

LESSON: Space Capsule Drop (Grades 6-8)

+ OVERVIEW



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In this design challenge, students will learn about space capsules and why they are used instead of shuttles. Students will also design a space capsule for an upcoming flight. The students will be presented with the following problem: “LU-X is looking to get involved in the space tourism business. However, they have mainly focused on designing shuttles rather than space capsules. LU-X is now in the process of developing space capsules that are safe for human flight and can be reused to keep costs down.” Students will put on their engineering hats to build a space capsule that can protect the astronauts inside. Students will engage in a STEM challenge to design a space capsule that is able to land on a target safely. Bonus points will be awarded to those who wish to push their designs to land within the targeted landing zone in windy conditions safely.

+ 2021 Science TEKS covered in this design challenge

Grade 6 TEKS: 6.1.B, 6.1.E, 6.1.G, 6.2.D, 6.7.A

Grade 7 TEKS: 7.1.B, 7.1.E, 7.1.G, 7.2.D, 7.7.A, 7.7.D

Grade 8 TEKS: 8.1.B, 8.1.E, 8.1.G, 8.2.D, 8.7.B

+ Math TEKS covered in this design challenge

Grade 6 TEKS: 6.3.D, 6.3.E

Grade 7 TEKS: 7.3.A, 7.3.B, 7.4.A

+ 2022 Technology Applications TEKS covered in this design challenge

Grade 6 TEKS: 6.3.A, 6.3.B, 6.3.C

Grade 7 TEKS: 7.3.A, 7.3.B, 7.3.C

Grade 8 TEKS: 8.3.A, 8.3.B, 8.3.C

+ The students will be able to:

- > Identify and describe the changes in position, direction, and speed of an object when acted upon by unbalanced forces
- > Calculate average speed using distance and time measurements
- > Investigate and describe applications of Newton's three laws of motion
- > Describe the future of space exploration, including the types of equipment and transportation needed for space travel
- > Identify the accommodations, considering the characteristics of our solar system, that enabled manned space exploration
- > Identify and explain how forces act on objects
- > Analyze the effect of balanced and unbalanced forces on the state of motion of an object using Newton's First Law of Motion
- > Solve a problem using the engineering design process
- > Represent constant rates of change in mathematical and real-world problems given pictorial, tabular, verbal, numeric, graphical, and algebraic representations, including $d=rt$

+ Students will use the following STEM fluency skills:

- > Communication
- > Collaboration
- > Creativity
- > Critical Thinking
- > Resilience
- > Time/Resource Management
- > Innovation
- > Adaptability

+ Materials needed for this design challenge:

- | | |
|------------------------------|-----------|
| > Bubble Wrap (sheet) | \$75,000 |
| > Scissors | \$100,000 |
| > Tape (4 inches) | \$50,000 |
| > Glue | \$100,000 |
| > Construction Paper (sheet) | \$75,000 |
| > Foam Board (sheet) | \$75,000 |
| > Newspaper (sheet) | \$75,000 |
| > Cotton Ball | \$10,000 |
| > Popsicle Stick | \$10,000 |
| > Chenille Stick | \$10,000 |
| > String (4 inches) | \$50,000 |
| > Plastic Shopping Bag | \$10,000 |
| > Paper Cup | \$10,000 |
| > Straw | \$10,000 |
| > Rubber Band | \$50,000 |

+ Materials needed by the facilitator:

- > Projector and computer
- > Internet access or [downloaded video](#)
- > Slide deck for the lesson
- > Copies of the scorecard for each group
- > Fan with multiple speeds
- > Timing device
- > Legos + Astronaut
- > Shock indicator labels
- > Masking tape to mark the landing zone
- > Stool or ladder to safely stand on for the test
- > Tennis ball
- > Lacrosse ball
- > Digital scale

