Facilitator Instructions
Safety

Safety, an important issue for all curricular areas of education, is of special concern for STEM-based activities and courses. Many national and state academic standards address the need for schools and subject areas to promote development of student knowledge and abilities in a safe learning environment.

School administrators, teachers, and facilitators are responsible for providing a learning environment that is safe, suitable, and supportive for all laboratory work. Facilitators are also responsible for their students’ welfare in the classroom and laboratory.

Facilitators should

- Approve all drawings before students start building their designs.
- Look for flimsy structure designs and potentially hazardous combinations of materials.
- Ensure that resources are clean and dry, with no sharp edges exposed.
- Make sure all materials are undamaged and in good repair.
- Prohibit students from bringing in or using additional materials for their designs without prior approval.
- Maintain a safe environment at all times.

Students should

- Make safety a priority during all activities.
- Wear safety goggles when conducting all investigations and the challenge.
- Demonstrate courtesy and respect for ideas expressed by others in the group.
- Use tools and equipment in a safe manner.
- Assume responsibility for their own safety and the safety of others.
- Follow instructions carefully and completely.

Classroom Management Tip

To help with safety management and materials, students could create and sign a pledge that they will abide by the safety rules listed on this page.

An example of a safety commitment from students:

"I have read and understand the safety rules. I agree to follow these rules for my safety, the safety of my teammates, and the safety of the whole group."
Recommended Materials

The following equipment and building materials are required to complete this challenge. The quantity will depend on the number of students participating. Alternatives and additional materials can be used if desired, but be mindful of safety when allowing students to bring in or handle materials that could potentially be dangerous.

Each team will require the following items:

- Digital scale or balance
- Measuring tape that includes metric units
- Rulers that include metric units
- Stopwatch
- Small sealable plastic bag to hold cargo inside capsule
- Weights, such as a penny or washer to serve as mass
- Hole reinforcements or stickers with holes
- Each team should have a copy of the Cargo Bay Template provided in this guide. It can be copied on any weight of paper, but all copies need to be the same paper weight.

Examples of additional building materials that may be used:

- Balloons
- Binder clips
- Bubble wrap
- 16-ounce clear drinking cups
- Cardstock
- Craft sticks, lollipop sticks, or tongue depressors
- Clothespins
- Cloth
- Coffee filters
- Cotton balls
- Glue
- Heavy-duty aluminum foil
- Magnifying lenses and mirrors
- Manila folders
- Miniature aluminum foil pie plates
- Modeling clay
- Paper (copier, construction, and waxed)
- Paper bags
- Paper towel tubes
- Plastic eggs
- Plastic wrap (clear and colored)
- Polystyrene cups
- Poster board
- Rubber bands
- Skewers
- Staplers and staples
- Tape (packing, duct, masking, and transparent)
- Yarn
- Washer

Figure 5. Household supplies that could be used as construction materials for the challenge.
Team Building

Teamwork and collaboration are important 21st century skills for students to practice. The following exercises are recommended to help teams begin to work together effectively. There is a page in the Student Journal to go along with this activity.

Begin by dividing students into teams of no more than four to give all students an opportunity to contribute. By working as members of a team, students develop skills such as trust, cooperation, and decision making.

**Establish a team name.** Many NASA teams are named based on the work they do.

**Design a mission patch.** Teams that work on NASA missions and spacecraft are unified under a mission patch designed with symbols and artwork to identify the group’s mission.

**Create a group motto.** This is a short inspirational sentence or phrase that describes the core goal of the team’s work. NASA’s current vision statement is “To discover and expand knowledge for the benefit of humanity.”

**Suggested Team Roles**

As students begin to work together, their individual strengths will become apparent. Students can volunteer or be assigned tasks or responsibilities that are vital to completing the challenge. Team jobs can be rotated throughout the team to give team members an opportunity to experience the different types of engineering and to improve their team skills. The following list includes examples of jobs that student teams will need to complete. Feel free to come up with others, and remember that all team members should serve as builders and engineers for the team.

