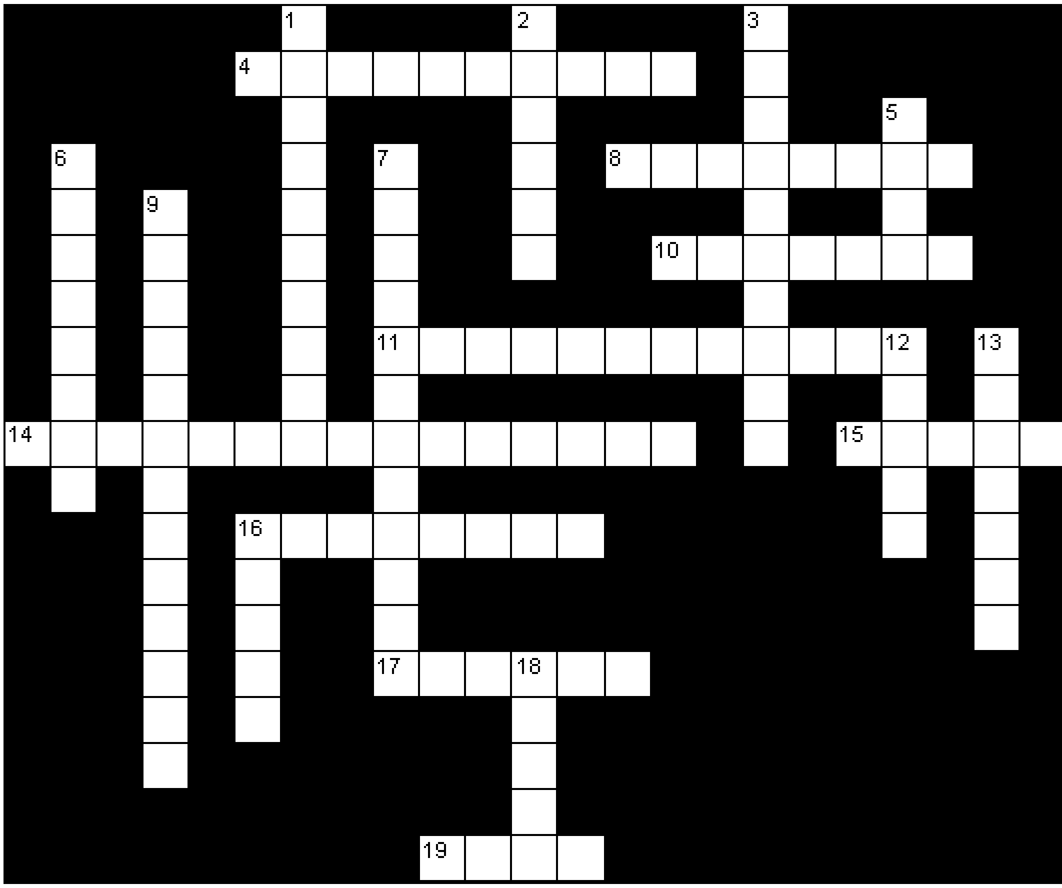
Directions: Use the chart below to make a time budget. Each block represents ½ hour. The first block can represent the time you wake up in the morning. If you wake up at 6:00 am, write 6:00 am in the first time space. How much time does it take you to get ready in the morning? If it takes you ½ hour to get up, shower, and get dressed, this is your first block. Do you eat breakfast in the morning? If so, how long does it take you? Fill in all your time blocks to include all your Have to's and Want to's from the other worksheet. When you have it filled in, raise your hand so your teacher can check it for you.

Time: _____	Time: _____	Time: _____	Time: _____	Time: _____	Time: _____	Time: _____	Time: _____
Time: _____	Time: _____	Time: _____	Time: _____	Time: _____	Time: _____	Time: _____	Time: _____
Time: _____	Time: _____	Time: _____	Time: _____	Time: _____	Time: _____	Time: _____	Time: _____
Time: _____	Time: _____	Time: _____	Time: _____	Time: _____	Time: _____	Time: _____	Time: _____

Weekly Planner for ______________________________

TIME	Monday	Tuesday	Wednesday	Thursday	Friday	Saturday	Sunday

Priorities	Upcoming Due Dates	Short Term Goals

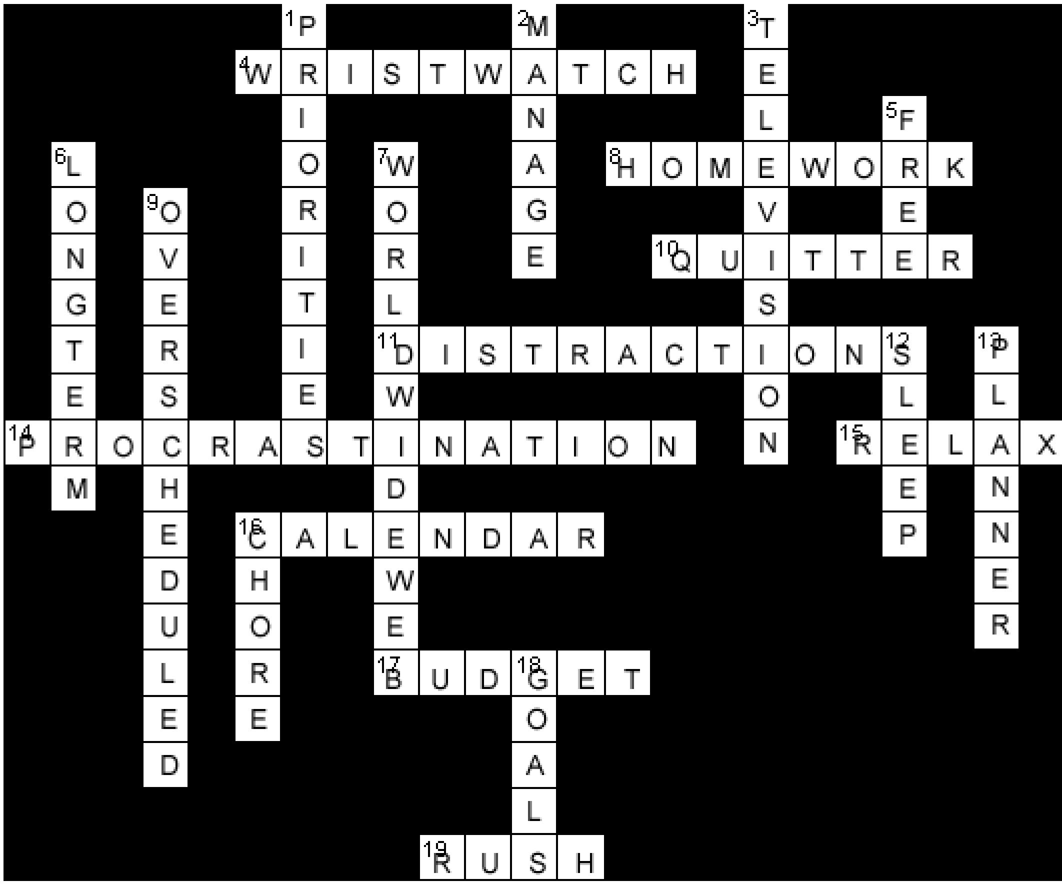


Across

4. Something you wear that tells time, or staring at the area between your arm and hand. (2 words)
8. Kids sometimes hate to get this from teachers, but it's an important part of learning school lessons.
10. Dropping an activity because you don't have enough time for it is not the same as being a _________.
11. These can compete for your attention while you're trying to get important things done.
14. Putting off until later what you could be doing now is called_________.
15. If you get everything done with time to spare, you can kick back and _________.
16. Use one of these to plan out your month.
17. How much time, or money, you have to spend is called your _________.
19. It's what you do when you're in a hurry, or famous monument "Mount _________ more."

Down

1. Deciding what things to spend your time on means choosing these.
2. We can't slow down or get more time, but we can learn how to _________ it.
3. It provides entertainment and education, but it can also lead to a lot of wasted time.
5. You might get a "_________ toy with purchase," or spend some " _________ time" by yourself.
6. Things that require time and effort over several weeks, months, or years are called _________ goals. (2 words)
7. Something that can easily take too much of your time, or spider's silk stretched across the globe. (3 words)
9. If you don't have enough time for all the clubs, sports, and activities you're signed up for, you're _________.
12. Experts agree: you should get about eight hours of this a night.
13. You can carry this around to record your daily tasks and responsibilities.
16. It's usually easier to just do a household _________ than complain about it.
18. We set these for ourselves to help us get things done.



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Lesson Activity

Title	**MESA CPW: What's My Style (60-80 minutes)**
ID Number	MS-CPW-3
Duration	• Lead In (5 minutes) • The Learning Brain (15 minutes) • What's My Style (40-50 minutes) • Closure (5 minutes)
Age Level	Middle School
Essential Question	**Which learning style is your strongest?**
Learning Objectives	The Learning Brain (activity 108 in Cooperative Games booklet) • TSW gain an understanding about the creation of learning pathways in their brain. • TSW gain an understanding about what positively and negatively affects the creation of learning pathways. What's My Style • TSW gain an understanding of different learning styles. • TSW identify what learning style(s) suit them best. • TSW apply their understanding of learning styles to communicate with others. • TSW identify study strategies that pertain to each learning style.
Other Objectives	• TSW track, analyze, and discuss how stress affects learning. • TSW discuss different stresses in their lives that affect learning. • TSW discuss how to improve their learning environment. • TSW identify with others and develop a better understanding of their peers.
Key Terms	• Learning Pathways • Neurons • Synaptic Connections • Hormones • Cortinoids • Learning Style
Materials Needed	<u>The Learning Brain</u> • Small balls or props (1/3 the number of the group) • Balloons (1/2 the number of the group) • Timer <u>What's My Style</u> Per Group • Visual Test - page with 15 graphics for visual test • Auditory Test - list of 15 items for auditory test • Kinesthetic Test - 10 small objects • Graphic for communication activity Per student • Handout: Learning Styles inventory • Handout: Traits of Learning Styles • Handout: Study Strategies for the Three Learning Styles • Handout: 20 Memory Techniques for More Productive Study Habits • Handout: Learning How to Learn
Lead In	o Pass out new MESA Notebook. o Tell students that they will be learning about their brain and learning. o Write the terms "neuron, synaptic connection, hormone, Cortinoids" on the board. Instruct students to write terms on their MESA Notebook. o Ask group if anyone knows what a neuron is and what it does. o Discuss and explain that neurons connect with each other and relay messages via synaptic connections creating learning pathways.
Activity	The Learning Brain 1. Tell the students that today they will be neurons and ask them to stand up.

2. Trial one –
    - Explain that they will have 20-30 seconds to relay messages to other neurons via a handshake, and that when they shake hands they must also carefully look into the eyes of the other person.
    - Explain that they will need to keep track of how many messages they pass/receive.
    - Run trial one.
    - Have students write down the number of messages in their MESA Notebook under procedure.
3. Trial two –
    - Explain that the brain is bathed by multiple chemicals and hormones that make learning easier or harder (*See Cooperative Games Booklet for more information)*.
    - Explain that the small props will represent a good balance of chemicals and that when you have them in your hand you, a neuron, will be very engaged, energized and happy.
    - Explain that we will again have 20-30 seconds to relay messages but that a few props, "chemicals", will be introduced and passed along with the handshake.
    - Explain that in addition to the number of messages passed/received they will need to have a rough idea of how many times they had the "chemicals"
    - Run trial two.
    - Have students write down the number of messages and number of messages with "chemicals" in their MESA notebook.
4. Trial three –
    - Explain that the brain can also be bathed with too many stress chemicals, called Cortinoids, which limit or prevent the passing of messages in learning pathways.
    - Explain that we will again have 20-30 seconds to relay messages and good "chemicals" but that the balloons will represent Cortinoids and must be kept in the air.
    - Explain that they will again need to track the number of messages and messages with "chemicals" they pass/receive.
    - Run trial three.
    - Have students write down the number of messages and messages with "chemicals" in their MESA Notebook.
5. Conclusion
    - Ask student to look at their data and write down what happened over the three trials.
    - Ask students if it was easy to shake hands when dealing with the balloons.
    - Ask them if they can relate this to different stresses in their lives and which ones (i.e. social, institutional, familial, stresses related to body appearance).
    - Ask them what this activity teaches us about creating an ideal learning environment.

What's My Style?

1. Pass out a second MESA Notebook handout.
2. Write the terms "learning style, auditory, visual, kinesthetic" on the board and ask the students to copy them onto their MESA Notebook.
3. Ask if anyone knows what a learning style is.
4. If needed, explain that a learning style is a way in which someone learns.
5. Explain that today they will learn about the three learning styles listed above.
6. Ask the students to create three columns in their MESA Notebook under procedure and label them A, V, and K.
7. Have the students turn their paper over and put their pencil down.
8. Visual Test
    - Show the group the Visual Test page for 20 seconds then cover.
    - Briefly distract the students by asking them what's their first class, what is 7 x 8, or to count backwards from 10.

	• Have them turn their paper over and write down as many of the objects they can remember in the "V" column. • Show them the Visual Test page again and have them count how many they had correct. They should write their answer at the bottom of the "V" column. 9. Auditory Test • Ask the students to turn their MESA Notebook over and put their pencils down. • Ask the students to close their eyes and put their heads on their desks. • Slowly read the list of words from the auditory page and then read it a second time. • Distract students. • Have them turn their paper over and write down as many of the words they can remember in the "A" column. • Repeat the list and have them count how many they had correct. They should write their answer at the bottom of the "A" Column. 10. Kinesthetic Test • Ask the students to stand and form a circle. • Have them close their eyes and keep them closed unless they are given an object. • Hand out the ten objects to ten students. • If they have an object they can open their eyes and examine the object by seeing and touching it for 10 seconds. • When time is up call out "pass" and have that student pass the object to their right. • Continue until every student has examined each object, and then have the students close their eyes and remove the objects from sight. • Have the students sit down and write down the objects they can remember in the "K" column. • Bring out the objects and have the students count how many they had. correct and write that number at the bottom of the "K" column. 11. Inventory • Ask the students to circle the column where they had the most correct. • Explain that each of the columns represented a learning style and that the one they circled was their strongest. • Hand out the "Learning Styles Inventory" worksheet. • Have the students fill it out on their own. • Discuss how closely the results matched the ones from above and why there might have been differences. 12. Communication Exercise • Have the students make groups of three containing one visual, one auditory, and one kinesthetic learner. Use second strongest style to even out groups. • Have all the visual learners come to the front and look at the communication graphic for 20-25 seconds and tell them to remember it exactly. • Have them explain the graphic to the auditory learner without allowing the kinesthetic learner to hear. Give them about 30 seconds. • Have the auditory learner explain the pattern to the kinesthetic learner, who will draw what is being described to them. • When finished have the kinesthetic person come to the front and show the class their design. Also, show everyone the original graphic. • Ask the students to discuss what caused differences between the designs and what could have helped them do it better. • Ask them if their learning styles succeeded in helping them teach each other. 13. Application Exercise • Ask the students to get into three groups according to their strongest learning style. Use the second strongest to even out the groups. • Hand out "20 Memory Techniques" and "Learning How to Learn".

	• Ask the groups to read through them and discuss how they can adapt this information to fit with their learning style. • Have each group present their ideas.
Closure	• Hand out "Traits of Learning Styles" and "Study Strategies for the Three Learning Modes". • Ask the students to review these handouts before the next meeting. • Ask the students to answer the following question in the 'conclusion' section of their MESA Handbook: What changes to my learning environments (school, home) will I make to help me learn and study more efficiently?
Informal Assessment	76. Monitor students to check for engagement. 77. Monitor students to check for understanding.
Formal Assessment	• Completed MESA Handbook for "The Learning Brain". • Completed MESA Handbook for "What's My Style". • Completed Learning Styles Inventory worksheet.
Trouble Shooting	• Make sure students are properly shaking hands during "The Learning Brain". • Make sure that balloons do not remain on floor. • Keep an eye on time. • Make sure students are closing eyes when needed. • Make sure students are not writing before allowed. • Have students assist you in passing out handouts to save time. • If running out of time, have students do application exercise on their own.
Extensions	• Career Exploration CPW discussing careers based on learning styles. • Discussion about learning styles in various contexts (i.e. sports, jobs). • Deeper discussion about how neurons work to translate thoughts into actions (i.e. speaking, moving). • Deeper discussion about how drugs like MAO/SSRI Inhibitors impact neurons • Discuss how students can improve their weaker learning styles. • Mention "Brain Age" game for Nintendo DS which uses fun visual/audio games to "train" your brain in different learning styles.