+ FACILITATION GUIDE

SECTION	PROCEDURE
INTRODUCTION	<p>Slide 1: Space Capsule Drop</p> <p>Slide 2: Newton's Laws of Motion</p> <ul style="list-style-type: none"> > Ask students if they know Newton's Laws of Motion. Ask for examples. <ul style="list-style-type: none"> ▪ Newton's First Law: An object in motion will remain in motion until actioned upon by an outside force. This means an object will either stay at rest, not move, or move in a straight line at a constant speed unless something causes it to change. Demonstrate this law to students by dropping a tennis ball. Ask students what was the outside force that stopped the tennis ball (The floor). ▪ Newton's Second Law: This is the mathematical formula: force equals mass times acceleration, $F=ma$. The second law states that acceleration occurs when an external force acts on the object. The greater the mass, the more force is needed to accelerate the object. Remind students that acceleration is a change in speed over time. Demonstrate this law to students by using a flat surface to push a tennis ball and a lacrosse ball. Students will be able to see the difference in the amount of effort and force required to move these balls across the surface. ▪ Newton's Third Law: For every action, there is an equal and opposite reaction. When force is applied in one direction, an equal amount of force is applied back. For example, rockets. When rockets burn fuel, the force is pushed towards the ground to make the rocket go up. Demonstrate this law to students by placing a lacrosse ball on a surface. Roll the tennis ball into the lacrosse ball and observe what happens. <p>Slide 3: What is a Space Capsule?</p> <ul style="list-style-type: none"> > Watch a brief video on space capsules. Recap with students on why engineers are using space capsules instead of shuttles. <ul style="list-style-type: none"> ▪ What are the advantages of using space shuttles? <ul style="list-style-type: none"> • These are reusable and can be operated more similarly to an airliner. They can land, be refueled and loaded with cargo, and quickly depart for their destination. ▪ What are the advantages of using a space capsule? <ul style="list-style-type: none"> • These are simpler and are a safer design as they are equipped with a crew ejection system. They are also less expensive than shuttles.

- What do you think is the most important factor for going back to space capsules?

Slide 4: Engineering Design 1

- > Ask students the question. What is engineering?
 - Explain to students that engineering is when engineers take what they know and apply it to solve problems by designing a product or process.
 - For example, phones could only be used at home or in specific locations. Why is this a problem? (Needing to make a call outside the home). What solution did engineers design to fix that problem? (Cell phones).
 - *Teacher's Note: Any example can be used here, but focus on examples that students are familiar with.*

Slide 5: Engineering Design 2

- > Ask students the question. What are some examples of engineering jobs?
 - *Teacher's Note: If students have trouble giving examples, ask students who they think makes the things they use. Who makes refrigerators, cars, helmets, cell phones, and sneakers?*

Slides 6-8: Engineering Jobs 1-3

- > Show students pictures related to engineering jobs connected to the challenge.
- > Aerospace Engineering
 - Ask students what they see in the pictures.
 - The people who work on spacecraft and similar machinery are called aerospace engineers. They design and build space capsules, rockets, satellites, etc., and improve safety for travel.
- > Software Engineering
 - Ask students what they see in the pictures.
 - The people who design the apps and video games used on devices like smartphones, tablets, laptops, and computers are called software engineers. They work to make devices more effective for users by designing new apps and writing code.
- > Chemical Engineering
 - Ask students what they see in the pictures.
 - Chemical engineers use their knowledge of chemistry to develop products that improve our lives. Chemical engineers help to develop the precise blend of chemicals needed for spacecraft fuel. Chemical engineers work in manufacturing, pharmaceuticals, healthcare, construction, food processing, electronic and advanced materials,

business services, biotechnology, and environmental health and safety industries, among others.

Slide 9: Engineering Design 3

- > Ask students the question: who can be an engineer?
 - Anyone!

Slide 10: Engineering Design Process Steps

- > Ask students if they think all engineers solve their problems in one try. Explain to students that it takes many tries to get something correct in engineering. In engineering, there is no such thing as a mistake; there are only opportunities to learn. It is okay to fail. Just find the mistake and correct it. In engineering, there is never one correct solution. There are always many solutions to a problem and always improvements that can be made. The steps that engineers take to find these solutions are called the *engineering design process*.
- > Ask students to read the first big step (Identify).
 - What does identify mean? (To point out or find). Engineers design solutions: what do they need to know first before they can find the answer? (The problem)
 - How do people know when they have found the correct answer? In engineering, there are no correct answers, just better ones. Explain to students that there are expectations that engineers must meet called *criteria*. For example, when engineering a football, what does a football need to do? (Bounce, look a certain way, have laces, have air inside, etc.). Those things are all called criteria. By comparing the design to the criteria, an engineer knows a solution will work. Is a child-sized football the same as an adult football? The criteria for both footballs include leather, the white laces for fingers, and the shape. However, the two footballs would have different criteria for the size. The footballs are similar but different because of different criteria.
 - Once the criteria are understood for the design challenge, what could make it difficult for an engineer to design their solution? (Money, time, materials, etc.) Explain to students that these rules are called *constraints* or rules that engineers must follow. Engineers are given constraints they must follow when finding the solution to a problem. Think about football again. What are college and professional footballs made from? (Leather). What if instead, the rule (or constraint) was not to use leather, could another type of