**Design engineer.** Sketches, outlines, patterns, or plans the ideas the team generates

**Technical engineer.** Assembles, maintains, repairs, and modifies the structural components of the design

**Operations engineer.** Sets up and operates the prototype to complete a test

**Technical writer/videographer.** Records and organizes data and prepares documentation (text, pictures, and/or video) to be reported and published

**Classroom Management Tip**

Spending time on this activity will enhance student teams and contribute to 21st century learning goals of collaboration, communication, and creativity.
Mars

Mars is the fourth planet from the Sun and is about 228 million km away from it. Mars is the next planet beyond Earth and is about one-half the size of Earth. Known as the Red Planet, Mars gets its red color from the iron in its soil. Mars is very cold and has an average temperature of –62 °C (–79.6 °F), far below the freezing point of water. Its rocky and dusty red surface is covered with canyons, inactive volcanoes, and craters. Although the Martian atmosphere is considerably different than Earth’s, Mars does have clouds, wind, and dust.

Mars and Earth are very different. The gravitational pull on Mars is less than on Earth, meaning that a rock dropped on Mars would fall more slowly than a rock dropped on Earth. A person who weighs 45 kilograms (about 100 pounds) on Earth would weigh only about 17 kilograms (37 pounds) on Mars because of the reduced gravity. The atmosphere of Mars is about 100 times thinner than Earth’s. The Martian atmosphere has much less oxygen and far more carbon dioxide than the Earth’s atmosphere. It is very difficult for NASA to land spacecraft on the surface of Mars because there are fewer molecules of air for the parachute to “catch.”

How is NASA exploring Mars today?

The spacecraft orbiting Mars today use tools to collect scientific information such as the temperature and the kinds of minerals on Mars. These spacecraft take images and search for water. NASA has also landed rovers called Sojourner, Spirit, Opportunity, and Curiosity on the surface of Mars. These rovers are robots that move around taking images, conducting scientific experiments, and collecting data about the planet’s soil and rocks. NASA uses the information gathered by the orbiting spacecraft and the rovers on the planet’s surface to help determine if life could ever have existed on Mars. Curiosity is still providing images and data to NASA.
What is the InSight lander?

In November 2018, the NASA lander InSight (Interior Exploration using Seismic Investigations, Geodesy and Heat Transport) successfully touched down on Mars. InSight traveled 300 million miles (485 million kilometers) on its journey from Earth to the Red Planet, taking almost 7 months to arrive. InSight’s 2-year mission is to study the deep interior of Mars to learn how all celestial bodies with rocky surfaces formed, including Earth and the Moon.

Multimedia Resource


How will NASA explore Mars in the future?

The Mars 2020 rover mission is part of NASA’s Mars Exploration Program. The mission is seeking signs of habitable conditions on Mars and also searching for signs of past microbial life. The mission will gather information to help future human expeditions to Mars. This includes improving landing techniques; identifying resources to enable human habitation; and characterizing weather, dust, and other environmental conditions that could affect how future astronauts live and work on Mars.

Multimedia Resource

How do spacecraft land on the Martian surface?

Devices that slow down moving objects by creating drag come in many shapes, sizes, and materials. NASA has used a basic parachute design as a drag device to land vehicles on the surface of Mars since 1976, when the first Viking lander touched down.

To conduct advanced exploration missions and safely land heavier spacecraft on Mars in the future, NASA must improve the technology of decelerating (slowing down) landing vehicles. NASA is developing large, sturdy, and lightweight systems to deliver the next generation of rovers and landers on the surface of Mars. These new technologies will be able to slow down larger, heavier landers from supersonic speeds to the slower speeds that are necessary for a safe landing on Mars.