SEI Strategies Used

Preparation
- ☐ Adaptation of Content
- ☐ Links to Background
- ☒ Links to Past Learning
- ☒ Strategies incorporated

Scaffolding
- ☐ Modeling
- ☒ Guided practice
- ☐ Independent practice
- ☒ Comprehensible input

Grouping Options
- ☒ Whole class
- ☒ Small groups
- ☐ Partners
- ☒ Independent

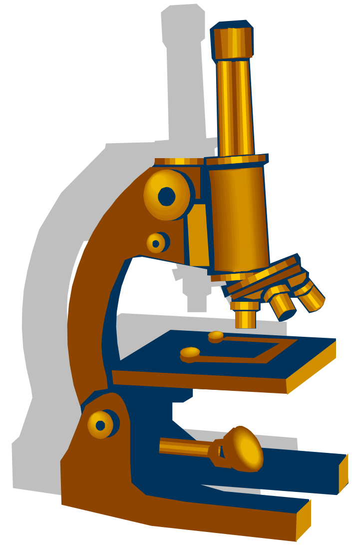
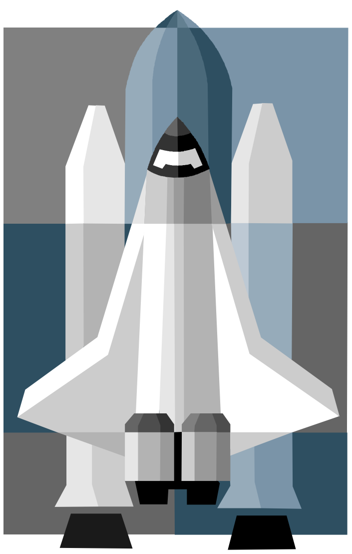
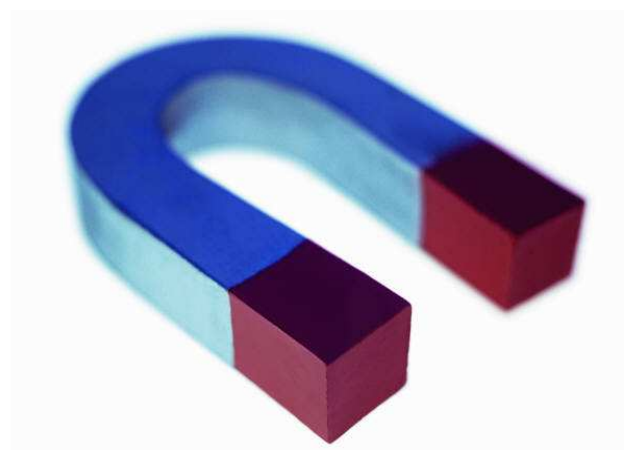
Integration of Processes
- ☒ Reading
- ☒ Writing
- ☒ Speaking
- ☒ Listening

Application
- ☒ Hands-on
- ☒ Meaningful
- ☒ Linked to objectives
- ☒ Promotes engagement

Assessment
- ☒ Individual
- ☒ Group
- ☒ Written
- ☐ Oral

Visual Test










12
3
6
9


Sample Word List for Auditory Test

(or use your own words)

Arizona

Blue

Book

College

Computer

Engineering

Graduation

Math

Red

Scholarship

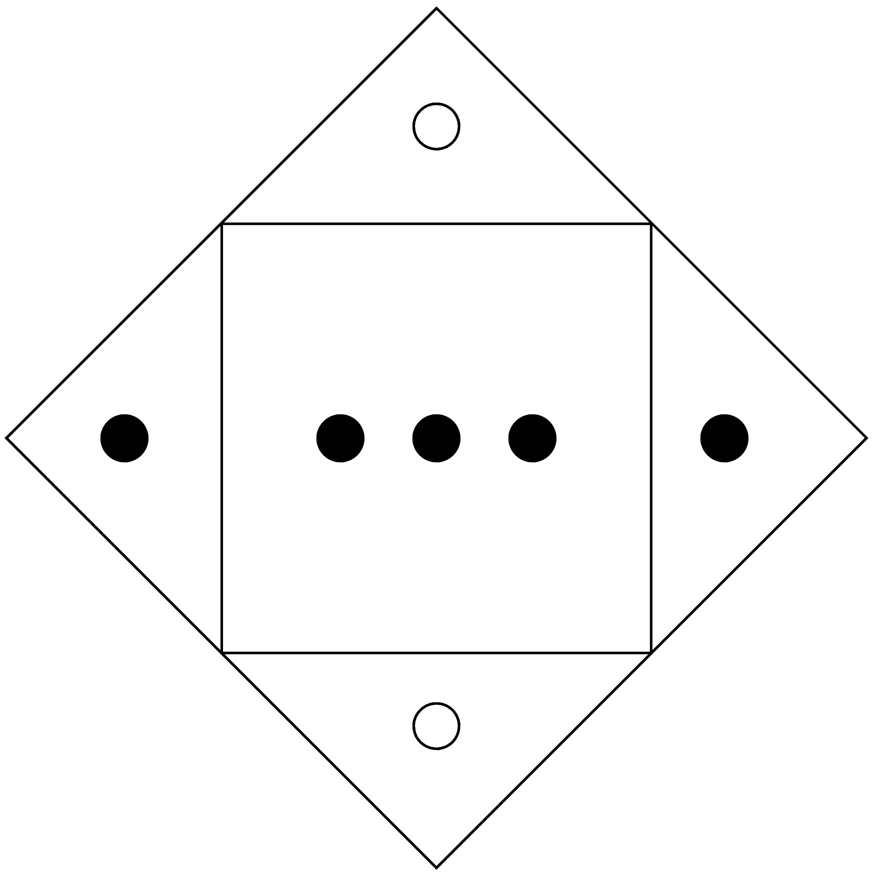
School

Science

Spaghetti

Star

Triangle



LEARNING STYLE INVENTORY

Read each statement carefully and consider how it applies to you. On the line next to each statement, write the number that indicates whether the statement . . . .

3 = **always** applies to you **2** = **sometimes** applies to you **1** = **never** applies to you

VISUAL

_____ I enjoy doodling and even my notes have lots of pictures, arrows, etc. in them.
_____ I remember something better if I write it down.
_____ I get lost or am late if someone TELLS me how to get to a new place and I didn't write down the directions.
_____ When trying to remember someone's telephone number, or something new like that, it helps me to get a picture of it in my head.
_____ If I am taking a test, I can "see" the textbook page and where the answer is.
_____ It helps me to LOOK at the person when listening. It keeps me focused.
_____ I had speech therapy.
_____ It's hard for me to understand what a person is saying when there are people talking or music playing.
_____ It is better for me to get work done in a quiet place.

_____ **VISUAL TOTAL**

AUDITORY

_____ My written work doesn't look neat to me. My papers have crossed-out words and erasures.
_____ It helps to use my finger as a pointer when reading to keep my place.
_____ Papers with very small print or blotchy dittos or poor copies are tough on me.
_____ I understand how to do something if someone tells me rather than having to read the same thing to myself.
_____ I remember things that I hear, rather than things that I see or read.
_____ Writing is tiring. I press down too hard with my pen or pencil.
_____ My eyes get tired fast, even though the eye doctor says my eyes are OK.
_____ When I read, I mix up words that look alike, such as *them* and *then*, and *bad* and *dad*.
_____ It's hard for me to read other people's handwriting.
_____ If I had my choice to learn new information from a lecture or a textbook, I would choose to hear it rather than read it.

_____ **AUDITORY TOTAL**

KINESTHETIC

_____ I don’t like to read directions; I’d rather just start doing.
_____ I learn best when I am shown how to do something, and I have the opportunity to do it.
_____ Studying at a desk is not for me.
_____ I tend to solve problems through a more trial and error approach, rather than using a step-by-step method.
_____ Before I follow directions, it helps me to see someone else do the task first.
_____ I find myself needing frequent breaks while studying.
_____ I am not skilled in giving verbal explanations or directions.
_____ I do not become easily lost, even in strange surroundings.
_____ I think better when I have the freedom to move around.
_____ When I can’t think of a specific word, I’ll use my hands a lot and call something a “what-cha-ma-call-it” or a “thing-a-ma-jig.”

_____ KINESTHETIC TOTAL

Total your score for each section:

Visual = _____ **Auditory** = _____ **Kinesthetic** = _____

The area with the **highest total** indicates your primary learning style, or the way that you learn most effectively.

My **primary** learning style is ____.

Your **second highest total** indicates the area that supports your primary learning style.

My **secondary** learning style is ____.

You are not always just one type of learner.
Your learning style may vary over time and by situation.

The University of Arizona Learning Center
Middlesex Community-Technical College

20 Memory Techniques
For More Productive Study Habits

Organize it.
Organized information is easier to find.

1. **Learn from the general to the specific.**
   Skim for a general idea. Make sure and get the big picture before the little details.
2. **Make it meaningful**
   When information helps you get something you want, it's easier to remember. That is one reason it pays to be specific about what you want.
3. **Create associations.**
   When you are learning something new, learn it in a way that makes sense to you. You can remember it better if you store it near similar or related ideas.

Use your body.
Learning is an active process; get all your senses involved.

4. **Learn it once, actively.**
   Be as active as possible. Move around when studying so that you don't get bored or fall asleep. Boredom puts memory to sleep. Wake up and learn!
5. **Relax.**
   When we're relaxed, we absorb new information quicker and recall it with greater accuracy. Being relaxed does not mean being drowsy or asleep. It means free of nervousness and tension, which decrease learning.
6. **Create pictures.**
   Draw diagrams. Make cartoons. Use them to connect facts and illustrate relationships.
7. **Recite and repeat.**
   When you repeat something out loud, you anchor the concept in two different senses, feeling and hearing. You can feel the words being spoken and you can hear them as you speak.
8. **Write it down.**
   Writing things down helps you to remember an idea, even if you only look at it once. If you continue to write, the repetition will help you to master the idea.

Use your brain.

Work with your memory, not against it.

9. Reduce interference.
Find a place that is quiet and free from distraction.

10. Use daylight.
Many people can concentrate more effectively during the day.

11. Over learn.
Learn a subject until it becomes second nature. When you have mastered not only the required material but supporting material your confidence in the subject will increase and you will be better at it.

12. Escape the short-term memory trap.
Short-term memory can decay after a few minutes and rarely lasts more than a few hours. Instead of cramming, do mini-reviews before a study session so that you can recall information during your testing time.

13. Distribute learning.
Do not do long marathon runs of studying. You will learn more by breaking down your study time into shorter, more productive sessions. Use breaks as mini-rewards from studying. But if you are on task and consumed by an idea, don't stop: you will learn more from your interest in the subject.

14. Be aware of attitudes.
People who believe that history is boring tend to have problems remembering historical facts. People who believe math is difficult have trouble recalling mathematical equations. Be positive about your learning.

15. Choose what not to store in memory.
Be picky about what you are remembering. Just think about what will be on the test and concentrate on learning those core concepts.

16. Combine memory techniques.
Choosing two or three of the above listed techniques will increase your chances of retention. Some techniques may work better in one subject than another. Try all different sorts of combinations to be as productive as possible.

Recall it.

This is easier when you use the other principles to store information.

17. Remember something else.
When you are stuck and can't remember a particular fact, remember something else that is related to the subject area. If you brainstorm what you do know, the answer you are looking for is bound to come up.

18. Notice when you do remember.
Notice the way that you are remembering things. If you are remembering ideas that you have read then it is better for you to study by reading. Be honest with yourself and learn what's best for you.

19. Use it before you lose it.
Even information that you have stored in long term memory can be hard to remember when you don't recall it. So practice and recall: speak it, read it, write it, and apply it. It will be easier once it is natural to you.

20. And remember, you never forget.
An idea never leaves your memory – it is just up to you to believe it is there and find where it is stored…it will eventually come to you.

MESA Mathematics Engineering Science Achievement

Learning How to Learn

Part 1: Information Processing System (IPS)

The IPS consists of three parts:

Short-Term Memory (STM) ► Working Memory (WM) ► Long-Term Memory (LTM)

All information is first inputted into the STM From there the information is either lost or put into the WM. Once in WM the information can either be lost or retained for a limited time in the WM, or moved into the LTM.

Short-Term Memory – All information attained from the environment that can be sensed (seen, heard, or smelled) enters into the STM. However, if this information is not attended to by the WM, then it is forgotten.

Working Memory – Information is stored for a small period of time (around 5 to 20 seconds) and can only hold five to nine chunks of information at one time or the "7±2Magic Number". By chunking data, more is able to be stored in the WM at one time. **Maintenance rehearsal** is the repetition of an idea in order to store that information for longer than 20 seconds.

Long Term Memory – All information we have but are not currently using is saved in the LTM. It is said that information is never forgotten, but rather becomes harder to retrieve or locate. Getting information into the LTM takes time and effort. Having prior knowledge on a topic makes it easier to learn, since new information is being added on to existing information. Reading the assignment before the lecture makes it easier to understand the information when presented in class.

There are two types of learning:

> **Rote learning –** information is learned by repetition or rehearsal. This is helpful for learning lists, dates, or other basic knowledge.
>
> **Meaningful learning –** the information is related to prior knowledge, making it easier to understand. The student tries to make sense of the information, helping them to understand complex issues.

Part 2: Learning Strategies

Different Learning Strategies promote the retention of different types of information. These consist of rehearsal, elaboration, and organizational strategies.

Rehearsal Strategies:
Reciting, repeating or practicing information over and over until it is remembered. Not helpful for learning complex information since it does not connect new information with information we already have in the LTM.

There are two types of rehearsal strategies:

- Distributed Practice
- Massed Practice

Distributed Practice is when the student uses short periods of studying to learn information. This method is more effective when the information is chunked into patterns that can be remembered.

Massed Practice is when the student tries to study a lot of information in a small amount of time, such as cramming for an exam the night before. This is a poor method of learning complex information or moving that information into the LTM, since little of the information is remembered after 24 hours.

Elaboration Strategies:
Uses mnemonic devices in order to connect present learning with past information.

Two mnemonic systems used are acronyms and key-word method.

Acronyms – A mnemonic is formed by the first letter in each word.

Roy G. Biv   Red orange yellow green blue indigo violet

Key-Word Method – an image is created in the mind to associate or relate with another word.

After note-taking in a lecture, students should note *make*. Go through your notes and write notes asking questions about or elaborating on the ideas that were presented in lecture.

Analogies are another method to learn more effectively. With this method, prior information is related to new information in order to better remember a concept.

Organizational Strategies:
Categorizing knowledge is a more effective way to remember information than trying to recall unorganized fragments. Organizing data makes it easier to retrieve that information later. Outlines can help to understand information in a text by categorizing that information into smaller ideas.

Information from: Dembo, Myron H., Motivation and Learning Strategies for College Success, 2000, Lawrence Erlbaum Associates, Publishers, Mahwah, NJ

TRAITS OF LEARNING STYLES

VISUAL LEARNER

I SEE

Visual Learners learn best through ***seeing***, using their eyes as the primary way to learn. These learners:

- Desire to see words written down;
- Enjoy a picture of something being described;
- Prefer a timeline to remember historical events;
- Prefer written instructions for assignments;
- Observe all the physical elements in a classroom;
- Carefully organize their learning materials;
- Enjoy decorating learning areas;
- Desire photography and illustrations with printed content;
- Remember and understand through the use of diagrams, charts, maps;
- Appreciate presentations using visuals or handouts;
- Study material by reading over notes and organizing in outline form;
- Enjoy visual art activities.

AUDITORY LEARNER

I HEAR

Auditory Learners learn best through ***hearing***, using their ears and their voices as the primary way to learn. These learners:

- Remember what they hear and their own verbal expressions;
- Remember by talking aloud and through verbal repetition;
- Desire to talk through a concept not yet understood;
- Verbally express excitement about learning;
- Can remember verbal instructions without recording them;
- Enjoy class discussions and talking with others;
- Are easily distracted by sound but also find silence distracting;
- Enjoy interesting lectures;
- Find it difficult to work quietly for extended periods of time;
- Enjoy music activities.

KINESTHETIC LEARNER

I DO

Kinesthetic Learners learn best through ***touch***, using their bodies as the primary way to learn. These learners:

- Become physically involved in the subject being studied;
- Enjoy acting out a situation through dramatic methods;
- Enjoy making a product or completing a project;
- Prefer building and physically handling learning materials;
- Remember and understand through doing something;
- Take study notes to keep busy but often do not read them;
- Enjoy using computers;
- Physically express enthusiasm by getting active and excited;
- Find it difficult to sit still for extended periods of time;
- Enjoy hands-on activities.

Study Strategies for the Three Learning Modes

THE SKILLS	VISUAL LEARNER *Learn the best by seeing*	AUDITORY LEARNER *Learn the best by hearing*	KINESTHETIC LEARNER *Learn the best by:* *-moving physically* *-participative experiences*
NOTE TAKING	1) Sit at the front of the room. 2) Use pictures, symbols and visual maps in your notes. 3) Ask for graphs and drawings to help remember main concepts. 4) Request written instructions. 5) Reword notes into charts and graphs.	1) Sit close to the speaker. 2) Repeat important points quietly. 3) Listen for specifics. Don't let note-taking interfere with listening. 4) Listen for **key words**. 5) Tape record lectures. Listen to tape and update your notes **immediately** after class.	1) **Move to remember!** During lecture tap foot, move head, write, stand up (if allowed). 2) Volunteer: answer questions, participate in discussions. 3) Take copious notes and make illustrations. **Move to remember!** 4) Recopy notes and vocabulary.
READING	1) **Survey by looking** at visual aids (pictures, graphs, & charts before you start to read a chapter). 2) As you read make a **visual map** of key headings and concepts. 3) Make charts and schematics of difficult concepts.	1) **Survey by reading** chapter headings and asking survey questions out loud. 2) Try reading difficult sections out loud. 3) Summarize **out loud** immediately after reading a paragraph or section.	1) **Survey by writing** preview questions and answers. Write as you review. 2) Use workbooks and computers to learn material whenever possible. 3) Try to **write a summary** immediately after reading a difficult paragraph or section.
TAKING TESTS	1) Request written instructions. 2) Picture your study materials in your head, and try to remember where the information you need is located.	1) Request that instructions be read out loud. 2) Repeat instructions (quietly) to yourself. Note: It is wise to check this out ahead of time with your instructor.	1) Position yourself where you have plenty of room to move. 2) To aid recall during exam: a. **Move** in your chair. b. **Feel yourself doing** a lab procedure or other experience that is relevant to the question.
EXAM PREP.	1) Use **visual images** to remember main points. 2) Use flash cards. 3) Use **visual maps** to help you understand & remember difficult concepts. 4) Use pictures and symbols in your text for emphasis & memory. 5) Look at soothing works of art to relax your mind during study breaks. 6) Check library for films & visual aids pertaining to your subject matter.	1) Read important material from notes or readings **out loud**. 2) Record and listen to vocabulary for each day's lesson. 3) Talk about what you have learned. Participate in study groups. Give oral presentations. 4) Use slow **Baroque Music** to enhance your concentration while studying. 5) Use special **Relaxation Music** for periodic study breaks.	1) Memorize **key words** & concepts using finger spelling. 2) Seek experiences that will teach you main concepts: labs, discussions, field work, etc. 3) Use **equipment**, tools, models, etc. of a subject as much as possible. 4) Try moving about while memorizing material: walk, use gestures, etc. 5) Use physical exercises for study breaks. 6) Seek on-the-job training, work study, field work, lab work, and cooperative learning experiences to become physically involved in your area of study.