	<p>football be made instead? Many of the footballs for sale are made of rubber because the engineer had different constraints.</p> <ul style="list-style-type: none"> > Ask students to read the next step (Imagine). <ul style="list-style-type: none"> ▪ Ask students what imagine, or imagination, means. Are these things real or tangible? They may not be real, but they help give us ideas about what things could be. In this step, see what materials are available, then brainstorm or think about possible ideas/solutions to the problems. ▪ Explain to students that there are no right answers in engineering. Start with as many ideas as possible. > Ask students to read the next step (Plan). <ul style="list-style-type: none"> ▪ The third big step of the engineering design process is to plan out the idea. Make sure that what is designed can be repeated. A plan will help an engineer identify where mistakes happen so they can be fixed. ▪ When planning, begin with the brainstorming phase. Each team member will contribute their ideas, and then the team combines the different ideas! ▪ Once ideas are combined into a single group idea, determine what materials will be used for the solution and make sure the design has met the criteria and constraints of the project. > Ask students to read the next step (Create). <ul style="list-style-type: none"> ▪ The fourth step is to create! Since this is the very first creation, it is called a <i>prototype</i>. A prototype is a first or preliminary model of something from which other forms are developed or copied. A prototype is created to test the engineer's idea or concept. Engineers ask themselves, "Did the idea work the way we wanted it to?" After testing the idea, the engineer will make improvements to the prototype. > Ask students to read the last step (Improve). <ul style="list-style-type: none"> ▪ Finally, the last step is to improve. How does an engineer know if the prototype did well on the test? It must meet certain expectations and follow some rules. But how do engineers determine how well it met the expectations and how well it followed the rules? In school, how do you know if you mastered something? (Grades). The prototypes made today will be scored using a scorecard or rubric. By looking at the score, each team will determine if the design could be better. If improvements should be made, then the team will revisit the plan and decide what to do to improve the score. Remember, there are no correct answers in engineering, just better solutions.
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IDENTIFY

Slides 11-12: Identify – Problem

- > Have students read the bolded section.
 - Ask students to *identify the problem*.
- > Explain to students that they will put on their engineering hats to design a space capsule that is safe for astronauts and reusable.

Slide 13: Identify – Criteria (Desired Outcomes)

- > Ask students what criteria or desired outcomes mean.
 - Explain to students that criteria are what engineers use to determine if they have successfully solved the engineering problem.
- > Ask students how we will know if we are successful engineers today.
 - A successfully designed capsule will include the following:
 - A seat for the astronaut
 - A mechanism to keep the astronaut in their seat
 - Impact dampening systems so that the capsule does not experience more than 15 g of force on impact
 - A mass under 48 grams
 - Ability to be reused in future drops

Bonus points will be awarded if the space capsule can land on the target in windy conditions (fan speed set to low or 1)

- *Teacher's Note: Let students see and/or feel fan speed set to low or 1.*

Slides 14-15: Identify – Constraints (Limitations)

- > Ask students what constraints or limitations mean.
 - Explain to students that constraints are the rules the engineers must follow.
- > Explain the constraints for this engineering design activity are the following:
 - Time Limit: Students will have 30 minutes to design their space capsule.
 - Materials: Students may only use the available materials.
 - Budget: Students will have \$1,000,000 to complete this challenge.
 - *Teacher's Note: If play money is available, we recommend using it. Monetary values may feel too abstract for students, so providing something more tangible will help. The budget is set for \$1,000,000 but can be lowered to \$100,000 and material cost can be divided by 10.*
 - Collaboration: One design element from each team member must be used in the final design. Explain to students that a design element is taking one part of someone's idea and adding it to another.