Helping Students Understand Drag

Take time to help students understand the concept of drag, as it is not something they can directly see. Drag is a force created when an object moves through air. The air pushes against the moving object, something people usually refer to as “air resistance.” Larger objects have a harder time moving through air than smaller objects. A large object has a larger surface area and creates more drag because air is pushing against the object as it moves. A small object has a smaller surface area and creates less drag because there is less air pushing against the object as it moves. This applies not only to objects like state-of-the-art racecars or airplanes, but also to people. Bike racers and skiers hunch over to try to make themselves as small as possible to reduce drag and go faster.

Ask students if they have ever put their hands out of a moving car window. If so, they have felt the force of drag pushing their hands back and forth. Ask students what they think would happen if they ran a race holding an open umbrella. Do they think it would make them go faster or slow them down? A runner would feel the force of drag on the umbrella as it moved through the air and this would slow the runner down.
Accessing Existing Knowledge

Prior to starting the engineering design challenge (EDC), it will be useful to identify students’ existing knowledge and level of understanding using a series of guided questions related to this specific challenge. This discussion will allow facilitators to tailor the challenge and the STEM Investigations to the group, maximizing the educational benefit.

The following questions provide a starting point from which additional topics may be discussed.

- Do you know what a scientist or engineer does at work?
- Do you know what an astronaut does at work?
- Where have you seen parachutes in use?
- What are some objects that create drag?

STEM Investigations

STEM Investigations are included for support prior to the EDC as students work on STEM material that may be unfamiliar to them. Facilitators can provide more assistance to students at the start of the STEM Investigations. As students become comfortable, step back to allow them to become more confident in their problem-solving skills.

Each of these investigations will help students build the STEM knowledge needed to complete the challenge. Refer back to these investigations to help students make connections from all of the experiences in this content guide.

A suggested collaborative strategy to use is Think–Pair–Share, which encourages individual participation, collaborative learning, and higher level thinking. This strategy consists of three parts:

- **Think:** Students think independently about the question that has been posed.
- **Pair:** Students are paired to discuss their thoughts.
- **Share:** Students share their ideas with the whole class.
Vocabulary Support

Engineering design challenges and the engineering design process (EDP) are concepts that may be unfamiliar to your students. Younger students may not have heard words like “criteria” or “constraints,” which are commonly associated with engineering design. **Criteria** are characteristics of a successful solution, such as a desired function. **Constraints** are limitations on the design, such as mass or funds.

- Criteria are what the design **MUST** do.
- Constraints are things the design **MUST NOT** do.

**Basic Vocabulary Words in the Challenge**

This guide includes a list of related STEM vocabulary words. While there are subject-specific vocabulary words embedded in the Student Journal, there are basic vocabulary words students should be familiar with. These words include: describe, design, evaluate, evidence, feedback, investigate, observe, model, process, research, solution, and test.

The Word Box vocabulary activity is an example of an activity to use with students who require additional vocabulary support.

### Vocabulary Activity Suggestion: Word Box

Allow students to scan through the Student Journal and highlight or underline any unfamiliar words. Discuss findings as a class. Draw students’ attention to the vocabulary words, definitions, sentences, and synonyms in the provided vocabulary list. Review with students the definition of **synonyms** (words with similar meanings) and **antonyms** (words with opposite meanings).

**Materials**

Blank paper, dictionaries

**Procedure**

1. Allow each student to pick one word from the vocabulary list to define and share.
2. Pass out the paper and direct students to fold the paper into four parts.
3. In the top left section, students will paraphrase the definition of their chosen word.
4. In the top right section, students will use their chosen word in an original sentence.
5. In the bottom left section, students will write one or two synonyms and one or two antonyms of their chosen word.
6. In the bottom right section, students will draw a visual representation of their chosen word.
7. On the back, students will write their name and the chosen vocabulary word.
8. Allow students to quiz each other on the vocabulary words, taking turns to guess at their peer’s chosen vocabulary word using the hints provided.
STEM Investigation 1: It’s a Drag

Objectives

• Students will investigate drag as a force that is created as an object interacts with air.
• Students will investigate the amount of drag created by paper of various sizes.
• Students will identify the difference between balanced and unbalanced forces.