Skill Set 4:
MESA

Lesson Activity

Title	**Careful Reading: Know the MESA Day Specs! (70-80 minutes)**
ID Number	MS-MESA-3
Sequence and Duration	• Lead In (10-15 minutes) • Activity (50-60) • Closure (10 minutes)
Age Level	Middle School
Essential Question	**What does careful reading have to do with being an engineer?**
Learning Objectives	• TSW discuss the importance of careful reading in the career of an engineer. • TSW review the MESA Day Competition Specifications. • TSW review critical reading strategies and apply them to understanding competition specifications. • TSW communicate information about an event to their classmates.
Other Objectives	• TSW communicate with their group by contributing their vocal input. • TSW utilize critical reading strategies. • TSW summarize and communicate information to their peers. • TSW engage in a group discussion about the importance of careful reading.
Key Terms	• Critical reading strategies
Materials Needed	For Teacher: • MESA Day Competition Specifications Per Team: • MESA Day Competition Specifications • Large paper or a section of the board Per Student: • Handout: Critical Reading Strategies
Lead In	1. Ask students, what does being a careful reader have to do with being a good engineer? Solicit student responses. Possible answers include preparing for college by using reading to help do well in your classes now, reading the warnings associated with dangerous materials they may be using, reading engineering plans and blueprints, and reading briefs and memos from the company the engineer is working for. 2. Ask students to think of examples, real or fictional, where NOT reading carefully could result in poor designing or even disaster. 3. Ask students what they think careful reading has to do with being successful on MESA Day [teams need to really know the specs for their competitions to ensure that their designs will pass inspection; all designs must conform to the same specs so the competitions are fair]. Ask students to think about what could happen if they do NOT read and follow the specs carefully [if their designs don't meet the specs they'll be disqualified, and the team won't be allowed to compete]. 4. Ask the students what strategies they can use to ensure that all team members for a competition are aware of the specs and follow them, so that the team's design will pass inspection. Suggestions may include rewriting the specs in a more concise form, making a checklist of the specs and checking the design against it periodically, or rewording the specs into non-technical language.
Activity	97. Hand out copies of the MESA Day specs to students in pairs or groups (depending on how many copies you were able to make). Have students flip through the pages, and look at and talk amongst themselves about whatever interests them. Give them five or ten minutes to do this. 98. After five or ten minutes, ask them, "Do you think you're ready to compete now? Do you think you have all the information you need to start designing and building? Why or why not?" Give them time to talk about how prepared they feel and why. Some students may be comfortable, but there will likely be some who are overwhelmed by the amount of information presented in the

	MESA Day book. 99. Ask students what they could do as a class that to help everyone become comfortable with what they're supposed to do. If need be, remind students of their previous discussion about the specs. What were their suggestions for ensuring all team members are aware of the specs? 100. Ask students what kinds of things they do when they're reading to make sure they've understood the material. Allow students to discuss their strategies and/or advice and tips from other sources that they've heard about. 101. Hand out the Critical Reading Strategies handout. Review the strategies with the students. 102. Ask all students to flip to the On-Site Engineering Design specs. Go through the reading strategies with this document, focusing first on the title (top right corner), then the headings, then the objective. There is not much information available for this event (since the specs are not handed out until students are on-site), but go through the document briefly, making notes about the information that will be most important to students. 103. When finished reading through the material together, create an outline on the board, letting the students assist in putting it together. Be sure to include the event title, and bullets for the number of teams per school, number of members per team, level of the competition, process of the event, and scoring procedures. Model for the students how to capture the most important information, paraphrase it by putting into one's own words, and boiling it down to the most essential elements. Tell students that creating an outline is one way of summarizing information to make it easier to understand. 104. Assign each group to a competition, excluding the national competition (which is probably much longer than the others). There may be more than one group for each competition. If students already know which competitions they will be involved in, they should not be on that team. Otherwise, assign randomly. 105. Tell the students their mission will be to become the experts on a certain event, and be able to communicate the rules of that event to the rest of the group. This means they'll need to be careful readers and careful communicators. They can use the strategies from the handout and their own strategies to carefully read through their specs, then come up with a presentation on it for the group. They can write a summary paragraph, create a bulleted list, draw a diagram, or whatever they like, to communicate the most essential information to their peers. They should also make note of any questions they come up with about the event, because their classmates will likely have similar questions when they learn about it, too. 106. Hand out large pieces of paper to each group, or assign them an area of the board for writing out their summaries. 107. Give students approximately twenty minutes to work together to read and summarize their event specs. Circulate among the groups to assist and answer questions. 108. When all groups are prepared, have them present one by one to the class. For events to which multiple groups were assigned, let the groups present side by side, and have the class compare the groups' different approaches to summarizing the information (just to highlight the fact that there are different ways to go about doing it, not to imply that one is better than another).
Closure	38. Ask the students if they now feel more comfortable understanding the information in the MESA Day book. Do they feel more ready to begin designing for one of the events now? Do they have a good idea about how to approach other reading materials they'll need to understand in the future? 39. Ask, how does reading and following the MESA Day specs relate to what real engineers do? [engineers have to know and be mindful of the parameters and constraints placed on their work ahead of time, so the design they create serves the intended purpose]
Informal Assessment	78. Monitor students for participation in group work and discussions. 79. Monitor students' understanding through questioning by both you and their peers.

Formal Assessment	• Completed event specification summary. • Presentation on summary.
Troubleshooting	• If students are not reading at grade level, this activity may be difficult for them. Encourage students to go at their own pace and not to give up. This activity can be extended over multiple class periods in conjunction with other activities, provided time permits prior to competition. The most important thing is that students know how to understand and follow the specs, not that they complete this activity in one session. • If time permits, consider giving the class time to peruse the national competition specs, using critical reading strategies. You can do this as a whole group or individually, depending on the level of interest and whether it seems the group needs more guided practice. • If there is sufficient space, consider leaving up students' summaries for the rest of the semester, or having the groups type them up and make them available to the rest of the class.

SEI Strategies Used

Preparation
- ☐ Adaptation of Content
- ☐ Links to Background
- ☒ Links to Past Learning
- ☒ Strategies incorporated

Scaffolding
- ☒ Modeling
- ☒ Guided practice
- ☒ Independent practice
- ☒ Comprehensible input

Grouping Options
- ☐ Whole class
- ☒ Small groups
- ☒ Partners
- ☐ Independent

Integration of Processes
- ☒ Reading
- ☒ Writing
- ☒ Speaking
- ☒ Listening

Application
- ☐ Hands-on
- ☒ Meaningful
- ☒ Linked to objectives
- ☒ Promotes engagement

Assessment
- ☐ Individual
- ☒ Group
- ☒ Written
- ☒ Oral

Arizona Math Standards Addressed	(none)
Arizona Science Standards Addressed	(none)

Critical Reading Strategies

Using critical reading strategies will allow you to be a more careful reader, helping you to get the most of your reading so you can understand and remember the material for later.

You can apply these strategies to reading the MESA Day event specifications, and to any other kind of material you want to be sure to read carefully.

Step 1: Before you read

- Read the title, the introduction or overview, and the headings.
- Scan the material and try to get a feel for its structure and what it's about.
- Look at the illustrations, if there are any.

Step 2: While you read

- Underline, circle, or highlight important ideas in the text.
- Jot down notes in the margins – your ideas, questions, and comments.

Step 3: After you read

- Review your notes and highlights.
- Rephrase the author's words in an outline or summary paragraph.

MESA Mathematics Engineering Science Achievement

Lesson Activity

Title	**Introduction to Technical Papers (70-80 minutes)**
ID Number	MS-MESA-4
Sequence and Duration	• Lead In: 10 minutes • Activity: 50-60 minutes • Closure: 10-15 minutes
Age Level	Middle School
Essential Question	**What goes into a technical paper?**
Learning Objectives	• TSW brainstorm about the kinds of information that go into each section of a technical paper. • TSW apply their understanding of technical papers to reflect on previous activities they've done and how they would write about them.
Other Objectives	• TSW engage their critical reading skills in reviewing the technical paper specs. • TSW present their ideas to the class. • TSW communicate with their group by contributing their vocal input. • TSW listen as their peers discuss their posters.
Key Terms	• Technical paper: paper describing one's own research.
Materials Needed	Per Class: • Students' MESA Notebooks from previous projects • Copies of instructions for different projects Per Team: • Handout: Parts of a Technical Paper • Handout: Technical Paper Brainstorming • Handout: Technical Paper Organizing • Handout: Guide to Technical Papers • Poster paper Per Student/Pair of Students: • Handout: Copies of MESA Day competition technical paper specs
Lead In	43. Ask students if they can think of any examples of writing an engineer would do. What are the reasons an engineer would write something? What would be the purposes for that writing? [In the course of their careers, engineers often have to prepare proposals for work they would like to do; manuals for products they design; letters to companies and state/city officials; reports on their work for funders and/or supervisors, etc. The purposes for the writing vary, but are often related to communicating to others the details of their work.] 44. Remind or inform students that the MESA national competition requires groups to submit a technical paper. The technical paper is worth more than 20% of the points for the competition, so it is a very important part of being successful with the national event. Why do students suppose the judges want to see a technical report on the team's work? [To help them practice the skills that a professional engineer needs to use.] 45. Ask students if they know what a technical paper is. Have they ever written one before? What goes into a technical paper? 46. Tell students that the purpose of a technical paper is to clearly document the engineering process and communicate to the reader everything they learn when they design, build and test their devices. 47. Writing the technical paper might seem like something they need to do AFTER they finish their engineering process, but if they keep careful notes and work on the paper as they do their designing and testing, writing it will be a lot easier. It can even help them as they do their projects, by helping them organize their thinking.
Activity	1. Have students get into pairs and hand out the "Parts of a Technical Paper" worksheet. Give students five to ten minutes to brainstorm what kind of information they think should go into each section of the paper. 2. Hand out the specs for the technical paper from the MESA Day book. Have

	students look at the requirements for the different sections of the paper. Make sure they take their time and read through it carefully (if they've done the Careful Reading lesson, they should be able to apply their critical reading skills). Advise them to highlight and underline important information, and to ask questions and discuss any areas that strike their interest. 3. In a whole-group discussion, have the students think back over projects they've done throughout the year (e.g. Newton's Scooters, Solar Ovens, Keep a Cube). Create a list of these activities on the board. What kind of writing did students do when they were doing these activities? [MESA Notebooks] How can their MESA Notebooks help them write a technical paper? [They took notes on their procedures, key terms, set-up and conclusions – information that can help them put together their report.] 4. Tell the students that they will be doing a brainstorming activity to help them think about writing a technical paper. In groups, they will choose one of the projects and find their MESA Notebooks for those projects. Allow a few minutes for students to decide on their projects, helping them to avoid overlapping when possible. 5. Hand out the "Technical Paper Brainstorming" worksheet. Tell students to write the name of the activity they chose at the top. The rest of the sheet is blank; tell students that in the blank area they can write anything about that activity that comes to mind, even if it's not on topic: words, phrases, pictures, sentences, etc. You will give them ten minutes and they should just keep going until they run out of time, or out of ideas! 6. Give students ten minutes to brainstorm anything they can think of relative to their project. After ten minutes, have the students get together with their group mates and circle anything they've written down that they think they can use for the paper. 7. Hand out the "Guide to Technical Papers" and "Technical Paper Organizing" handouts, and have the students work in their groups to sort their thoughts into the appropriate sections of the paper. Tell them they will be creating a poster for their activity to present to the rest of the class. The poster should have the same headings as the "Technical Paper Organizing" worksheet, and can have other headings if students have ideas they want to place in them. 8. When groups are ready, hand them a piece of poster paper so they can prepare their presentations. 9. Have groups present their posters to the class. Allow the rest of the students to add their comments about the project, and other information they would include on the poster. Have the presenting group add other students' thoughts to their posters in the appropriate sections.
Closure	40. Tell students that these posters can now serve as an outline for technical papers about these activities. Ask, how might students proceed to write their papers from here? 41. What kinds of information should students be mindful of as they conduct investigations, in order to be prepared to write technical papers about those investigations? Have students discuss what kinds of information they need and how best to record it as they engage in the engineering process. 42. Tell students that when they begin preparing for the competition on MESA Day, they can go through this process as a class to help the competing team outline their paper. 43. Point out that this is only the first step; writing the paper and getting it to its final draft will take a lot of time! Ask students what they might do to help them prepare a well-written technical paper in time for MESA Day. [They should start early!]
Informal Assessment	80. Monitor students for participation in group work and discussions. 81. Monitor students' brainstorming for parts of a technical paper and for ideas about a project.
Formal Assessment	• Completed worksheets. • Completed poster.
Trouble Shooting	• If you aren't saving students' MESA Notebooks, or aren't using them, this activity will be more difficult but not impossible. Consider having the whole class brainstorm on just one project, and have the creation of the poster be a

	more collaborative process among all the students. • If students have difficulty with reading the specs, read through them together as a class, taking plenty of time to discuss the different components and ensure that all students have a good understanding of what is expected.

SEI Strategies Used

Preparation	Scaffolding	Grouping Options
☒ Adaptation of Content	☐ Modeling	☒ Whole class
☐ Links to Background	☒ Guided practice	☒ Small groups
☒ Links to Past Learning	☒ Independent practice	☒ Partners
☒ Strategies incorporated	☒ Comprehensible input	☐ Independent

Integration of Processes	Application	Assessment
☒ Reading	☐ Hands-on	☐ Individual
☒ Writing	☒ Meaningful	☒ Group
☒ Speaking	☒ Linked to objectives	☒ Written
☒ Listening	☒ Promotes engagement	☒ Oral

Arizona Math Standards Addressed	• (none)
Arizona Science Standards Addressed	• S1C4: Communicate results of investigations.

Parts of a Technical Paper

Instructions:

Read each of the headings for a technical paper, listed below. With a partner, brainstorm about what kinds of information you think should be included under each of these headings.

Title Page:

Abstract:

Table of Contents:

Introduction:

Discussion:

Conclusions:

Recommendations:

References:

Acknowledgments:

Appendix:

Technical Paper Brainstorming

Title of Project: ____

Technical Paper Organizing

Introduction:

Discussion:

Conclusion:

Recommendation:

Guide to Technical Papers

Title Page:
The title page includes the title of the project, information about the authors (their names, state and school), and the date.

Abstract:
The abstract is a paragraph-long synopsis of your *whole* paper (including the conclusions and recommendations!). A reader should be able to read the abstract and understand what your whole paper is about, including its purpose, an overview of the discussion, its main conclusions and recommendations. The abstract should be written *last*. It is worth **20 points**.

Table of Contents:
The table of contents should list the required sections and the page number where you can find each of them.

Introduction:
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Discussion:
The discussion is the longest section of the paper, detailing everything you did and everything that happened as you went through your project. It should include scientific concepts that relate to your project, the procedures of your project (include pictures where needed), the your data and the ways you analyzed it, including data charts, graphs, pictures and diagrams, and the results from the data. It is worth **40 points**.

Conclusion:
Here, you draw a conclusion from the results you reported in the previous section. Based on what you learned from doing your project, what can you say about the concept or device you studied?

Recommendations:
Your recommendations should be a discussion of further work to be done or a strong suggestion about what to do next. The conclusion and recommendations together are worth **15 points**.

References:
List and properly cite all sources you used in doing your project and writing your paper.

Acknowledgments:
The acknowledgment section recognizes and thanks people who helped you along the way.

Appendix:
The appendix, or appendices (more than one appendix), contain all the information that doesn't belong in the rest of the paper but is needed to support it. It can be additional evidence that supports your conclusions, such as data charts, photos, results, etc.

Lesson Activity

Title	**MESA Policies and Procedures (45-55 minutes)**
ID Number	MS-MESA-2
Sequence and Duration	• MESA Student Policies and Procedures (35-45 minutes) • MESA Student AIF Data (10-15 minutes)
Age Level	Middle School
Essential Question	**As a member of MESA, what am I expected to do?**
Learning Objectives	• TSW become familiar with the MESA Program mission, calendar and policies. • TSW understand what is expected of them as members of the MESA Program.
Other Objectives	• TSW listen as advisor presents information and answers questions. • TSW participate in a discussion about the MESA Program.
Materials Needed	Per Group • MESA Mission • MESA Calendar (handouts or overhead) Per Student • Handout: Student Policies and Procedures • Handout: MESA Parent Permission and Student Information Form (AIF)
Activity #1	**MESA Student Policies and Procedures** 1. Review MESA Mission. Answer questions they may have. 2. Pass out a MESA calendar for the year or show them on an overhead. 3. Point out all the dates that involve students and give them a brief explanation of what will happen at each event. 4. When discussing Southern Regionals and MESA Day, emphasize that for competitions students will be engineering and constructing projects just like the ones they do in class. 1. Ask for questions and discuss. 2. Pass out handouts that give Student Policies and Procedures Overview. 3. Go over what is expected of students and your role in helping them successfully achieve these expectations. 4. Discuss and answer questions.
Activity #2	**MESA Student AIF Data** 8. Pass out AIF packet. 9. Discuss and clarify the MESA family agreement component. Answer any questions. 10. Encourage students to discuss the parent responsibilities with their family when they get home. 11. Emphasize the importance and conditions of the form. The student needs to understand the meaning of completing the AIF form and how it will affect them. Items to address: access to their school records for data development, usage of their image in pictures for MESA promotion.
Informal Assessment	82. Monitor students for engagement. 83. Monitor students for understanding.
Formal Assessment	• Completed AIF form.

SEI Strategies Used

Preparation	Scaffolding	Grouping Options
☐ Adaptation of Content	☒ Modeling	☒ Whole class
☐ Links to Background	☐ Guided practice	☐ Small groups
☐ Links to Past Learning	☐ Independent practice	☐ Partners
☒ Strategies incorporated	☒ Comprehensible input	☐ Independent
Integration of Processes	Application	Assessment
☒ Reading	☐ Hands-on	☐ Individual
☐ Writing	☐ Meaningful	☒ Group
☒ Speaking	☒ Linked to objectives	☐ Written
☒ Listening	☐ Promotes engagement	☒ Oral

MESA Mathematics Engineering Science Achievement

Lesson Activity

Title	**Welcome to MESA (20-30 minutes)**
ID Number	MS-MESA-1
Sequence and Duration	• Name Game (10-15 minutes) • Introduction to MESA (10-15 minutes)
Age Level	Middle School
Essential Question	**What is MESA all about?**
Learning Objectives	• TSW will learn about the purpose and objectives of MESA. • TSW will meet and learn the names of the other MESA students.
Other Objectives	• TSW will practice teamwork. • TSW will practice non-verbal communication.
Name Game	o Ask the students to introduce themselves loud and clear, giving their names and why they are here. Also, tell everyone that it is important that they listen to everyone. o Make sure everyone's introduction is loud and clear. o After everyone has introduced themselves tell everyone to stand. Let them know that they will have 3 minutes to put themselves into alphabetical order, but there are rules: 1) can only use helpful pointing, 2) no talking, no signing, no gesturing. o After three minutes, have everyone repeat their name to see how close they were.
Introduction to MESA	1. Ask students why they are interested in MESA. 2. Ask students what they think MESA is about and what they think they will be doing at MESA meetings. 3. Introduce and discuss what MESA is about and how it will make them more successful in various aspects of their life. 4. Have a former member of MESA describe their experiences with MESA and allow students the opportunity to ask questions. 5. Inform students of the next MESA meeting and give them a heads up about what the next activity will be.
Informal Assessment	84. Monitor students for participation in group activity.