	<ul style="list-style-type: none"> ▪ Redesign: Each team can test their prototype as many times as needed during the 30-minute design phase. Remind students what a prototype is. It is the first creation of our design. <ul style="list-style-type: none"> • <i>Teacher's Note: When a team is ready to test their design, they should raise their hand and the teacher should assist the team with their score. If the team receives a low score on any part of the design, the team should redesign if they still have time.</i>
IMAGINE	<p>Slide 16: Identify – Explore Materials</p> <ul style="list-style-type: none"> > Students will be provided a Lego foundation for their shuttle and astronaut. They will have a choice of various materials to build their space capsule that can absorb the impact of landing and protect the astronaut inside. Space capsules will be tested with a drop from 2 meters above the landing zone. The landing zone will be one square foot. Bonus points will be given to teams who have their space capsule land in the landing zone under windy conditions. Windy conditions are defined by a fan set to low speed on either side of where the space capsule will be dropped. There should be no obstruction between the space capsule and the fan. <p>Slide 17: Imagine – Brainstorm</p> <ul style="list-style-type: none"> > Give students one minute to individually design and draw a plan of what they think their space shuttle should look like. Emphasize that students should not talk during this minute or share ideas. Remind students their ideas will be used as design elements for the final design. > After a minute, give students five minutes to present and share their ideas with their group. Let students know that they should focus on key aspects of their idea that they like and want to be used as design elements for the final design when sharing. <ul style="list-style-type: none"> ▪ <i>Teacher's Note: If students are struggling with an idea for their design, provide ideas without giving the solution. For example, "This is a design that I tried earlier, but it failed. What could I do to improve it?" Emphasize that the design failed to reinforce that it is okay to fail and to let students know they cannot copy the design and expect success.</i>
PLAN	<p>Slide 18: Plan – Gather Materials</p> <ul style="list-style-type: none"> > Hand out the scorecard that will be used during the design challenge. Review the testing criteria with the class and answer questions. The testing criteria will inform their design decisions. > Have students collaborate to come up with a final design. Let students know they must include at least one element from each team member for their final design. > Ask students again what the design criteria are: <ul style="list-style-type: none"> ▪ A successfully designed capsule will include the following:

	<ul style="list-style-type: none"> • A seat for the astronaut • A mechanism to keep the astronaut in their seat • Impact dampening systems so that the capsule does not experience more than 15 g of force on impact • A mass under 48 grams • Ability to be reused in future drops <p>Bonus points will be awarded if the space capsule can land on the target in windy conditions (fan speed set to low or 1)</p> <ul style="list-style-type: none"> > Students will need to select the materials to be used for the design and develop a budget for the project. Students will have \$1,000,000 to “purchase” materials for their build at the classroom supply table. The prices used in this challenge can be found in the materials list. Students will raise their hands when they are ready to purchase materials. The teacher will make sure the appropriate amount of money is spent to purchase each material but will not guide students on following their budget. Students can go over budget, but remind them that they will lose points on their scorecard. <p>Slide 19: Plan – Team Member Responsibilities</p> <ul style="list-style-type: none"> > Each team member must be given responsibility, such as materials manager, banker, head engineer, and quality control manager.
<p>CREATE</p>	<p>Slide 20: Create – Design Your Capsule</p> <ul style="list-style-type: none"> > Let students know to have fun, be creative with their designs, and work together. > Remind students that being an engineer is not about getting the solution on the first try. There is no right answer, just better solutions. <p>Slide 21: Identify – Criteria</p> <ul style="list-style-type: none"> > Display the reminder slide for students to look at while working. <p>Slides 22-23: Create - Test</p> <ul style="list-style-type: none"> > Students will calculate their scores when testing in front of the teacher. The teacher will go through each of the categories on the scorecard with the students. The students will mark their scores and calculate the total. > The teacher will recap the point total with the students and how many points the team received for each category to make sure it matches with what the students recorded. > Students should record how long it takes their capsule to drop from 2 meters and record the time on page two of the rubric. Students will calculate the speed of their capsule by using the speed formula. Students will then look at their results and find the relationship to the color on the force indicator attached to the astronaut. They will use this information during the redesign portion of the engineering design process.

IMPROVE

Slide 24: Improve - Redesign: Discussion

- > Students will reflect on their scores and discuss:
 - What worked?
 - *Teacher's Note: Focus on the materials being used and ask why they think those materials were helpful. Ask students what characteristics of the materials allowed for a safe space capsule.*
 - What did not work?
 - *Teacher's Note: Focus on the materials being used and ask why they think those materials did not work as well. Ask students what characteristics of the materials made the space capsule less safe.*
 - What do you want to improve?
 - *Teacher's Note: Focus on engineering aspects with students. Ask students why they were designing a space capsule. Ask students if they found a solution or just part of one. Reinforce that it is okay to not succeed on the first try and that engineering is about making improvements over time. Ask students how they would design their capsule differently if they had no rules. Ask students if working together was difficult. Learning to work together is very important, and it is easier to find a solution with many ideas rather than just one idea.*
- > Ask students about the average speed they calculated. Have students share their results to determine what speed range will allow for their design to be successful.
- > Have students redesign their capsule using the information they gathered on page two of the rubric. Remind them to redesign and aim for the speed range determined by the data gathered in class.