Guiding Questions

Use the following questions as discussion prompts:

• Which of the various sizes of folded paper do you think will create more drag and fall to the ground more slowly?
• How will you apply what you learned in this investigation to your design?

Instructional Procedure

1. Prepare the materials for students.
2. Have students think about the different sizes of paper and predict what may happen.
3. Have students follow the procedures in the Student Journal.
4. Remind teams to record the results and observations on the Data Collection Sheet in the Student Journal.
5. Have students answer the questions on the Data Collection Sheet.

Student Connections

Objects fall due to gravity. In order to stop an object or slow it down, a certain amount of drag needs to be applied to oppose the acceleration. As drag increases, an object will slow its rate of fall. In this activity, students will see the effects of drag on a falling object by shaping a large sheet of paper and measuring the time it takes to fall from a fixed distance. Guide students to connect this investigation with the engineering design challenge using these discussion questions:

• What did your team discover about the size of the paper and the amount of time it took to fall to the ground?
• How do you think these ideas will connect to the challenge?

Figure 11. A drag chute helped slow down Space Shuttle Endeavour when it landed at Edwards Air Force Base in 2002. (NASA)
STEM Investigation 2: Touchdown

Objective

- Students will investigate ways to create a shock-absorbing system for a landing device.

Guiding Questions

- What kinds of systems could be used to absorb the shock of an object falling to the ground?
- How will you apply what you learned in this investigation to your design?

Instructional Procedure

1. Prepare materials for students.
2. Have student teams follow the procedures in the Student Journal.
3. Remind students that the goal is to create a shock-absorbing system that will protect the cargo inside the lander and that they may not secure the cargo with tape.
4. Make sure teams record data and observations.
5. Have students answer the questions provided on the Data Collection Sheet.

Student Connections

Teams are challenged to make a shock-absorbing system that absorbs, or softens, the transfer of energy when the lander hits the ground. The marshmallows should stay in the cup, or cargo bay, upon landing. These are concepts some students may find challenging. However, this experience can help students think about the many ways there are to solve a problem. Thinking of alternative answers helps build problem-solving skills. If students are familiar with the basic idea of gravity being a force pulling an object down, it can be mentioned in this investigation. Guide students to connect this investigation with the engineering design challenge using these discussion questions:

- What are some of the ways teams modified the lander to absorb the energy when it hit the ground? Did that protect the cargo?
- How do you think using a shock-absorbing system and a drag device would work to protect cargo when landing on another planet?
Engineering Design Process

Discuss the engineering design process (EDP) with students and explain how students will use this process to work through the engineering design challenge (EDC).

The following pages explain how each phase of the EDP relates to the challenge and how to facilitate the process with students. Explain the EDP sheets and how to use the appropriate pages for recording group ideas.

Review with students the information covered within the EDC. Using the background information, talk about current NASA missions and how those relate to this challenge. As a class, discuss the individual components of this challenge. Whenever possible, relate ideas to students’ daily lives. Check for student understanding of the words “criteria” and “constraints.”

Real-World Connection

A budgetary constraint is added as part of the EDC. Teams should use the Budget Reporting Worksheet to determine the cost of their solution.

How to Use the Budget Reporting Worksheet

- Set specific prices for the materials students will use.
- Set a specific budget for the challenge.
- Provide students with a price sheet so teams can use that list to keep track of the cost of the items for the challenge.

Differentiation Suggestions

- Facilitators may need to monitor students’ attention levels and break for more hands-on or physical activities as needed.
- Students can color code each section of their journals or use highlighters to make the informational text stand out.
- Teams can use a large whiteboard or butcher paper to create a cartoon or flowchart of the EDP as they progress through the challenge.
- Students can use sticky notes or markers to take notes of each phase and then refer to the chart when they create their presentation.