SEI Strategies Used

Preparation
- ☐ Adaptation of Content
- ☒ Links to Background
- ☐ Links to Past Learning
- ☐ Strategies incorporated

Scaffolding
- ☐ Modeling
- ☐ Guided practice
- ☒ Independent practice
- ☒ Comprehensible input

Grouping Options
- ☒ Whole class
- ☐ Small groups
- ☐ Partners
- ☐ Independent

Integration of Processes
- ☐ Reading
- ☐ Writing
- ☒ Speaking
- ☒ Listening

Application
- ☐ Hands-on
- ☒ Meaningful
- ☒ Linked to objectives
- ☒ Promotes engagement

Assessment
- ☐ Individual
- ☒ Group
- ☐ Written
- ☒ Oral

Lesson Activity

Title	**Writing a Technical Paper (80 minutes)**
ID Number	MS-MESA-5
Sequence and Duration	• Lead In: 20 minutes • Activity: 55 minutes • Closure: 5 minutes
Age Level	Middle School
Essential Question	**How do I write a good technical paper on my project?**
Learning Objectives	• TSW identify the characteristics of well-done and poorly-done technical papers. • TSW conduct an investigation in groups, fulfilling the responsibilities of their chosen role. • TSW prepare an outline of a technical paper that approaches competition standards.
Other Objectives	• TSW practice their reading and writing skills. • TSW present their ideas to the class. • TSW communicate with their group by contributing their vocal input. • TSW listen as their peers discuss their posters.
Key Terms	• Technical paper • Roles
Materials Needed	Per Class: • Large collection of coins, including a variety of different coins • Middle school-level technical papers and score sheets from previous years Per Team: • 10 paper clips, all identical • Handout: Investigation – Coin Carrier • Scissors • Poster paper Per Student: • Handout: Guide to Technical Papers (if students do not already have them) • Handout: The Technical Paper Process • Handout: Tasks for Different Roles
Lead In	1. Tell students that in this session, they will practice writing a technical paper with their teammates about an investigation. Before they do this, they will have a chance to look at examples of real technical papers and how judges scored them. 2. Hand out examples of technical papers and score sheets to pairs of students. If they do not already have them, hand out the "Guide to Technical Papers" handouts as well. 3. As students read the papers, focus their attention on the papers' sections and the kinds of information the authors put in each section. Encourage them to look at how the papers were scored for each criterion, and think about how the papers could have scored higher. 4. Allow time for students to share out to the whole group about the papers they read and what they were able to learn about technical papers by reading them. Were there any that were especially good? Especially bad? Why?
Activity	1. Have students get into groups of four. Tell them they will be conducting an investigation and preparing to write a technical paper on it. They will each have a role to play in preparing the paper as they conduct the investigation. 2. Hand out "The Technical Paper Process" and the "Tasks for Different Roles" table. Read through the handouts with the students. Make sure all students have their roles and understand what they're expected to do. 3. Hand out the "Coin Carrier" investigation instructions. Hand out the supplies for the investigation, or send students to stations where the

	materials are set up. 4. Give students ten to fifteen minutes to complete their devices. Circulate among the groups and make sure that they are being careful to document their process as well as work on their designs. 5. Test the final designs as a group. Remind the groups that their Notetakers and Illustrators should be recording the results, and the Researchers and Spec Checkers should be assisting with this. 6. After testing, give the students roughly twenty minutes to work on outlining their papers – more if time is available. During this time, hand out the poster paper. Circulate among the groups to answer questions and provide guidance. 7. With fifteen minutes remaining in the session, have students present their posters.
Closure	1. Ask students what it was like to think about writing and doing an investigation at the same time. Was it harder? Was it helpful? Did doing it help them write their technical paper? 2. Ask students to look again at the question at the bottom of the worksheet. How *would* they proceed to write real sentences and paragraphs from the outlines they created? What else would they need to do? [E.g. revise, edit, send to peers and teachers for critiques.]
Informal Assessment	85. Monitor students for participation. 86. Monitor students' understanding through observation and direct questioning.
Formal Assessment	• Completed paper outline. • Completed poster. • Presentation on poster.
Trouble Shooting	• Although there is a lot to pack into this session, if you have different students coming each week, try to keep the investigation and paper outlining to one session. If necessary, separate the lesson between the "Lead In" and "Activity" sections.

SEI Strategies Used

Preparation
- ☐ Adaptation of Content
- ☐ Links to Background
- ☒ Links to Past Learning
- ☒ Strategies incorporated

Scaffolding
- ☐ Modeling
- ☐ Guided practice
- ☒ Independent practice
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Grouping Options
- ☐ Whole class
- ☒ Small groups
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- ☐ Independent

Integration of Processes
- ☒ Reading
- ☒ Writing
- ☒ Speaking
- ☒ Listening

Application
- ☒ Hands-on
- ☒ Meaningful
- ☒ Linked to objectives
- ☒ Promotes engagement

Assessment
- ☐ Individual
- ☒ Group
- ☒ Written
- ☒ Oral

Arizona Math Standards Addressed	• (none)
Arizona Science Standards Addressed	• S1C1: Formulate predictions, questions or hypotheses based on observations and locate appropriate resources. • S1C2: Participate in planning and conducting investigations and recording data; design and conduct controlled investigations. • S1C3: Organize and analyze data; evaluate experimental design and analyze data to explain results and propose further investigations. • S1C4: Communicate results of investigations.

Guide to Technical Papers

Title Page:
The title page includes the title of the project, information about the authors (their names, state and school), and the date.

Abstract:
The abstract is a paragraph-long synopsis of your *whole* paper (including the conclusions and recommendations!). A reader should be able to read the abstract and understand what your whole paper is about, including its purpose, an overview of the discussion, its main conclusions and recommendations. The abstract should be written *last*. It is worth **20 points**.

Table of Contents:
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Conclusion:
Here, you draw a conclusion from the results you reported in the previous section. Based on what you learned from doing your project, what can you say about the concept or device you studied?

Recommendations:
Your recommendations should be a discussion of further work to be done or a strong suggestion about what to do next. The conclusion and recommendations together are worth **15 points**.

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The appendix, or appendices (more than one appendix), contain all the information that doesn’t belong in the rest of the paper but is needed to support it. It can be additional evidence that supports your conclusions, such as data charts, photos, results, etc.

Phase of the Project:	Tasks for Different Roles:			
Each member of the group choose a role:	**<u>Researcher</u>** Finds resources and keeps track of sources; tests the properties of materials, etc.	**<u>Notetaker</u>** Records ideas discussed by the group; records data from tests.	**<u>Illustrator</u>** Creates all tables, charts, graphs, and sketches needed.	**<u>Spec Checker</u>** Becomes the expert on the investigation and paper specs and makes sure that the group follows them.
Identify the technical question	Find additional information and record the sources.	Record the results of the group's discussion.	Create any diagrams or models needed.	Review the specs and identify the purpose of the investigation.
Brainstorm possibilities	Brainstorm with the group.	Brainstorm with the group; write down the group's ideas.	Brainstorm with the group.	Brainstorm with the group.
Come up a hypothesis	Work with the group to come up with a hypothesis.	Record the hypothesis.	Sketch a diagram representing the hypothesis.	Make sure the hypothesized solution fits with the investigation specs.
Test your ideas	Perform any tests that need to be done. Work with the group to come up with new ideas.	Record data from testing. Keep track of group's ideas.	Create diagrams of testing set-ups and representations of data (e.g. charts, tables).	Ensure design is staying within the specs. Make sure information for the paper is recorded.
Build and test your final design	Work with the group to decide on the final design. Build the final design. Perform testing.	Work with the group to decide on the final design. Record the group's ideas and data.	Work with the group to decide on the final design. Finalize representations of data.	Work with the group to decide on the final design. Make sure the design fits within the investigation specs.
Refine your design	Work with the group to make final adjustments.	Work with the group to make final adjustments.	Work with the group to make final adjustments.	Work with the group to make final adjustments.
Outline the *Discussion* section	Work with the group to organize ideas.	Work with the group to organize ideas. Make sure all important data and notes are included.	Work with the group to organize ideas. Insert important illustrations into the outline.	Work with the group to organize ideas. Make sure group follows the paper specs.
Write the *Conclusion* and *Recommendation*	Draw conclusions and recommendations with the group.	Draw conclusions and recommendations with the group.	Draw conclusions and recommendations with the group.	Draw conclusions and recommendations with the group. Make sure group follows the paper specs.
Outline the *Introduction*	Work with the group to organize ideas. Insert any resources and citations recorded earlier.	Work with the group to organize ideas. Make sure all important notes are included.	Work with the group to organize ideas. Insert pictures, etc. from resources.	Work with the group to organize ideas. Make sure group follows the paper specs.
Outline the *Abstract*	Summarize the paper with the group.	Summarize the paper with the group.	Summarize the paper with the group.	Summarize the paper with the group. Make sure group follows the paper specs.

Getting Started: The Technical Paper Process

I. Assigning roles to group members helps you organize your thoughts and keep your paper in mind while you design. Assign one role from the list below to each group member:
   a. Researcher: Finds needed information and keeps track of sources; leads the investigation.
   b. Spec Checker: Is the expert on the specs and ensures that the group follows them.
   c. Notetaker: Records any ideas discussed by the group.
   d. Illustrator: Creates any tables, charts, graphs, and sketches needed.

ii. Review the table showing the tasks for each role. This table shows *possible* responsibilities for each team member. Keep in mind that each team member is equally responsible for the investigation and paper! Every member of the group should be helping every other member with each part of the investigation.

iii. Get your supplies and begin the investigation. As you get started, think about the questions below:
   1. How will you tell your reader what you were investigating?
   2. What background information will your reader need in order to understand the investigation?
   3. How will you document the steps you took in your investigation?
   4. What diagrams, pictures, data tables, charts, etc. can you create to help the reader visualize your investigation and results?
   5. How can you provide enough information for your reader to believe in your conclusion(s) and recommendation(s)?
   6. What can each group member do along the way that will help the group write their technical paper?

iv. When you are finished with the investigation, you can focus on organizing your paper. You should already have a good start from working on it while you were doing your investigation. Work together to put your ideas into the outline of a technical paper.

v. When you have your paper outlined, prepare to present it by creating a poster.

vi. For this activity, you are only creating an outline of your paper. How would you go from an outline to a final written paper?

<u>Investigation: Coin Carrier</u>

For this investigation, your team will be creating a device that will be able to hold coins.

Your mission is to design a coin carrier that is able to carry the **greatest amount of money possible**. So for instance, a coin carrier that holds five nickels (25 cents) is not as desirable as a coin carrier that holds five dimes (50 cents).

<u>Rules</u>:

1. You may only use the materials that are given to you.
2. You may change the materials in any way you see fit.
3. The coin carrier must be able to hold all the coins for **ten seconds**. If any coins are dropped, the group is disqualified.
4. The coin carrier that holds the greatest amount of money wins the competition.
5. In the case of a tie, the coin carrier holding the greatest *weight* of coins will be declared the winner.

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3/17/2004

TECHNICAL PAPER SCORING CRITERIA

[redacted] MESA USA National Engineering Design Competition

TEAM: [redacted] **SCHOOL:** [redacted] **LEVEL: MS or HS**

Discussion (Physical Phenomena, Experiment Procedures, Data & Analysis, Tables & Charts, Results)	**Abstract** (Length, Purpose & Key Features, Conclusions & Recommendations, Non-technical, Informative & Interesting)	**[redacted]roduction** (Purpose, Scope, Background Information)	**Conclusion & [redacted]mmendations** (Inferences & Evidence – Further Work & Reasoning)	**Written Presentation** (Length, Font, Key Sections, Supporting Sections)
31-40 • Very thorough discussion of Physics, Math and/or Engineering concepts • Very complete description of experimental/testing procedures including diagrams or pictures • Thorough description of analysis tools used • Highly relevant tables, graphs, charts, etc. • Very clear explanation of results w/graphics	16-20 • Length: <250 words • Very clearly restates Purpose & Key Features of report • Very clearly restates Conclusions and Recommendations of report • Written very clearly in non-technical terms • Engages and informs the reader	13-15 • Purpose: Very clearly states why project undertaken AND why report developed • Scope: A very thorough description of parameters, methods, limiting factors & technical terms • Background: Share key facts, conditions, events prior to project AND previous work on this topic	13-15 • Conclusion: • Inferences follow very logically from discussion evidence • No new material included • Recommendations: • Further work/best solution well identified • Written in first person w/ active verbs	9-10 • Length: 5-15 pages (-cover & title page) • Font: 12, Times New Roman • Spacing: double spaced • All Key Sections included: Title page, Abstract, Contents, Introduction, Discussion, Conclusion, Recommendations • All Supporting Sections included: References, Acknowledgments, Appendix
21-30 • Effective discussion of key concepts • Effective description of procedures including diagrams or pictures • Good description of analysis tools • Tables, graphs, charts, etc. useful to report • Good explanation of results w/graphics	11-15 • Length: Slightly over length • Good restatement of Purpose/Key Features • Good restatement of Conclusions & Recommendations • Well written, but includes some technical terms • Modestly engages and informs reader	9-12 • Effective/complete statement of purpose • Effective statement of scope, 1 or 2 items appear missing or overlooked • Effective and complete background details, 1 or 2 items appear missing or overlooked	9-12 • Conclusion: • Inferences follow loosely from discussion evidence • No new material included • Recommendations: • Further work/best solution not well identified	5-8 • Length: Slightly over or under length • Font: Some inconsistency throughout • Spacing: Some inconsistency throughout • 1 Key Section not identified or missing • 1 Supporting Section not identified or missing
11-20 • Limited discussion of key concepts • Limited description of procedures, with few diagrams or pictures • Analysis tools poorly described or not used • Graphics not well used to support report • Very little discussion of results, no graphics	6-10 • Length: too short 10 • Poor restatement of Purpose or Key Features • Poor restatement of Conclusion or Recommendations • Many technical terms • Uninteresting to reader	5-8 • Incomplete statement of purpose for project and report • Incomplete statement of scope, multiple items missing or overlooked • Limited background information included	5-8 • Conclusion: • Inferences follow poorly from discussion, evidence not clear • Some new material included • Recommendations: • Further work/best solution not well identified	3-4 • Length: too short/long (-cover & title page) • Font: very inconsistent throughout • Spacing: very inconsistent throughout • 2-3 Key Sections not identified or missing • 2 Supporting Sections not identified or missing
0-10 • Little or no discussion of key concepts • Little or no description procedures • Data analysis not included • Graphics do not support report • No discussion of finding/results	0-5 • Length: >250 words • Purpose or Key Features not included • Conclusion or Recommendations not included • Does not engage reader	0-4 • Very poor statement of purpose for project • Very poor statement of scope, very little information included • Very poor background provided, very little information provided	0-4 • Conclusion: • Inferences do not follow from discussion or evidence present • new material included • Recommendations: • Further work/best solution not identified	0-2 • Length: <5 pages or >15 page • Font: incorrect throughout • Spacing: incorrect throughout • Most Key and Supporting Sections not identified or missing
Score 35/40	Score 10 /20	Score 13 /15	Score 12 /15	Score 10 /10
Judge	[redacted]		Total	80

MS-A

MESA

TECHNICAL PAPER SCORING CRITERIA

[redacted] MESA USA National Engineering Design Competition

TEAM: [redacted] **SCHOOL:** [redacted] **LEVEL: MS or HS**

Discussion (Physical Phenomena, Experiment Procedures, Data & Analysis, Tables & Charts, Results)	**Abstract** (Length, Purpose & Key Features, Conclusions & Recommendations, Non-technical, Informative & Interesting)	**Introduction** (Purpose, Scope, Background Information)	**Conclusion & Recommendations** (Inferences & Evidence – Further Work & Reasoning)	**Written Presentation** (Length, Font, Key Sections, Supporting Sections)
31-40 • Very thorough discussion of Physics, Math and/or Engineering concepts • Very complete description of experimental/testing procedures including diagrams or pictures • Thorough description of analysis tools used • Highly relevant tables, graphs, charts, etc. • Very clear explanation of results w/graphics	16-20 • Length: <250 words • Very clearly restates Purpose & Key Features of report + – • Very clearly restates Conclusions and Recommendations of report – • Written very clearly in non-technical terms • Engages and informs the reader	13-15 • Purpose: Very clearly states why project undertaken AND why report developed • Scope: A very thorough description of parameters, methods, limiting factors & technical terms • Background: Share key facts, conditions, events prior to project AND previous work on this topic	13-15 • Conclusion: • Inferences follow very logically from discussion evidence • No new material included • Recommendations: • Further work/best solution well identified • Written in first person w/ active verbs	9-10 • Length: 5-15 pages (-cover & title page) • Font: 12, Times New Roman • Spacing: double spaced • All Key Sections included: Title page, Abstract, Contents, Introduction, Discussion, Conclusion, Recommendations • All Supporting Sections included: References, Acknowledgments, Appendix
21-30 • Effective discussion of key concepts • Effective description of procedures including diagrams or pictures • Good description of analysis tools • Tables, graphs, charts, etc. useful to report • Good explanation of results w/graphics	11-15 • Length: Slightly over length • Good restatement of Purpose/Key Features • Good restatement of Conclusions & Recommendations • Well written, but includes some technical terms • Modestly engages and informs reader	9-12 • Effective/complete statement of purpose • Effective statement of scope, 1 or 2 items appear missing or overlooked • Effective and complete background details, 1 or 2 items appear missing or overlooked	9-12 • Conclusion: • Inferences follow loosely from discussion evidence • No new material included • Recommendations: • Further work/best solution not well identified	5-8 • Length: Slightly over or under length • Font: Some inconsistency throughout • Spacing: Some inconsistency throughout • 1 Key Section not identified or missing • 1 Supporting Section not identified or missing
11-20 • Limited discussion of key concepts + • Limited description of procedures, with few diagrams or pictures –1 • Analysis tools poorly described or not used • Graphics not well used to support report • Very little discussion of results, no graphics	6-10 • Length: too short ½ • Poor restatement of Purpose or Key Features –1 • Poor restatement of Conclusion or Recommendations ½ • Many technical terms • Uninteresting to reader	5-8 • Incomplete statement of purpose for project and report • Incomplete statement of scope, multiple items missing or overlooked • Limited background information included	5-8 • Conclusion: • Inferences follow poorly from discussion, evidence not clear • Some new material included • Recommendations: • Further work/best solution not well identified	3-4 • Length: too short/long (-cover & title page) • Font: very inconsistent throughout • Spacing: very inconsistent throughout • 2-3 Key Sections not identified or missing • 2 Supporting Sections not identified or missing
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Score 14/40	Score 8/20	Score 7 /15	Score 10 /15	Score 9 /10
Judge			Total	48

MS-A 12/18

MS-A

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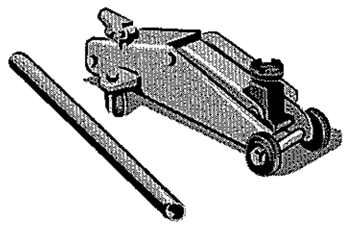

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Abstract

The purpose of this activity is to build a mousetrap vehicle, powered by a single standard sized mousetrap, designed to travel the farthest distance up a 30-degree incline. That will also travel 10 meters in the shortest time. A mousetrap-powered car is a vehicle that uses a mousetrap for a motor. There are many different Ideas but the most common and probably the most successful ideas are to attach a string to the mousetrap and axle or the string pull. In this method, one end of a string is attached or tied to the arm on the mousetrap and the other end of the string is wound around an axle. By winding the string around the axle the mouse trap's spring is stretched and now you have your stored energy. As the mousetrap car is released, the mousetrap pulls the string off the axle causing the wheels to turn and off the vehicle goes. The two most important things in making a good mousetrap care is: getting the wheels to turn easily, and getting the wheels on as straight as possible. After the tires have been connected to the vehicle, spin the wheels as fast as possible. The inertia of the wheel centers it on the axle, and when it is properly assembled, the wheels will be close to being centered on the axle. Using big wheels is also an advantage. By keeping the wheel to the axle ratio low, and using a long arm connected to your mousetrap, you should achieve a maximum distance.