<table>
<thead>
<tr>
<th>Line Item Number</th>
<th>Material</th>
<th>Unit Cost</th>
<th>Quantity</th>
<th>Item Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>2</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>3</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>4</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>5</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>6</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>7</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>8</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>9</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>10</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td><strong>Total Cost:</strong></td>
</tr>
</tbody>
</table>
Engineering Design Challenge

The Challenge

Students will work in teams to design and construct a drag device that will slow down the cargo bay when it is dropped from a consistent height. The template for the cargo bay is in the back of this guide. Students should test the cargo bay without the drag device first, as a control test, and then test it with the device attached to show that deceleration has been achieved.

Criteria and Constraints

1. Each team must design and make a drag device to connect to the cargo bay. The device must make the cargo bay slow down when it is tested, or dropped.
2. The entire device must be deployed from 2 meters and must remain intact throughout the drop.
3. The cargo bay must hold 10 grams of cargo secured inside.
4. The overall mass must not exceed 50 grams.

Differentiation Suggestions

- Assemble the cargo bay, with the weight inside, for students.
- Eliminate, decrease, or increase the mass restriction.

Figure 14. Illustration of NASA’s InSight lander descending toward the surface of Mars with its parachute. The lander arrived on Mars in November 2018. (NASA)
Identify a Need or Problem

Engineering design begins by identifying a need or problem that an attempt can be made to solve, improve, and/or fix. This typically includes articulation of criteria and constraints that will define a successful solution.

Objectives

- Students will be able to identify the problem of this engineering design challenge (EDC).
- Students will be able to identify the criteria and constraints of this EDC.

Guiding Questions

Use the following guiding questions as discussion prompts to focus student understanding.

- What needs to be solved or improved?
- How can our team design a _____ that will _____?
- What are the things our solution must do?
- What are the things our solution must not do?

Instructional Procedure

1. Review the engineering design process with students.
2. Ask student teams to read the challenge and discuss within the team.
3. Ask students to identify the specific criteria and constraints of the design challenge.
4. Have students complete the Identify a Need or Problem page in the Student Journal.
5. Show the NASA Beginning Engineering Science and Technology (BEST) video “Repeatability,” found here: https://www.youtube.com/watch?v=-2Az1KDn-YM.

Differentiation Suggestions

- Allow students extra time to discuss the challenge itself, the problem that needs to be solved, and how the problem could be solved.
- Introduce criteria and constraints one at a time and discuss with students.
- Allow student designs to meet one challenge requirement successfully before introducing additional requirements.
Research

Research is done to learn more about the identified need or problem and potential solution strategies. Students can use resources from the internet, the library, or discussion with experts to examine how this problem or similar problems are currently being solved.

This phase connects student thinking about the problem in the challenge, what questions they have, and how they may begin to think about possible solutions. Use these pages to launch student interest.

As students prepare to connect with a NASA scientist or engineer, they should think about and then research specific questions using books, NASA websites, and other reliable websites. Students will have the opportunity to ask a NASA person questions regarding the challenge, the engineering design process, or their job.

Objectives

• Students will be able to analyze the need or problem and research possible solutions.
• Students will be able to think about questions to ask a NASA scientist or engineer about the challenge problem.

Guiding Questions

• Where can you find more information about the topic?
• What questions would you ask a NASA scientist or engineer who is currently working on this problem?
• Why are we trying to solve this problem?
• What objects in this room have been made or developed by a scientist?

Instructional Procedure

1. The facilitator should connect to the You for Youth (Y4Y) website and arrange a time for the group to connect with a NASA scientist or engineer. A good time for a first connection is when students have completed this phase of the EDP.
M2M: Mission to Mars

2. Brainstorm a list of five questions to be included in the NASA Connection KWL (Know, Wonder, Learn) chart.
3. Help students answer any questions they have about the challenge. Use the internet or a school library to research answers.
4. Have students spend research time on this problem and possible solutions.

Differentiation Suggestions
- Provide a list of reputable online resources students can use.
- Arrange a visit to a library.
- Pair students to complete research together.

Career Connection
Arrange for different types of engineers to visit and allow students to discuss engineering with them.

Technology Connection
Have students build QR codes containing the information they learn. Teams can then create questions for a Family Night scavenger hunt. Community participants can search for answers by using an app to scan the QR codes.
Research With a NASA Scientist or Engineer

Part of a NASA engineering design challenge is an opportunity for your students to virtually connect with a NASA scientist or engineer. Think about your program’s schedule and when the best time for this connection may be. It is recommended to make a virtual connection at least once throughout the challenge. Optimal times for this vary, depending on your students, but these connections may be especially advantageous during the research, design, and testing phases.

Prepare students for the NASA connection by viewing this video in which Commander Sunita Williams gives a tour of the International Space Station. This will help answer students' basic questions about space travel and living in space.

https://www.youtube.com/watch?v=ukws3oLMDc8

Use the following guiding questions to help students create authentic questions for the NASA scientist or engineer. Have students use the NASA Connection KWL chart in their Student Journals to document the questions they are interested in asking.

Guiding Questions for a NASA Scientist or Engineer Connection

- What do NASA scientists and engineers design that may affect our daily lives?
- What kinds of jobs are found at NASA?
- Is working in a team important at NASA?

The following videos may be helpful for students who need extra support in visualizing what kind of work an engineer does.
**Career Connections**

What is an engineer? An engineer is a person who works on a team to solve a problem that humans want to solve or make better. Engineers are at the heart of every engineering challenge. Engineers design and build things we use every day. The NASA for Kids video “Intro to Engineering” explains the role of an engineer and can be shared with your students: [http://youtu.be/wE-z_Tjyzl](http://youtu.be/wE-z_Tjyzl). After viewing the video, have students discuss what they learned about what an engineer does.

NASA employees meet needs and identify problems every day, and not just in space. To find out more about the people who work at NASA, have students visit “My Everyday Extraordinary.” [https://www.nasa.gov/careers/my-everyday-extraordinary](https://www.nasa.gov/careers/my-everyday-extraordinary)

To learn more about what astronauts and engineers do, watch NASA’s YouTube series “In Their Own Words.”
[https://www.youtube.com/user/NASAgovVideo/search?query=in+their+own+words](https://www.youtube.com/user/NASAgovVideo/search?query=in+their+own+words)
Design

The design phase includes drawing models of possible solutions, refining the models, and collaborating as a team to choose the idea that best meets the original need or problem. First, students work independently. This allows students to define the ideas they have on their own before they work in a group. Next, teams collaborate to create a team design combined from the individual ideas. All designs should be drawn precisely and labeled with a key. Facilitators should approve final drawings before building begins.

Objectives

- Students will use knowledge gained to design a possible solution.
- Student teams will compare and contrast designs within the team and collaborate to create a team design that meets the criteria and constraints.

Guiding Questions

- What are all the different ways each member of the team can imagine to solve the problem?
- How can the team collaborate to design our best solution idea?
- Do the drawings address all the criteria and constraints?

Instructional Procedure

1. Ask each team member to brainstorm individually and make a sketch representing their ideas for a solution. Students must clearly label and identify each part of their drawing.
2. Remind students to make sure designs meet all criteria and constraints. Also remind students to think about what they learned in the STEM Investigations.
3. Ask team members to discuss their ideas and drawings with the rest of the team.
4. Based on a team discussion, students will collaborate to determine which design elements will be used to solve the problem and what features will be included to create the team’s model. The most promising solution should include elements from more than one design. Teams will need time to discuss and agree on what their model design will include.
5. Have students record the strengths of each of the designs on the Team Discussion and Selection page in the Student Journal.

6. When their group collaboration is complete, students should take a moment to pause and reflect on the work so far. Students can work individually or as a team to complete the first Stop and Check page in the Student Journal.