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Introduction

The purpose of this activity is to build a vehicle powered by a single, standard sized mousetrap, designed to travel the farthest distance up a 30 degree incline and travel 10 meters in the shortest time.

We had several trials with various styles of vehicles. We built vehicles that had big wheels in front and in back. We built vehicles that were short and some that were long. We built vehicles that were wide, where wheels were very far apart. In the end, we found that the vehicle that worked best for us was the vehicle that was closest to the ground. The inertia of the wheels had to be centered on the axle. The wheels had to be close in order to achieve this. Using the big wheels was an advantage. By keeping the wheels to axle ratio low, and using a long arm connected to the mousetrap, maximum distance was achieved. Before this activity, we built mousetrap cars where we were able to rearrange the arm of the mousetrap in order to manipulate the speed. We also used rubber bands to make the mousetrap car travel further than it would with a string. Having had that experience, it was difficult to go to a string. A string does not create the same tension that a rubber band does, therefore the mousetrap car moves much slower. We tested our ideas to see what would come of them.

Discussion

When building our mousetrap vehicle we came to learn many new terms Involved in the movement of the mousetrap. We found that how the mass of the mousetrap car is distributed leads to optimum performance. An object at rest tends to stay at rest and an object in motion tends to stay in motion, so an object that is rotating about an axis tends to remain rotating about the same axis unless an external force or torque acts on it. The property of an object to oppose changes in its rotational state of motion is called rotational inertia and is a restatement of Newton's First Law of Motion. Rotational inertia is the resistance an object has to changes in rotation. Just as inertia for linear motion depends on one more component- the position of the mass with respect to the axis of rotation. The larger the distance between the mass of the an objects magnitude and it's axis of rotation, the better the rotational inertia. A weight lifter demonstrates this principal, when he or she twists a barbell with mass located on the ends. When the mass of the barbell is far from the axis of rotation, its mid point, and the bar, has substantial rotational inertia and it is hard to turn or twist. If the mass is placed closer to the center of rotation, the bar twists with a lesser amount of effort. It follows that the greater the rotational inertia of an object, the harder it is to transform the rotational state of the object. If rotating it is hard to stop; if at rest, it is not easy to rotate. That is why it is important that the wheels are centered on the axle. If the wheels are fairly close to being centered on the axle, then the inertia of the wheels is centered. When a mousetrap car is set up this way, using big wheels adds to the advantage on the momentum of the vehicle. We also discovered that the tires we were using did not create enough friction between the tire and the surface. We discovered that friction is a force that always opposes motion in a direction that is opposite to the motion of an object. An object that is sliding to the right experiences a force of friction towards the left. If it were not for friction, an object would roll or move forever, as long as there was nothing—like a wall—to stop its motion. Our mousetrap car could not create enough friction to get it moving in any direction. We needed to create friction, so we did this by adding rubber to the surface of our tires. This way friction acted against the motion of the car and made it climb a 30-degree ramp. Otherwise, the tires just rotated but never climbed. Friction occurs anytime two surfaces slip, slide, or move against each other The greater the amount of friction between two surfaces, the larger the force that will be required to keep an object moving. In order to overcome friction, a constant force is needed. In order to maintain the constant force, there must be a supply of energy. The arm attached to the mousetrap and the string that is attached to the axle created the energy on our mousetrap car. The moment that it is set in motion energy is created because surface friction occurs between any two surfaces that touch or rub up against one another. The cause of the surface friction is mutual contact of irregularities between the touching surfaces. The irregularities act as obstructions to motion. Even surfaces that appear to be very smooth are irregular when viewed closely on a microscope. Luckily, during motion surface friction is unaffected by the relative speed of an object; even though the speed of an object may increase, the force of the surface friction will remain constant. This means that the same force is required to slide an object at a slow or fast rate of speed on a given surface. We used rubber to create this tension because the amount of friction acting between two surfaces depends on the kinds of material from which the two surfaces are made and how hard the surfaces are pressed together. We need friction, without it we could not move anywhere; it is friction that allows us to grip the surfaces we move on. We tried several types of string and several lengths because we needed one that would have enough elastic in it to react similar to a rubber band and one that could capture the greatest distance. We found that this was the key to creating the most energy. Energy is a product of an applied force through a distance. Changing the diameter of either the wheel(s) or the axel controls the mechanical advantage of the wheel-axle system. When the ratios of the length of string used per turn divided by the distance traveled is less than one, the mechanical advantage is small, and the car travels slow and far. When the ratios of the length of string used per turn divided by the distance traveled is greater than one the car accelerated very quickly and uses only a small amount of string. Then we explored changes in the wheels. By increasing or decreasing the wheel-to –axle ratio, you will change the mechanical advantage of the mousetrap car. We kept in mind that changing the mechanical advantage does not increase the work we got from our mousetrap; it only changes the size of the force and the distance the force is applied. With this distance vehicle, we wanted a small force over a long distance; therefore, we used a large wheel with a small axle. A large wheel with a small axle will cover more distance per each turn of the axle when compared to a smaller wheel with the same axle. We found that there is a trade-off for having a large wheel-to-axle ratio. The trade-off is that it takes more force to accelerate the vehicle to the same speed in the same time as a vehicle that has a small wheel-to-axle ratio, but this was ok because distance cars should not be fast in order to cut down on air resistance. It is essential that a vehicle with a large wheel-to-axle ratio have a small rotational inertia wheel, since low rotational inertia wheels are much easier to rotate than large rotational inertia wheels.

Conclusion

The five most important aspects in making a good mousetrap car are getting the wheels to turn easily, and getting the wheels on as straight a possible. Ounce we had that set up, creating the surface tension and energy was easy. The rubber used on the car wheels caused the car to begin to climb. Using shorter string that had enough elastic in it, created the energy source to climb the 30-degree ramp. Keeping the wheel to axle ratio as low as possible maintained the constant energy. Because every time the axle went around, our wheel went around one time. In addition, because the wheels had a much larger circumference, the car went a long ways with less string. Therefore, we conclude that making a mousetrap car that will produce the energy necessary requires a low tire to axel ratio and a short string and rubber on the tires to create the friction needed to climb.

Recommendations

We recommend that if anyone wants to build a mousetrap car that will not only go the furthest distance but will also climb a 30-degree ramp, they must follow our instructions. Through testing, we discovered that a mousetrap car requires a very special design in order to optimize its performance. Discovering that the wheel to axle ratio had to be small and low to the ground was the key to our success. Then discovering that a shorter string is better than a longer string proved the defining moment in our exploration. Because once the car is released, this mechanical set up proves to be the best in achieving the objectives. We were instructed to build a vehicle that would travel the farthest distance up a 30-degree incline and would travel 10 meters in the shortest time; we believe that in this design, we have met the criteria.

References

Mousetrap Science is Fun- ISBN 0-965-3457-1-8

The Best in Mousetrap Cars and Boats –ISBN 0-965-3457-3-4

The Best in Mousetrap Cars- ISBN 965-3457-2-6

Mousetrap Cars: The Secrets to Success – ISBN 0-9656674-1-3

Websites-

http: //www.msu.edu/users/fawcett3/zeb.html

http: //www.mousetrap- vehicles.com/article.cfm?article_id=122

Acknowledgements

We would like to thank the following people for their support and encouragement during the days and nights of after school testing and building.

1. [redacted]-for helping us correct our grammar and for staying late at school when every other teacher was already at home asleep.
2. [redacted]for helping us with the design process of this activity. He always thought of a better way we could do something. Therefore, making us continually revamp our designs.
3. Our parents- for being helpful and understanding when asked to pick us up at 10 pm from school.
4. The custodians at[redacted]for never complaining about the huge mess we would leave behind.

3/17/2004

MESA

TECHNICAL PAPER SCORING CRITERIA

[redacted] MESA USA National Engineering Design Competition

TEAM: SCHOOL: [redacted] LEVEL: MS or HS

Discussion (Physical Phenomena, Experiment Procedures, Data & Analysis, Tables & Charts, Results)	Abstract (Length, Purpose & Key Features, Conclusions & Recommendations, Non-technical, Informative & Interesting)	Introduction (Purpose, Scope, Background Information)	Conclusion & Recommendations (Inferences & Evidence – Further Work & Reasoning)	Written Presentation (Length, Font, Key Sections, Supporting Sections)
31-40 • Very thorough discussion of Physics, Math and/or Engineering concepts • Very complete description of experimental/testing procedures including diagrams or pictures • Thorough description of analysis tools used • Highly relevant tables, graphs, charts, etc. • Very clear explanation of results w/graphics	16-20 • Length: <250 words • Very clearly restates Purpose & Key Features of report • Very clearly restates Conclusions and Recommendations of report • Written very clearly in non-technical terms • Engages and informs the reader	13-15 • Purpose: Very clearly states why project undertaken AND why report developed • Scope: A very thorough description of parameters, methods, limiting factors & technical terms • Background: Share key facts, conditions, events prior to project AND previous work on this topic	13-15 • Conclusion: • Inferences follow very logically from discussion evidence • No new material included • Recommendations: • Further work/best solution well identified • Written in first person w/ active verbs	9-10 • Length: 5-15 pages (-cover & title page) • Font: 12, Times New Roman • Spacing: double spaced • All Key Sections included: Title page, Abstract, Contents, Introduction, Discussion, Conclusion, Recommendations • All Supporting Sections included: References, Acknowledgments, Appendix
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Score 21 /40	Score 11 /20	Score 10 /15	Score 13 /15	Score 9 /10
Judge			Total	64

MS-B

12/18

MESA

TECHNICAL PAPER SCORING CRITERIA

[redacted] MESA USA National Engineering Design Competition

TEAM: **SCHOOL:** [redacted] **LEVEL: MS or HS**

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Score 38 /40	Score 19 /20	Score 15 /15	Score 13 /15	Score 10 /10
Judge	[redacted]		Total	95

MS-B

Multi-Purpose Vehicles

[redacted]

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MS-B

Abstract

Research was conducted to create the most effective mousetrap vehicle for speed and power. Topics researched included inertia, friction, torque, and kinetic and potential energy. The mousetrap car was built applying different combinations of scientific principles to obtain the best possible results.

The car kept the basic mousetrap design. It consistently traveled a minimum distance of 30 feet. A string was used to drive the axle by putting tension on the mousetrap spring. Releasing the arm moved the car forward. Two wheels were made from compact disks to minimize the amount of energy needed to compensate for the friction created. A small axle to a large wheel ratio will cover more distance per turn of the axle and the speed is increased through the use of a short lever arm which gives greater acceleration.

Constructing the mousetrap vehicle caused us to realize that trade-offs had to be made in order to have it accomplish what it needed to do. Building a car which accelerates quickly usually sacrificed distance. Yet a car that could go a good distance usually meant a slower moving vehicle. We noticed that focusing on one variable had an effect on other variables used to make the vehicle go. The recommendation to build a successful mousetrap vehicle would be to apply different combinations of scientific principles to obtain the desired results.

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Introduction

Purpose

The main goal of the multi-purpose vehicle experiment was to design a vehicle, powered by a single, standard sized mousetrap, that achieves both power and speed. The vehicle would have to travel up a ramp angled at a 30-degree incline to test its power. Speed will be computed by how fast the vehicle traveled a distance of ten meters on a level surface.

A number of variables had to be considered in order to find the best balance so maximum performance could be achieved. The knowledge gained through research and experimentation was used to build the best machine possible. This information can be used to improve future vehicle designs.

Scope

Newton's First Laws of Motion were investigated to determine the best combination of force, mass and acceleration. Rotational inertia, friction, kinetic and potential energy, torque, wheels to axle ratios and traction were all considered when building a vehicle for speed and power.

The scope of this study was limited to the use of a single, standard size mousetrap. The original mousetrap mechanism must be tripped to activate the power. No energy source may be added nor may the mechanism be altered. In the power task, the vehicle must climb a 4' X 8' smooth ramp supported at a 30-degree angle. The speed of the vehicle will be determined by the distance (10 meters) divided by the time it takes the vehicle to cover that distance. The surface will be a smooth, level tile floor.

Tests will be conducted to see what enables the vehicle to go farther and faster. These tests will be used to determine how well the vehicle will do in competition.

For the purpose of this research the following terms have been defined:

(1) Rotational inertia – The ability of an object to resist changes in its rotational state of motion.

(2) Friction – A force that opposes motion in a direction that is opposite to the motion of the object.

(3) Kinetic energy – Energy of motion or the energy a moving object has.

(4) Potential energy – Energy that is stored or held in readiness.

(5) Torque – Force applied to make an object turn or rotate.

(6) Traction – Type of friction which keeps items from slipping and allows movement

(7) Newton's First Law of Motion – Every material object continues in its state of rest or in uniform motion in a straight line unless it is compelled to change that state by forces acting on it.

(8) Newton's Second Law – The acceleration of an object is directly proportional to the net force acting on the object and is inversely proportional to the mass of the object.

(9) Newton's Third Law – Whenever one object exerts force on a second object, the second object exerts an equal and opposite force on the first.

Background Information

The fact that the vehicle was limited to using only the energy produced by the springing of the mousetrap mechanism proved to be the focus point of our experiments.

Since no additional energy could be added, other factors had to be considered. Potential energy had to be changed to kinetic. This would mean that the starting energy should be turned to work. Work overcomes frictional forces against the vehicle. The largest amount of friction is rolling friction. Travel distance is equal to the starting energy divided by the force of rolling friction. The less rolling friction that there is, the greater the distance a vehicle should travel.

Discussion

Discussion of Physical Phenomena Related to the Project

When considering building a vehicle powered by the energy produced by a snapping mousetrap, the purpose had to be considered. What was needed was motion. Motion on the other hand depends on so many variables many of which are controlled by the physical characteristics of the vehicle. Energy is either potential or kinetic. Stored energy is potential energy since it has the potential to do something. Kinetic energy is the energy of motion. The Law of Conservation of Energy states that energy can not be created or destroyed. It can only be changed from one type to the other. Friction converts energy into heat and sound and takes it away from motion. The vehicle needs to loose energy at the lowest possible rate. This can be accomplished by reducing friction to the lowest possible force.

Friction always opposes motion in a direction opposite the motion of the object. There are two basic types of friction: surface and fluid. Fluid friction is air resistance. Anything going through the air is slowed down by fluid friction. Surface friction is caused when two items rub against each other. The greater the friction, the harder it will be to keep the car going. The kinds of materials chosen can determine how hard they press against each other thus determining how much friction is applied. Even if the speed is increased, the force of surface friction remains constant. On the vehicle, the most common area for surface friction is between the axle and the chassis. In order to reduce friction at this location, small bushings with ball bearings were used. This should increase the speed and reduce surface friction. A lubricant will be used to help the moving parts sliding against each other to have less energy loss and reduce surface friction.

The amount of fluid friction will depend largely on the speed and shape of the vehicle. The slower the vehicle, the less fluid friction. Making the car more aerodynamic can reduce fluid friction. Sandpaper was used to reshape the edge surfaces which would be making contact with air resistance causing drag. Narrow tires were also going to be used. They would be more aerodynamic and have less air drag. The narrowest objects acquired for this job were computer CDs. Rubber stoppers were used to keep the wheels from wobbling and balloons to keep the tires from sliding. CDs also reduced the amount of rotational inertia reducing the amount of force needed for pulling. They also provided better acceleration.

Saying that mass is resistance to change can sum up Newton's Laws. This means that the more massive the vehicle, the more force and energy it would take to move it. That is why the vehicle was build as light as possible. The decision was made to use balsa wood in the construction. A lighter vehicle is easier to get moving and has less friction acting on the bearings. Since mass works against acceleration, the vehicle was kept small. On the other hand, force causes acceleration. In order to increase force, the length of our lever arm was shortened and the mousetrap was moved closer to the drive wheels. This placed the string closer to the hinge on the mousetrap.

One of the problems experienced was that the vehicle had a harder time accelerating due to lack of traction. The front tire was changed to a smaller heavier design.