**Debriefing Questions**

- How does my model represent the criteria and the constraints of the challenge?
- What are the strengths and weaknesses of my individual drawing of my model?
- How does our drawing of our team model meet the criteria and constraints of the challenge?

**Differentiation Suggestions**

- Show students the building materials prior to beginning the drawing.
- Allow students to experiment with different materials to build their model before they draw their design.
- Give students an 11- by 17-inch sheet of paper to construct a collaborative team drawing.
- Require students to make a scale drawing using proper ratios.

**Math Connection**

Require students to draw one or more parts of the design to scale.

**Technology Collection**

Have students use a computer program to design a 3D model of the team prototype and, if time permits, present to the whole group.

**Multimedia Resource**

To learn more about NASA aeronautics research and design, visit [https://www.nasa.gov/centers/armstrong/features/afrc-interns-create-new-way-to-explore-flight.html](https://www.nasa.gov/centers/armstrong/features/afrc-interns-create-new-way-to-explore-flight.html)
Model

A model is constructed based on the design from the team collaboration. Its purpose is to test the proposed solution. A final design should be drawn precisely and labeled with a key. Facilitators should approve final drawings before building begins.

Taking a photograph or video recording at intermittent points in this phase will allow students to make more complete comparisons when they begin to analyze their engineering work.

Objectives

- Students will create a model representing the team’s design from available materials.
- Students will create a budget sheet that will record and calculate the material cost of the team’s model within an established budget.

Guiding Questions

- How can our team create a model representing the team’s design from available and provided building materials?
- How can our team create a budget sheet that will record and calculate the material cost of the team’s model within an established budget?
- How can our team Communicate, Explain, and Share the reasons for the team’s decisions, research, and improvements?

Instructional Procedure

1. Predetermine the cost of the materials that will be available to students. Label those items and decide on a total budget amount, for example, $5.
2. Introduce the budget sheet to student teams and have them complete it while working on this phase of the engineering design process. Younger students may struggle with the budget on this engineering design challenge (EDC); it can be optional if the facilitator feels students are not ready for this concept.
3. This is a good point in the EDC to show teams the materials for the first time.
4. Have each team determine what materials they will need to build their design and encourage team members to do their assigned jobs within the group.
roles and collaboration can be critical during this phase. Students within a collaborative team and defined roles will be best prepared for success.

5. Remind teams to check the criteria and constraints as they begin hands-on work.

6. Have teams construct their models using the drawing.

7. As the students are constructing their models, encourage them to explain their engineering thinking as they adapt the building materials to their model. Students can demonstrate the cause-and-effect relationships as they construct their model.

8. Remind teams to discuss and record the reasons for the team’s decisions, research, improvements, and budget during this phase.

**Differentiation Suggestions**

- Give students extra time to explore various materials prior to building the model.
- Limit materials to add complexity (e.g., only 1 meter of duct tape).
- Students can compare and contrast their models and write a persuasive paragraph arguing for what should and should not be in their final design and why.

**Debriefing Questions**

- How can we create a model representing the team’s design from available materials?
- How did we create a model within the established budget for materials?
- Did we make sure we met all of the criteria and constraints?
- What are two engineering ideas the team had during this phase?
- How can we Communicate, Explain, and Share the reasons for the team’s decisions, research, and improvements?
Test and Improve

During this phase of the engineering design process (EDP), student teams will conduct drop tests, record observations, and make improvements to their models. During each of the drop tests, students will need to collect and record data and observe how their models have met the criteria and constraints of the challenge.

Objectives

- Students will conduct tests of the model solution.
- Students will identify areas for improvement based on test data.
- Students will identify whether any part of the model needs to be redesigned.
- Student teams will move forward or return to previous EDP phases if they need to redesign the model based on new research or test data.