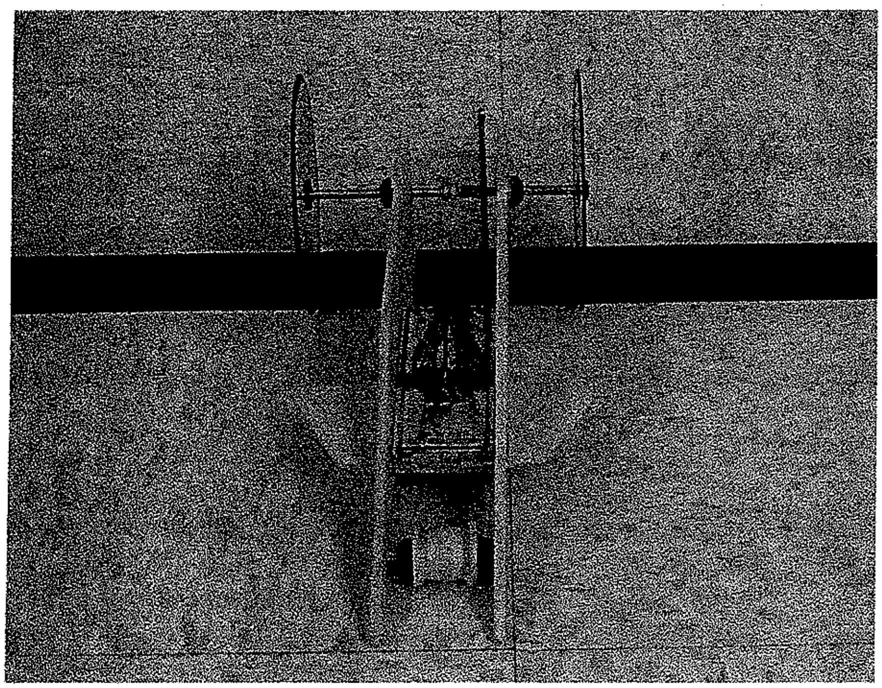
Experimental Procedures and Test Setup

Initially, we just wanted the car to move forward. The car consistently went the length of the classroom, approximately ten meters. It would stop because it would hit the baseboard. The vehicle was taken to the cafeteria. The floor is tile so there would not be any difference with the testing conditions of those that would be used at the competition.

A distance of ten meters in length and two meters in width was measured. The length was marked at one-meter intervals. The vehicle was tested for speed twice. It made three separate runs each time. The distance was divided by time to compute the rate or speed in seconds. A ramp was set up to test the vehicle's power. The car was tested to see if it had enough energy to travel up a 30-degree incline.

After the first test of the vehicle, improvements had to be made. The car was not completing the10-meter distance. It was going out of bounds too early. The body of the vehicle had not been glued together at this point. It was held together with putty just in case we had to make some alterations. This decision created problems. The body of the car was flexing causing it to pull to the right. A wing design was placed on the sides of the chassis to make it aerodynamic. This complicated our building design and we were having trouble lining the left and right sides exactly the same. The wings were a single piece of wood that went all the way across and through the chassis. This caused the front axle to also be out of alignment. Since the right side extended forward about two millimeters farther then the left, it had to be adjusted back. The wings were aligned properly and glued down. Now the axle was straight. A piece of wood was added to the bottom frame of the chassis to keep it from flexing and the parts were all glued together for stability. One of the CD wheels also had a crack close to the sink washer. It had to be changed before the next trial run.

Another problem encountered was having the string roll around the front wheel after the lever had snapped forward. This caused the car to stop short of ten-meters. Extending the length of the string so the snapping arm could go through its full cycle and tying the string to the axle solved this problem. The string would not come loose and extend forward wrapping itself around the front wheel.



Vehicle Figure 1

When the vehicle was placed on the 30 degree angled board, the vehicle did not move. After several tries, it became evident that adjustments had to be made. A spool was placed on the rear axle. According to research, this would increase the torque and should help get the car moving solving the problem.

Data Reduction, Analysis tools, and Models

Once all of the trial runs were conducted, we had to examine the data. Data was recorded to determine the speed of the vehicle. Distance would be divided by the time the vehicle traveled said distance to compute the rate or speed of the vehicle. The graphs provided information that helped us reach the conclusions based on the results from the experiments.

On the first trial, the vehicle was not traveling the full ten meters. Adjustments had to be made or it would be disqualified as a contender. Note that the farther the vehicle traveled, the slower the average speed of the vehicle. That was due to the exhausting of kinetic energy from the mousetrap mechanism. After the vehicle ran out of energy, it continued to roll until friction brought it to a complete stop.

After the second test, the data showed the vehicle was able to travel the full ten meters. The time it took to travel the ten-meters remained within nineteen hundredths of a second. Average speed for all three runs was 1.19 meters per second.

The data for measuring the power of the vehicle equaled zero for both occasions. The adjustment that was made to the axle did not provide enough energy to propel the vehicle forward.

Manipulated Data

1st Trial Run For Speed

	DISTANCE (METERS)	TIME (SECONDS)	RATE OR SPEED (METERS PER SECOND)
1ST RUN	6.75	7.8	0.98
2ND RUN	9.2	8.32	1.11
3RD RUN	8.8	8.49	1.03

Figure 2

2nd Trial Run For Speed

	DISTANCE (METERS)	TIME (SECONDS)	RATE OR SPEED (METERS PER SECOND)
1ST RUN	10	8.43	1.18
2ND RUN	10	8.24	1.21
3RD RUN	10	8.35	1.19

Figure 3

Results

From the tests and research conducted, the vehicle will have no problems competing in the speed trials. All criteria were met using the stated parameters. It is doubtful however, that the vehicle will be able to place in the power segment of the competition. The data shows that the vehicle is not strong enough to travel up the angled board.

Conclusion

The results of the experiments show how difficult it is to build a multi-purpose vehicle. The body design and reduction of friction allowed it to travel the required ten meters without any problems. The vehicle was aerodynamic reducing the amount of fluid friction. Bearings, bushings, narrow tires and lubricants reduced surface friction. Straightening the axle made the car travel straight and not turn to the left or right causing it to travel out of the two-meter boundaries. Keeping the balloons on the wheels kept them from sliding and wasting energy. The vehicle was kept small to comply with Newton's Laws.

The problem still exists with the power component. At this point, there must be more force influencing the vehicle to not move rather then to move up the 30-degree incline.

Recommendations

Adjustments have to be made to the vehicle to allow it to travel up the 30-degree incline. The larger axle concept must continue to be tested using multi-strings which can be used. One should be attached to the narrow part of the axle and used for the speed trials. The second could be attached to a thimble placed to one side of the smaller axle. The string can be taped down when not in use. Tests will have to be conducted to measure the effect of added weight to the vehicle for the speed trials.

The vehicle will probably need a component to separate the wheels from the wooden board they are resting on before starting the power trial. The wheels resting against the piece of wood and the angles of the vehicle on the board are acting as a brake. This is what Newton meant by things at rest tend to remain at rest. The energy from the mousetrap is not sufficient enough to propel the vehicle forward.

Gears might also have to be considered in order to acquire the necessary torque required to propel the vehicle up the incline. This increases the mechanical advantage of the gearing resulting in more torque. Keeping in mind that this will cost the vehicle speed, the vehicle may have to be adapted to using two different types of transmissions.

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3/17/2004

MESA

TECHNICAL PAPER SCORING CRITERIA

[redacted] MESA USA National Engineering Design Competition

TEAM: **SCHOOL:** [redacted] **LEVEL:** MS or HS

Discussion (Physical Phenomena, Experiment Procedures, Data & Analysis, Tables & Charts, Results)	Abstract (Length, Purpose & Key Features, Conclusions & Recommendations, Non-technical, Informative & Interesting)	Introduction (Purpose, Scope, Background Information)	Conclusion & Recommendations (Inferences & Evidence – Further Work & Reasoning)	Written Presentation (Length, Font, Key Sections, Supporting Sections)
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Score 29 /40	Score 10 /20	Score 13 /15	Score 9 /15	Score 8 /10
Judge	[redacted]		Total	69

MS-C

MESA

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TEAM: **SCHOOL:** [redacted] **LEVEL: MS or HS**

Discussion (Physical Phenomena, Experiment Procedures, Data & Analysis, Tables & Charts, Results)	**Abstract** (Length, Purpose & Key Features, Conclusions & Recommendations, Non-technical, Informative & Interesting)	**Introduction** (Purpose, Scope, Background Information)	**Conclusion & Recommendations** (Inferences & Evidence – Further Work & Reasoning)	**Written Presentation** (Length, Font, Key Sections, Supporting Sections)
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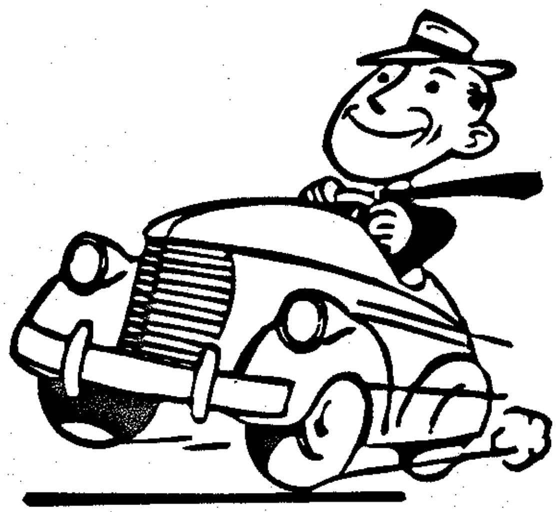
Score 5 /40	Score 3 /20	Score 11 /15	Score 6 /15	Score 9 /10
Judge			Total	34

MS ~~C~~

Technical Paper

Title:
Multi-Purpose vehicle



MS-C

[redacted]

[redacted]
Arizona

Table of Contents

Abstract

A Multi-Purpose Vehicle is a miniaturized car that is powered only by a mouse trap. The materials that you can use are one standard sized mouse trap, all other materials to build the vehicle are acceptable. MESA staff will test them for fastest time in 10 meters, farthest distance up a 30 degree ramp, and stopping nearest to 5 meters. The group had may arguments on the design of vehicle. They deicide that they will get a design form a resource and advance it. The group found out that they should not take an idea they found at Regional. Still from what we got at regional the group was clue less on what to do next. So the team divided into three groups to work on events in multi-purpose vehicle: Oral. Display Board, vehicle performance. Vehicle performance group made a list on what they could do differently. The group made a new car and tested it, they were not happy with results. Right now is continuously working on getting it ready for MESA Day. They have made solutions to their car .

Introduction

Purpose:

The purpose for this study was to increase our knowledge of multi-purpose vehicle, so we would be able to build an efficient car. Our reason for building a multi-purpose vehicle is to compete in the MESA Day Completion and do well. My peers and I went into the project knowing a little information about the weight would affect how fast and how far a car and multi-purpose vehicle, but we came out knowing more than enough to build a wonderful multi-purpose vehicle. With the information that we learned began our experimental phase and let the tinkering begin from there. Though the information that we learned provided us with an advantage, only testing and changing our multi-purpose vehicle multiple times gave us our final product.

Scope

I learning the basics of drag came the task of putting a well-written paper together and being able to understand all the information in it. The group members spent time searching the web and scanning the library for any information that would help us about making the ultimate multi-purpose vehicle and how to build one. After the information was gathered the group began to pull all the pieces together, but we did this separately and then in the end it came all together to put everything together.

This is when the group separated to help put the paper together and build a multi-purpose vehicle; half of the group worked on the paper while the other half began to build and test the gliders. After many tests of our glider we were able to compile the appropriate data to be added to our final paper. Many days of pre=writing and editing within our group help to create the final product and it was something we were very satisfied with.

<u>Background Information</u>

This multi-purpose vehicle and paper is all being done for the MESA Day competition, for the "Multi-Purpose Vehicle" event. A mouse trap is a piece of wood and a metal coil, this mouse trap is used for catching mousses. This is the first year that MESA has had the Multi-Purpose Vehicle event for Middle School, but we had little amount of information from or failure of the car from the recent regional competition to compare our ideas with. What we did have from the regional competition ideas of other models[less weight is better] that we incorporated into one of our designs. Information from other members of our MESA club show us that maybe the previous car was not very successful and that the research to do better the car was never done. Knowing this was began to form our own designs without any influence from the previous year and designed a couple of completely original car designs.

Discussion

<u>Wheels and Axles</u>

Energy is the product of an applied force through a distance. With a lever, when one force is smaller force must travel a greater distance than the larger force so that the energy input on the system is equal to the out put energy of the system. Changing the diameter of the diameter of either the wheels or the axle controls the mechanical advantage of a wheel-axle system. The diameter of a drive wheel and drive axle represent your gearing. With another mouse-trap car, power is transferred to the wheels. In addition to getting energy from one place to another, it can be used to trade speed for torque. So if the diameter of the axle is greater mouse-trap car will either increase power or torque on mouse-trap cars performance.

Experimental procedures and test setup

MESA Day staff will test the following: fastest time over 10 meters, farthest distance up a

30 degree incline, nearest stop to 5 meter target. Teams will submit a 5-15 page technical paper that details the design, development, experimentation and understanding of their vehicle, teams will make an oral presentation based on investigation, experimentation, design, testing, and experiences related to their vehicle. Ramp specification:4' x 8' smooth, finish grade plywood, arranged and supported at a 30 degree angle, with a 1'' x 2'' attached to the lower end to establish a "Start Block."

Materials

The materials that we have used to make multi-purpose vehicle are the following: Balsa Wood, Bass Wood, One standard Victor Mouse trap, one CD, two Hobby Wheels, four brass pipes, Elmers Glue All.

Conclusion

There are many factors that effect the speed, power, and torque of a multi-purpose vehicle, and can affect the design in building a multi-purpose vehicle. Weight, power, torque and many other things must be kept in mind when designing and building a multi-purpose vehicle. There are many advantages and disadvantages of a car when designing it, such as drag and kinetic energy and potential energy, weight, length, Wight, power, speed, torque, but all of these can be manipulated but the design of the multi-purpose vehicle. Thought the knowledge gained through writing this paper gave a proper advantage in building our glider we could not perfect it with out building and testing many designs. Through this we were able to build a multi-purpose vehicle that was very efficient and that we were all satisfied with.

Recommendations

though many trials and tests launches we decided on the final design of our multi-purpose vehicle, but we also believe that there are some things that we should change. First we would like to make the length of the car shorter so that the car can be faster. We also need to find a way to make the car as light as possible so it can travel longer on 30 degree ram, find a way to make it more powerful. One change that we might have to try on another occasion is to use a original design that the group has made up on our own an not from other designs that the group has seen but, can use ideas from it or to advance the car.

Acknowledgments

The group would like to recognize [redacted] for giving all his efforts in making this paper. Also we would like to recognize the group members for making ideas, and helping make Multi-Purpose Vehicle.

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March 10, 2004

3/17/2004

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Score 2 /40	Score 2 /20	Score 3 /15	Score 1 /15	Score 10 /10
Judge			Total	18

MS-D

12/18

3/17/2004

MESA

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Score 21 /40	Score 10 /20	Score 9 /15	Score 9 /15	Score 8 /10
Judge	[redacted]		Total	57

MS-D

12/18

Exploring the Multi-Purpose Vehicle

By:

[redacted]

Arizona

[redacted]

MS-D

Abstract

Hello! We're the team members of [redacted] Multi-Purpose Vehicle. Today you will be reading about our Mousetrap Car.

As a team, we worked hard constructing this vehicle. We came upon countless problems and solutions to our questions. We were tested to find out if we really could achieve to build this car. In general we journeyed from this automobile that wouldn't run to this incredible piece.

The students in this group welcome you to join us in this paper. Hopefully you will discover the most important features and the purpose of this report. Personally, we think the Discussion is what you should flip to. There you will learn exactly what our car is made of, what was our main purpose in the car, and what it was built for. So continue reading and have a great day!

Introduction

While compiling all of our hard work and research together, we found out that kinetic energy and aerodynamics play a huge role in making our car run. The purpose of our vehicle was to ensure that our car ran from at a stop to a reasonable speed. So therefore, we built a lightweight mousetrap car, but when we tested it, it only went two inches! From that one car we started to learn what we should and should not do on our next design, which brings us to our second plan.

We assembled a new car. A flat, slight heavier auto built for speed based on our prior results from our first car. As it went through our testing it moved with great speed. But we had to evaluate other possibilities. Would our design improve our kinetic energy or aerodynamics? Time went on and as more testing continued our car was getting even better.

Facts are very important when dealing with science. It can help you a great deal in learning from other people's mistakes. In this paragraph I am going to introduce you to important facts that you must know before you continue to find out about this Mousetrap Car. For one thing, acceleration makes all the difference in how fast or slow your car is going to move but that all depends on your motor. Our motor which was our mousetrap needed a good snap to get the car moving and when we examined our car, getting it going was no problem at all. So therefore, our acceleration was indeed fine. The kinetic energy which our teacher presented to us also needed to be just right. Which was a no brainer because of course how would it go far if it didn't even move? That kinetic energy would turn out perfect thanks to the guys' brains in our group!

Discussion

Everything the first time doesn't always come out the best. That's why we made a lot of changes to our car. Wheels, the body, the string all played a role in our mousetrap. Every change that we made would somehow impact the way our car would work. Below is what we did to make our car turn out the way it is today.

The most significant part of this car was the body. Situating the mousetrap so that it would allow the car to run and provide it with a good start was the first big task. Also this is where a lot of the mass would come from. It would determine how light our car would be which would then affect how much the car would run. The lighter the load the farther it would go was one of our first objectives to think about. So we found the lightest piece of wood possible and tested its durability and found that this would work the best, which indeed it did. ☺

The wheels were another big issue that we discussed. Should these wheels be light or heavy? Smooth or rugged? As we consulted one of our books that helped us out a lot, we decided to use CDs as our wheels. Not only would their lightness help us in our mass but their smoothness would allow the car to run faster but also with ease. One other thing we thought about but not very long was should the wheels be all the same size? Yes, of course this would make the car have stronger aerodynamics.

In addition to our many problems we were concerned about how we would piece it all together while still maintaining the lightest mass possible. We disagreed with each other trying to state what we thought would be better or just wanting our ideas put on the car but we reached a happy median between us all.

Conclusions

Our car, once all finished, was really cool to look at, but that didn't matter at all! We still had to test it to find out how it stood its ground. Our first test was to check its status on aerodynamics. Its flat surface helped the air pass around it which pushed the car to go further. One other thought that we considered was the car's potential energy. Would the car be high up off the ground or closer to the surface? This one was tough to think about because we had so much to worry about. As we read a very handy book we built the car close to the ground to provide more stability for it and hopefully more potential energy too.

Our setup of the car and the data was made easy by many diagrams and tables in a book titled, <u>Doc Fizzix's Mousetrap Car.</u> As said in above we wanted the car to be built for speed so our lever arms were very long. Our wheels also needed not to have so much resistance. We worked hard and long trying our very best to make everything about this car in tune with everything else that was on it. Which wasn't that easy but it all worked out in the end.

When we were making our mousetrap car we didn't use very much tools at all. Our materials were the size that we needed them. The only tool that we really used was a very much needed dremel. We just used it to cut a piece of wood off. Other than that it was all tool free!

Months went by and hours were spent trying to improve this car. Steadily it got better and better until finally it was just good! In conclusion our wheels helped the car run fast and smooth, the body was lightweight allowing the mass to be low, the pulley arm was long giving our car extreme speed, and the snap of our string moved our car from zero to moving and a distance of 10 meters!

Recommendations

In the Discussion above you can infer that physics has a lot to do with how your mousetrap car is going to perform. Also, you have to worry about several things such as aerodynamics, kinetic energy, and potential energy, because if one doesn't fit then the whole car won't run as well as you'd like.

Also, I think you can tell that research has a lot to do with your project! We found out what was most important and we built it from there. Also, everything has to be exact with everything else. Measurements must be exact. If one thing is off then your whole project is off.

Teamwork is essential too. Work as one and whatever you're working on will show in its performance.

References
Or
Bibliography

Balmer, Alden, (2002) *Doc Fizzix's Mousetrap Powered Cars and Boats.* Austin, Texas: Armstrong Printing

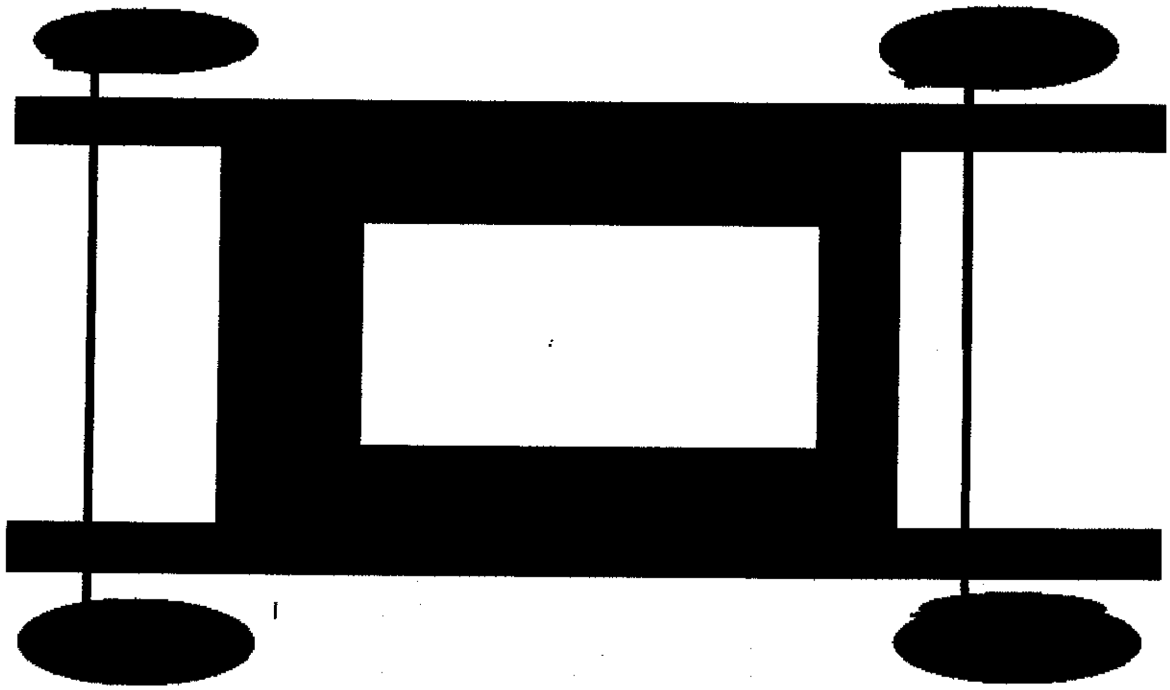
Gundersen P. Erik, (1999) *The Handy Physics Answer Book.* Canton, Mississippi: Visible Ink Press

Acknowledgments

We all had to deal with each other when we were the most irritable so in that case thanks to our team for contributing what we could into this project. But mostly we would like to thank those who have helped us when we really needed it.

[redacted]; we want to thank you so much for providing us with the most appreciated books and for giving us encouragement when we really needed it the most. You were there always smiling saying that we could do it and to not "freak out". Where would we be? Also, you told us to get involved in this project. It was hard and so was this report but we made it through! Yay! We hope that we made you proud. And once again thank you!!

Appendix



MESA

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[redacted] MESA USA National Engineering Design Competition

TEAM: [redacted] SCHOOL: [redacted] LEVEL: MS or HS

Discussion (Physical Phenomena, Experiment Procedures, Data & Analysis, Tables & Charts, Results)	Abstract (Length, Purpose & Key Features, Conclusions & Recommendations, Non-technical, Informative & Interesting)	Introduction (Purpose, Scope, Background Information)	Conclusion & Recommendations (Inferences & Evidence – Further Work & Reasoning)	Written Presentation (Length, Font, Key Sections, Supporting Sections)
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Score 20/40	Score 10 /20	Score 12 /15	Score 4 /15	Score 4 /10
Judge	[redacted]		Total	50/100

MS-E

3/17/2004

MESA

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Score 3 /40	Score 5 /20	Score 3 /15	Score 1 /15	Score 5 /10
Judge			Total	17

MS-E

12/18

[redacted]

Multi Purpose Vehicle

by

[redacted]

Mesa of Arizona

[redacted]

MS-E

Multi-Purpose Vehicle

Abstract

A Multi-Purpose Vehicle should be able to over come challenges. We are attempting to create a Multi-Purpose Vehicle through the use of a standard mousetrap as an energy source to power the vehicle. Our concept needs to achieve:

- Speed for a distance runs on a specific track.
- Power to climb a 30-degree incline.

The purpose of this project is to use everyday use mousetraps to see if it could overcome these challenges; consequently, we are presently experimenting with a vehicle that uses a raised mousetrap to generate power for energy. We are not going to give up yet. This is our first year on MESA and we are behind schedule, but we are hoping the car will be a successful project. Throughout our project we were having technical difficulties. For example, the weight of the car. We are using heavy flywheel to increase the power; nevertheless, it might not increase the speed. That's a big problem for two of the challenges. Also the assembly is behind schedule to be honest we don't actually know if it will achieve our purpose. We are afraid it might be a complete disappointment, but the fun is in the trying.

Table of contents

Introduction

Our purpose of building an multi-purpose vehicle was to prove that mousetrap car spring powered car can climb on an incline and run on flat level ground. This report is to show our results though our planning, construction, and discussions along with our findings.

Our scope consisted of discovery, which included:

- **Different locations for the mousetrap on the vehicle.**
- **A weighted flywheel that will move the car.**
- **Testing of the designed vehicle.**

We researched and discussed the feasibility of rising the mouse trap and though building attempts we attempted to prove our hypothesis.

We had problems in construction with weight, fraction, and the forces that acted on the vehicle. The placement of our equipment on the car caused numerous time constants that has caused us to be behind with our final results.

Our background was very limited and our learning curve was great. We are behind schedule because this was our first time in a MESA competition and we are learning as we go along. Our conclusion and results will be coming with us on April 3rd when we meet for MESA Day.

Discussion

While we were constructing our MPV we ran into many problems. One problem was finding a way to measure the amounts of kinetic energy and potential energy. We first had to measure the kinetic energy we decided that a spring scale would be best for this; next we had to measure the amount of potential energy we chose a scale to measure the weight exerted. We also had to have enough mass, we had to make sure the MPV weighed enough and wasn't too light or too heavy. Aerodynamics also came into play but not a lot, we figured that we shouldn't worry too much about that.

The next obstacle we came to was drag and friction. We decided the best way to reduce drag was through bearings and lubricants. Next we decided to raise the mousetrap to gain leverage because this gave us the potential to use the full pull of the mousetrap. Although the extra weight might slow it down the leverage will make up for it. The mousetrap provides a forced acceleration for the car.

We tested the mousetrap's strength by measuring the trap by using a scale and found how much poundage it had which was more then 5lbs of pull. (Example A in appendix). This force from the compressed spring would be the power for our car. Attaching a rod with epoxy extends the spring. We attached a 1in pulley to increase the force and performance of the vehicle. We attached an eyelet to the body and connected the string to the eyelet and ran through the pulley to the flywheel.

The flywheel is made of heavy brass and once it is placed in motion we are hopeful that it will work well. Our plans are to then attempt to graph our findings by filming runs and through the use of Newton's second Law we hope to see if our acceleration curve is expectable both on flat runs and climbs.

Conclusions

We are still working on the car at this time and do not have any real conclusions to our work. We will be bring an addendum to our paper to show our conclusions and findings in before April 3rd. Thank you for understanding this is a work in progress and that we realize points will be deducted but it is our belief that our finding could have been fake and false and we would just prefer to take our chances that by losing some points now we can still be in the running for the national contest even if we are behind. Thank you

3/17/2004

MESA

TECHNICAL PAPER SCORING CRITERIA

[redacted] MESA USA National Engineering Design Competition

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Score 16 /40	Score 10 /20	Score 12 /15	Score 13 /15	Score 8 /10
Judge	[redacted]		Total	53

MS-F

12/18

3/17/2004

MESA

TECHNICAL PAPER SCORING CRITERIA

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Score 2 /40	Score 6 /20	Score 4/15	Score 2 /15	Score 9 /10
Judge			Total	23

MS-F 12/18

MULTI-PURPOSE VEHICLE COMPETITION

Authors:

[redacted]

State: Arizona

School: [redacted]

Date of submission: [redacted]

MS-F

Abstract

For our project we had to make a mousetrap car. We made a small, fast, and speedy car. The complications of our mousetrap car were getting it to go straight. To do this you have to lineup the wheels so that they are perfectly straight. If you get the wheels straight then you will have a car that will go straight. To make our car faster, we put a shorter string on the car for acceleration. We recommend a smaller car because it moves quicker and is lighter. Another complication we had was making the car go far. We had to take the wheels off the back because they were too small. Then, we put cd's for back wheels. After we put the cds on the car we tested it. The car got stopped by a backpack because it was in the way. We did not no what the length was but the car did work. We will test it again but this time we will have the cars upgrades. Also we will test it on the 45-degree angle slope. Our upgrades were making the car out of real wood and not out of balsa wood. Also we made the car smaller and better. We made the car smaller because it is lighter and it is stronger than our other car. It was made out of balsa wood. We thought that the project was a good learning experience. We all learned a little about building a mousetrap car. Also, we thought that the project was fun and interesting.

Table of contents

[redacted]

Introduction

Our project was to design a mousetrap car that was both powerful and could travel a long distance. The only source of power is the mousetrap itself. This is a difficult challenge! Some of the specific challenges were: the wheels were fragile; the tension broke the balsa wood body, we couldn't get traction. Also, friction caused us to lose a lot of energy. We had to work together as a team and all contribute. We learned about simple machines and leverage, gears and pulleys. We consider ourselves to be a success because overall the whole team helped out in the whole project. We had some challenges on the way of doing the project as told before like the balsa wood breaking also the wheels breaking. We had all the materials like light balsa wood and light wheels that makes the overall structure of the car fast and strong.

The mousetrap car had to be fast and strong, and it had to go a long distance. At first it just went really slow. The wood was breaking a lot on our balsa wood frame for the mousetrap car. The wheels on the car where too big and too shaky and they would move a lot.

Methods of investigation included: hands-on building and problem solving. We researched different designs of mousetrap cars on the Internet and in books. We gathered data with experiments. Some of us had previously built cars in the past.

[redacted]

Discussion

The mousetrap car had to be strong and it had to go far. The first time we tested the car it didn't go very far because the back wheels started going to the side and the car hit a object that was in the way so we had to fix the wheels. The front wheels where made of plastic for toys and the back where Cds so the back of the car was taller than the front part. The first car was breaking all the time because the frame was made out of balsa wood. But the second car went 35ft when driven before in a sience project. But this time we are trying to improve the car by making it go farther and making it be stronger with new adjustments. Like new frame for the first car and better wheels for the second car. The one thing that kept on messing up our project was the frame breaking on the car. We needed better wheels and bearings for the car for more traction and better speed with thin wheels. The car had to go far and I think our car did well because overall we worked hard on the car with putting the first car together and overcoming the obstacles in our path. I think that we will do good in mesa day with the car and we will be triumphant.

Conclusion

During the process of this project we acquired a lot more intelligence. There were a lot of ideas that we came up with after it was too late and the project was due. We enjoyed our project and appreciate the opportunity to do it. Because not only did we demonstrate architectural skills we had a chance to work with physics. The knowledge that we gained will leave us because we know we can use it for the future.

Recommendations

First of all, one of our recommendations is that we could have used different wheels. For the wheels we could have used cd's, Lego wheels and other kind of wheels but not too big. Another recommendation is to make a smaller mousetrap car because it is easier to carry it and you could just put it in your pocket. To make a great mousetrap car you should use a different kind of wood rather that balsa wood because it's weak. It is hard to find materials that are both light and strong.

We have heard of mousetrap cars with transmissions in them: different gear ratios like in a car or bicycles. If we had more time we could have tried to make one just like that. If we could change one thing it would be to start earlier. We have enjoyed working on this project and we feel that it was educational! Since we used a long string, I recommend that we should have used less string so that way maybe it would go faster.

References

Our References were:

- www.google.com, www.yahoo.com
- .Doc Fizzix Engineering Department: http://www.docfizzix.com (mousetrap car building tips.)
- The Ultimate Visual Dictionary of Science. DK Publishing. 1998. Pages 23 – 27. (Chapter on Newtonian Laws and simple machines).

Acknowledgements

We'd like to thank the following people: [redacted] our parents and our fellow students. Students gave us advice as well as the teachers. And our parents helped us build the car and [redacted] bought us supplies. We'd like to acknowledge [redacted] who helped us during class and who also on several occasions almost broke our mousetrap.

8/1/2005

AZ

MESA

TECHNICAL PAPER SCORING CRITERIA

2005-2006 MESA USA National Engineering Design Competition

TEAM: [redacted]CHOOL: [redacted] **LEVEL: MS or HS**

Discussion (Physical Phenomena, Experiment Procedures, Data & Analysis, Tables & Charts, Results)	**Abstract** (Length, Purpose & Key Features, Conclusions & Recommendations, Non-technical, Informative & Interesting)	**Introduction** (Purpose, Scope, Background Information)	**Conclusion & Recommendations** (Inferences & Evidence – Further Work & Reasoning)	**Written Presentation** (Length, Font, Key Sections, Supporting Sections)
8 points each a. Very thorough discussion of Physics, Math and/or Engineering concepts b. Very complete description of experimental/testing procedures including diagrams or pictures c. Thorough description of analysis tools used d. Highly relevant tables, graphs, charts, etc. e. Very clear explanation of results w/graphics	4 points each a. Length: <250 words b. Very clearly restates Purpose & Key Features of report c. Very clearly restates Conclusions and Recommendations of report d. Written very clearly in non-technical terms e. Engages and informs the reader	5 points each a. Purpose: Very clearly states why project undertaken AND why report developed b. Scope: A very thorough description of parameters, methods, limiting factors & technical terms c. Background: Share key facts, conditions, events prior to project AND previous work on this topic	7.5 points each a. Conclusion: Inferences follow very logically from discussion evidence No new material included b. Recommendations: Further work/best solution well identified Written in first person w/ active verbs	2 points each a. Length: 5-15 pages (cover & title page) b. Font: 12, Times New Roman c. Spacing: double spaced d. All Key Sections included: Title page, Abstract, Contents, Introduction, Discussion, Conclusion, Recommendations e. All Supporting Sections included: References, Acknowledgments, Appendix
6 points each a. Effective discussion of key concepts b. Effective description of procedures including diagrams or pictures c. Good description of analysis tools d. Tables, graphs, charts, etc. useful to report e. Good explanation of results w/graphics	3 points each a. Length: Slightly over length b. Good restatement of Purpose/Key Features c. Good restatement of Conclusions & Recommendations d. Well written, but includes some technical terms e. Modestly engages and informs reader	4 points each a. Effective/complete statement of purpose b. Effective statement of scope, 1 or 2 items appear missing or overlooked c. Effective and complete background details, 1 or 2 items appear missing or overlooked need more description of previous work	6 points each a. Conclusion: Inferences follow loosely from discussion evidence No new material included b. Recommendations: Further work/best solution not well identified	1½ points each a. Length: Slightly over or under length b. Font: Some inconsistency throughout c. Spacing: Some inconsistency throughout d. 1 Key Section not identified or missing e. 1 Supporting Section not identified or missing
4 points each a. Limited discussion of key concepts b. Limited description of procedures, with few diagrams or pictures c. Analysis tools poorly described or not used d. Graphics not well used to support report e. Very little discussion of results, no graphics	2 points each a. Length: too short b. Poor restatement of Purpose or Key Features c. Poor restatement of Conclusion or Recommendations d. Many technical terms e. Uninteresting to reader	3 points each a. Incomplete statement of purpose for project and report b. Incomplete statement of scope, multiple items missing or overlooked c. Limited background information included	4 points each a. Conclusion: Inferences follow poorly from discussion, evidence not clear Some new material included b. Recommendations: Further work/best solution not well identified	1 point each a. Length: too short/long (cover & title page) b. Font: very inconsistent throughout c. Spacing: very inconsistent throughout d. 2-3 Key Sections not identified or missing e. 2 Supporting Sections not identified or missing
2 points each a. Little or no discussion of key concepts b. Little or no description procedures c. Data analysis not included d. Graphics do not support report e. No discussion of finding/results	1 point each a. Length: >250 words b. Purpose or Key Features not included c. Conclusion or Recommendations not included d. Does not engage reader	2 points each a. Very poor statement of purpose for project b. Very poor statement of scope, very little information included c. Very poor background provided, very little information provided	2 point each a. Conclusion: Inferences do not follow from discussion or evidence present new material included b. Recommendations: Further work/best solution not identified	½ point each a. Length: <5 pages or >15 page b. Font: incorrect throughout or not typed c. Spacing: incorrect throughout d. Most Key and Supporting Sections not identified or missing
Score 28 /40	Score 18 /20	Score 13 /15	Score 15 /15	Score 10/10
Judge	[redacted]		Total	84