Guiding Questions

- How can our team conduct tests that represent the criteria and constraints of the challenge?
- How will our team identify areas for model improvements based on test data?
- What were the reasons for the model failure during the tests? How will we address these issues during the redesign of the model?
- When will our team need to progress forward or return to previous EDP phases to redesign the model based on new research or test data?

Instructional Procedure

1. Using the model student teams made with the available building materials, teams will conduct a drop test from a height of 2 meters. Students will record observations, paying close attention to the specified criteria.
2. Based on the data, teams can make improvements to the model and the design.
3. Allow teams time to collaborate with each other and with other teams to identify the cause-and-effect relationships that contribute to the failure or success of the model.
4. As testing continues, teams may need to return to previous phases in the EDP to research new questions, modify the model design, and/or reconstruct the model itself.

5. Students should take a moment and pause to reflect on the work so far. Students can work individually or as a team to complete the second Stop and Check page in the Student Journal.

6. Encourage teams to Communicate, Explain, and Share the reasons for the team’s decisions, research, improvements, and budget as they create a presentation script.

**Debriefing Questions**

- How did the data from our tests represent the criteria and the constraints of the challenge?
- What areas of our model need to be improved based on the test data?
- What were the reasons for the model’s failure during the tests? How can these issues be addressed during the redesign of the model?

**Differentiation Suggestions**

- Encourage students to test only one criteria or constraint at a time rather than all of them at once.
- Allow students extra time to test and record their model’s iterations.
Communicate, Explain, and Share

For the final phase of the challenge, teams will create a presentation. The Student Journal is designed to help document each phase of the engineering design process (EDP). Encourage students to use their journals to help build the presentation.

Objective

- Students will communicate complex ideas clearly and effectively by creating or using a variety of digital objects such as visualizations, models, or simulations to create a final presentation of the engineering design challenge.

Guiding Questions

- How can our team Communicate, Explain, and Share the reasons for the team's decisions, research, and improvements?
- How can the team use technology to represent and describe their solution to the challenge?

Instructional Procedure

1. Review the presentation submission guidelines with students.
2. Using an appropriate software platform, student teams will assemble, edit, and produce a video that describes their journey through each phase of the EDP.
3. Allow student teams plenty of time to be creative and to use all of the documentation recorded during this challenge to clearly communicate the team’s work.
4. Remind teams to use the rubric as a guide when creating the presentation.

Debriefing Questions

- How can we Communicate, Explain, and Share the reasons for the team’s decisions, research, and improvements?
- Were complex ideas communicated clearly through digital means?
- How was technology used to describe the team’s progress through the EDP?
Student Presentation Guidelines

Each student presentation must be submitted as a video but can be documented using any communication method. Remind students to use the pages of the Student Team Challenge Journal to help complete the presentation.

The finished presentation must meet the following guidelines:

- The introduction must say this: “This is team (team name), and we worked on the (name of challenge). The title of our presentation is (presentation title).”

  Do not identify by name any student, teacher, school, group, city, or region in the presentation. Submissions that do not follow these directions will be disqualified.

- The presentation must document every step teams took to complete the challenge, including
  - STEM Investigations
  - Each phase of the engineering design process
  - Any problems in design or teamwork that happened and how they were resolved

- Student teams must identify any information provided by a NASA scientist or engineer that helped in the design or testing.

- Presentations must explain which characteristics of the design provided the most reliable results and why.

- Presentations must describe the final design.

- Total length of the presentation must be 3 to 5 minutes.

- Every student should participate in the presentation.

Help guide students to think of creative ways to share what they have learned. Exciting ways to present a video with team information might include these:

- Stop-gap animation movie of photos taken during the process
- Trifold display similar to a science fair presentation as part of the video
- Video presentation using a virtual slide deck with videos, photos, and narration
- Cartoon depicting how the team progressed through the challenge
- Virtual storybooks created on a website as part of the video
- Photos and video documentation

Once the video is complete, submit the presentations using the process explained on the You for Youth (Y4Y) website.