Judge Feedback (optional):

MS-6

MESA

TECHNICAL PAPER SCORING CRITERIA

[redacted] MESA USA National Engineering Design Competition

TEAM: [redacted] SCHOOL: [redacted] LEVEL: MS or HS

Discussion (Physical Phenomena, Experiment Procedures, Data & Analysis, Tables & Charts, Results)	Abstract (Length, Purpose & Key Features, Conclusions & Recommendations, Non-technical, Informative & Interesting)	Introduction (Purpose, Scope, Background Information)	Conclusion & Recommendations (Inferences & Evidence -- Further Work & Reasoning)	Written Presentation (Length, Font, Key Sections, Supporting Sections)
8 points each a. Very thorough discussion of Physics, Math and/or Engineering concepts b. Very complete description of experimental/testing procedures including diagrams or pictures c. Thorough description of analysis tools used d. Highly relevant tables, graphs, charts, etc. e. Very clear explanation of results w/graphics 8	4 points each a. Length: <250 words b. Very clearly restates Purpose & Key Features of report c. Very clearly restates Conclusions and Recommendations of report d. Written very clearly in non-technical terms e. Engages and informs the reader 12	5 points each a. Purpose: Very clearly states why project undertaken AND why report developed b. Scope: A very thorough description of parameters, methods, limiting factors & technical terms c. Background: Share key facts, conditions, events prior to project AND previous work on this topic 15	5 points each a. Conclusion: Inferences follow very logically from discussion evidence No new material included b. Recommendations: Further work/best solution well identified Written in first person w/ active verbs 15	2 points each a. Length: 5-15 pages (cover & title page) b. Font: 12, Times New Roman c. Spacing: double spaced d. All Key Sections included: Title page, Abstract, Contents, Introduction, Discussion, Conclusion, Recommendations e. All Supporting Sections included: References, Acknowledgments, Appendix 10
6 points each a. Effective discussion of key concepts b. Effective description of procedures including diagrams or pictures c. Good description of analysis tools d. Tables, graphs, charts, etc. useful to report e. Good explanation of results w/graphics 24	3 points each a. Length: Slightly over length b. Good restatement of Purpose/Key Features c. Good restatement of Conclusions & Recommendations d. Well written, but includes some technical terms e. Modestly engages and informs reader 6	4 points each a. Effective/complete statement of purpose b. Effective statement of scope, 1 or 2 items appear missing or overlooked c. Effective and complete background details, 1 or 2 items appear missing or overlooked	4 points each a. Conclusion: Inferences follow loosely from discussion evidence No new material included b. Recommendations: Further work/best solution not well identified	1½ points each a. Length: Slightly over or under length b. Font: Some inconsistency throughout c. Spacing: Some inconsistency throughout d. 1 Key Section not identified or missing e. 1 Supporting Section not identified or missing
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Score 32 /40	Score 18 /20	Score 15 /15	Score 15 /15	Score 10 /10
Judge	[redacted]		Total 90	

Judge Feedback (optional):

MS-6

8/1/2005

TECHNICAL PAPER SCORING CRITERIA

[redacted] MESA USA National Engineering Design Competition

TEAM [redacted] **SCHOOL:** [redacted] **LEVEL:** MS or HS

Discussion (Physical Phenomena, Experiment Procedures, Data & Analysis, Tables & Charts, Results)	Abstract (Length, Purpose & Key Features, Conclusions & Recommendations, Non-technical, Informative & Interesting)	Introduction (Purpose, Scope, Background Information)	Conclusion & Recommendations (Inferences & Evidence – Further Work & Reasoning)	Written Presentation (Length, Font, Key Sections, Supporting Sections)
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Score 30 /40	Score 20 /20	Score 15 /15	Score 8 /15	Score 10 /10
Judge	[redacted]		Total	83

Judge Feedback (optional): on report

14

MS-6

Multi-Purpose Vehicle
Technical Paper

[redacted]

Tucson, Arizona

[redacted]

[redacted]

MS-6

Abstract

Building a mousetrap vehicle required careful research, creativity, intelligence, the ability to manage difficult tasks, and the ability to solve problems. While conducting our research we determined that the following physical science principles applied to the creation of the vehicle: Newton's three laws, aerodynamics, friction, kinetic and potential energy. Research was conducted to determine what we would need to change in order to improve our vehicle design.

Once the design was completed the vehicle was tested. We first tested our vehicle on a 30°incline to test its power. The power test was to evaluate how high the vehicle would climb. We then tested the vehicle on how fast it could travel across a 10m track while staying within the 2m boundary. The results were instrumental in determining how to redesign the vehicle.

Releasing the arm moved the vehicle forward. Two wheels were made from compact disks to minimize the amount of energy needed to compensate for the friction created. A small axle to a large wheel ratio will cover more distance per turn of the axle and the speed is increased through the use of a short lever arm, which gives greater acceleration.

Our results showed that in order to achieve both speed and power a good design would need to be constructed to reduce friction and increase energy. The recommendation would be to build a mousetrap vehicle that would be light and fast enough to complete 10m and have the ability to climb a 30° incline.

Table of Contents

Introduction

Purpose

The purpose of this project was to design a multi-purpose vehicle, powered by a single, standard sized mousetrap that demonstrated both speed and power. We used a 30° incline to test our vehicle's power and how high the vehicle could climb. We used a 10m by 2m track to test the vehicle's speed and distance. We utilized this information to maximize the vehicle's performance.

A number of variables had to be considered in order to find the best balance so maximum performance could be achieved. The knowledge gained through research and experimentation was used to build the best machine possible.

Scope

After research was conducted, we began designing our vehicle. During the building phase, we tested the vehicle to determine what configuration worked best. As a result of our trial and error method, we refined the design of our vehicle to travel faster and climb higher. We did this by making our vehicle lighter but sleeker. We used balsa wood in the construction of our vehicle because we found it to be durable and lightweight material. In our study we used a single, standard sized mousetrap. We did not use any other source of energy to produce power for our vehicle. Our vehicle was to complete the 10m speed track, without going out of bounds and in the least amount of time. Additionally, our vehicle was to climb a 1.2m by 2.4m ramp. This ramp was angled at 30°. These tests will show how the vehicle did in the trial runs before and at the regional competition.

Background Information

The fact that our vehicle was limited to using the energy produced by the springing of the mousetrap mechanism proved to be the focal point of our experiment. Potential energy had to be changed into kinetic energy. This would mean that the starting energy should be turned into work. Work overcomes frictional forces against the vehicle. Friction is an important part of this vehicle. If you have too much friction the vehicle will not travel as far, resulting in less speed. Less friction will result in a vehicle that will travel further at a much faster rate of speed. The largest amount of friction is rolling friction. Travel distance is equal to the starting energy divided by the force of rolling friction. The less rolling friction there is the greater the distance the vehicle should travel.

One person on our team had prior knowledge on how to build and construct a mousetrap vehicle, having competed the previous year. By conducting more research, the entire team came together and redesigned several vehicles to produce a more efficient mousetrap vehicle.

<u>Discussion</u>

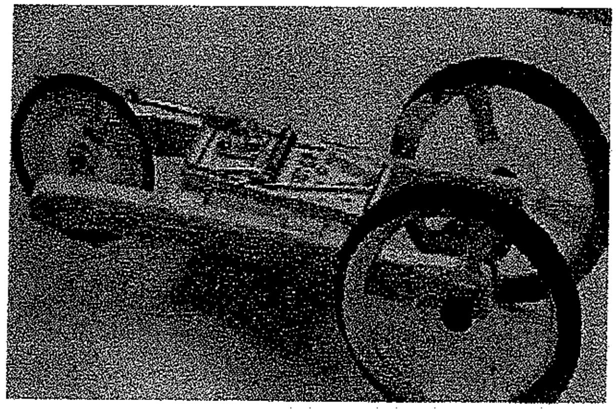
Discussion of Physical Phenomena Related to the Project

Before building began a discussion of the purpose was necessary. The vehicle powered only by a mousetrap that needed speed and power to climb. What we needed to make the vehicle move was, energy. Potential energy means the stored energy, this is the set mousetrap. Kinetic energy is the energy of motion, this is started when the mousetrap is sprung, and sets the vehicle in motion. We turned potential energy into kinetic energy by springing the mousetrap.

Any vehicle in motion produces friction, which is a force that opposes the motion of the object. Friction decreases the motion resulting in a slower moving vehicle, and impedes friction from climbing a 30°incline. Kinetic energy was increased by reducing friction. In our research, we found that there are two types of friction. There is surface friction and fluid friction. Surface friction is determined when two objects rub against each other. Fluid friction is air resistance. This is the air pushing on the vehicle. Depending on the materials we used in the construction of the vehicle determined the amount of air resistance. If the speed increases, the fluid friction is increased. Our research demonstrated that the most friction is found between the axle and the mounts. To reduce the friction in this area, we designed a lightweight, sleek model. By doing this, we reduced the amount of fluid friction. Fluid friction was reduced because there was not as much surface area for the air to push the vehicle. We reduced surface friction by using ball bearings attached to the back axles. For the front axle, we used neodymium magnets that also reduced friction immensely.

A type of surface friction is traction. We needed traction to keep our wheels from spinning. We did not want our vehicle to waste all its kinetic energy so we used parts of cut out balloons to attach to the wheels. The balloons gave our car traction and grip so that the wheels would not spin.

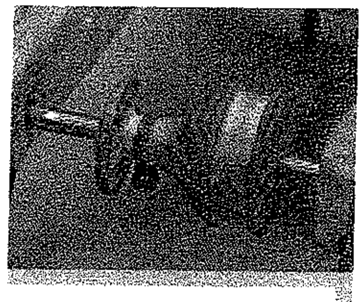
Our wheels are made out of CD's. Aerodynamics takes place in the structure of the wheels. We needed narrow and thin wheels to let the air pass through. This is why we chose to use CD's for our wheels. We used two standard sized CD's on the back of our vehicle and one small CD on the front of our car. After completing the research we concluded that the CD's provided less weight and less fluid friction, resulting in greater speed and better climbing ability. (See Figure 1)



Vehicle Figure 1

Experimental Procedures and Test Setup

We wanted to make our car go 10m in less then 5 seconds and be able to climb 85 cm. To test our vehicle, we went to the [redacted] gym and measured out a 2m by 10m testing area. We set up a 30° incline according to the competition guidelines. In the making of the vehicle, we made a heavier model that was not very fast and could not make a practical distance for the climb. So we examined the data and the vehicle to see what was preventing the vehicle from climbing a reasonable distance. We came to the conclusion that there was not enough torque, and not enough pull from the mousetrap. Also, the body of the vehicle was very heavy. We realized that we had to a make a smaller pull arm on our mousetrap. By doing this it went significantly faster but did not solve the problem of climbing. We still needed more torque. When the smaller pull arm did not make our vehicle climb we went back to our research. We concluded that our vehicle's axle was too small. Our research indicated that a larger axle was needed. We established that we needed to make a transmission. Our transmission is a large bobbin connected to the back axle. The transmission gradually got smaller. The smaller part of the transmission was created to maintain speed. The larger part of the transmission was made to provide more torque. (See Figure 2) The torque created by transmission allowed the vehicle to climb the incline. We tested our vehicle on the 30° incline. Our first test showed that the vehicle was able to climb.



Transmission Figure 2

Data Reduction, Analysis tools, and Models

After we completed all our trails, we recorded it and examined the data. The distance was divided by the time the vehicle traveled and distance to compute the rate, or speed, of the vehicle. The data obtained by graphing the results helped us make necessary changes to the vehicle's performance.

Manipulated Data

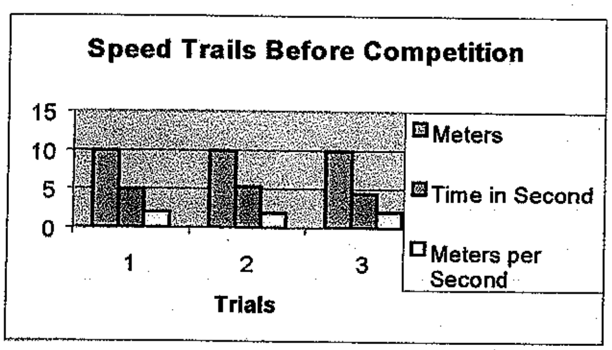


Figure 3

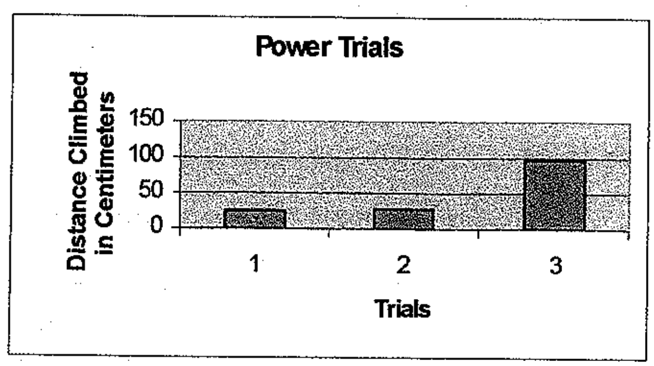


Figure 4

Results

From the tests and research conducted, the vehicle will have no problems competing in the speed trials. All criteria were met using the stated parameters. Also, the vehicle should have no problems in completing in the power trials. Since none of the other vehicles completed the speed trials and power tasks, we were able to receive first place in the Southern MESA regionals. At the regional competition our vehicle was unable to finish the 10m because there was fault in the wrapping of the string. Despite the unfortunate events of the speed trials the vehicle was able to climb. The results of the power event are depicted in the graph below.

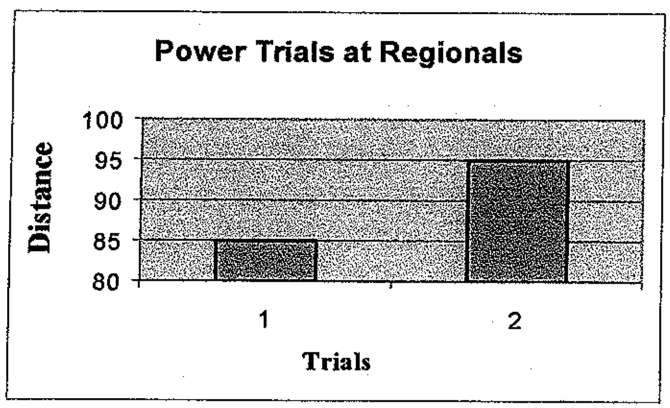


Figure 5

Conclusions

The results of our experiment demonstrated the difficulty and effort required to build a mousetrap vehicle that would demonstrate both speed and power. Our design was made to create the least amount of friction, travel 10m, and climb the greatest distance up the ramp without encountering any problems. We used narrow CD's, neodymium magnets and ball bearings. We used a small and a lightweight body on the vehicle in an effort to reduce friction. We used the balloons to prevent the wheels from slipping and losing energy. Our research helped us achieve a better design of a mousetrap vehicle. Our data guided us in modifying our vehicle, and applying different scientific principles in order to gain top speed and power.

Recommendations

Our vehicle could always use more enhancements. Additional research and experiments will be conducted. We want our vehicle to demonstrate superior power and speed. To achieve our goal, we will make the vehicle lighter by making the car smaller and more aerodynamic. A covering might be used to protect the arm from rubbing against the wheel. The arm of the mousetrap could be made longer. The position of the mousetrap on the vehicle may be adjusted to find the ideal location for speed and power.

Tests will need to be conducted and the results measured.

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Leonard Bernstein, Martin Schachter, Alan Winkler, Stanley Wolfe. (1998) Concepts and Challenges in Physical Science. Upper Saddle River, New Jersey. Globe Fearon.

E.L. Thorndike/ Clarence L. Barnhart. (1983) Scott Foresman Advanced Dictionary. Scott Foresman and Company.

Balmer, Alden J. (2002). Doc Fizzix's Mousetrap Powered Cars & Boats. Round Rock, Texas. Doc Fizzix Publishing Company.

Acknowledgments

We would be pleased to acknowledge the following people for their support, help and advice;

[redacted] Raytheon volunteer; [redacted] and [redacted] MESA Organizers; and

[redacted] MESA Volunteer

Appendix

We found that the vehicle uses inertia, kinetic energy, potential energy, friction, acceleration, torque, velocity, traction, aerodynamics, and all three of Newton's Laws. We have defined these terms for this research:

1. Kinetic Energy - of or relating to the motion of material bodies and their forces and energy
2. Potential Energy - energy an object has because of its position or nature or the arrangement
3. Friction - a force that resists motion or tendency to such motion of two bodies in contact
4. Newton's First Law - every object at rest or in motion, will remain in that state, unless acted upon by an outside force
5. Newton's Second Law - unbalanced forces acting upon an object is equal to the mass of the object times its acceleration. It is measured in Newtons.
6. Newton's Third Law - for every action, there's an equal and opposite reaction
7. Aerodynamics - Science dealing with the forces acting on bodies in motion
8. Traction - friction between a body and a surface on which it moves, enabling the body to move without slipping
9. Torque - force causing rotation or torsion
10. Acceleration - change in speed or direction
11. Velocity - speed and direction
12. Drag - pull along heavily or slowly

1st Trial Run for Speed

	Distance (Meters)	Time (Seconds)	Rate or Speed (Meters per second)
1st Run	10	5.0	2
2nd Run	10	5.3	1.9
3rd Run	10	4.5	2.1

2nd Trial Run for Speed

(At Regionals)

	Distance (Meters)	Time (Seconds)	Rate or Speed (Meters per second)
1st Run	0	0	0
2nd Run	0	0	0

1st Trial Run for Power

Distance Climbed

(In Centimeters)

1st Run................26

2nd Run..............29

3rd Run................97

2nd Trial Run for Power

(At Regionals)

1st Run..............95

2nd Run..............93