Space Week Engineering Design Challenge: Building Trusses

Teacher Overview:

Students will learn about the truss beam of the International Space Station and how to design a lightweight but strong and rigid structure that employs geometric forms.

This lesson includes 3 parts:

1. **Pre-KSC Trip Paper Truss Design Challenge (approximately 3 or 4 45-minute sessions)**
2. **KSC Trip: K'NEX Truss Design Challenge – at Kennedy Space Center**
3. **Post-KSC Trip: K'NEX Truss Design Challenge**

Doing all three parts with fidelity ensures that students build a strong understanding of the engineering design process with a real-world application.

Using CPALMS Lesson Plan Template – Guided or Open Inquiry

The following prompts were taken from the CPALMS online lesson-planning tool to accommodate educators who wish to work on lesson plans offline. The tool can be accessed by logging into http://www.floridastandards.org and going to "Instructional Resources".

In a Guided Inquiry (Level 3) lesson, the teacher provides a question for investigation as well as the necessary materials. Students develop the procedure to investigate a teacher-selected question. In an Open Inquiry lesson, the teacher acts as the facilitator, while students formulate a question they want to answer and the methods for the investigation. The Guided and Open Inquiry lesson plan template includes text fields for guiding questions, learning objectives, prior knowledge, introduction, investigate, analyze, closure.

I. Standards

Next Generation Sunshine State Standards:

SC.6.N.1.1: Define a problem from the sixth grade curriculum, use appropriate reference materials to support scientific understanding, plan and carry out scientific investigation of various types, such as systematic observations or experiments, identify variables, collect and organize data, interpret data in charts, tables, and graphics, analyze information, make predictions, and defend conclusions.
SC.6.N.1.4: Discuss, compare, and negotiate methods used, results obtained, and explanations among groups of students conducting the same investigation.
SC.6.N.1.5: Recognize that science involves creativity, not just in designing experiments, but also in creating explanations that fit evidence.
SC.6.N.2.3: Recognize that scientists who make contributions to scientific knowledge come from all kinds of backgrounds and possess varied talents, interests, and goals.
SC.6.N.3.4: Identify the roles of models in the context of the sixth grade science benchmarks.
SC.6.P.13.1: Investigate and describe types of forces including contact forces and forces acting at a distance, such as electrical, magnetic, and gravitational.
SC.6.P.13.3: Investigate and describe that an unbalanced force acting on an object changes its speed, or direction of motion, or both.

Common Core

LACC.6.SL.1.1 Engage effectively in a range of collaborative discussions (one-on-one, in groups, and teacher-led) with diverse partners on *grade 6 topics, texts, and issues,* building on others' ideas and expressing their own clearly.

II. Assessment

Formative Assessment

Describe how the teacher will gather information about student understanding and prior knowledge before the lesson or at the beginning of the lesson. How and when can the teacher use this information during the lesson?

Ask the students:

- Has anyone ever seen a truss? How does it work?" *A structural frame made up of geometric shapes in a single plane. The geometric shapes provide structural support.*
- Where could you find an example of a truss? *Bridges, roof support*

Then ask the students:

- What can we do to increase the amount of weight that is supported by your truss?" *Explore the placement of geometric shapes in the design.*

Educative Assessment

Describe how and when the students will get feedback about their performance or understanding during the lesson. How and when will they have an opportunity to use this feedback to improve their performance?

Ask the students:

- How successful do you think your truss design will be in supporting weight?
- How will you design your truss to support weight? What geometric shapes might be used in your design?

Summative Assessment

Describe how the teacher will determine if the students have reached the learning targets for this lesson. How will the teacher measure the impact of this lesson on student learning?

A. Teacher evaluation, part 1 (Recorded in student notebook)
   1. Feasibility Report: Have students decide which of the presented solutions would be the most feasible, citing evidence from the Engineers' Conference to support his/her evaluation. (It can be their own team's truss or another team's design.). Students' explanations must include:
      a. Detailed information, in the form of words and labeled pictures, about the design.
      b. The words **balanced and unbalanced forces (**Teachers can assess student responses based on the details provided and clarity of describing the truss's ability to support weight.)
   2. Students will answer the following in their notebooks:
      How can you increase the weight that is supported by your truss? Use evidence from the Engineers' Conference/Community Meeting to support your evaluation.

B. Teacher evaluation, part 2: Use the attached Engineering Design Process Evaluation Rubric to assess students.

C. Provide students with prompts to discuss based on the many benchmarks that this lesson addresses. Students should participate in whole-class and small-group discussions. Then have students respond to prompts in their notebooks and use as a summative assessment.

III. Lesson Content

Learning Objectives: What should students know and be able to do as a result of this lesson?

What are the learning objectives for this lesson? What will students know and be able to do as a result of this lesson? Try to make the objectives measurable and specific.

- Students will design and construct prototypes of a truss to support weight (use weights, such as washers).
- Students will keep careful records, test the prototypes, analyze the results, and modify the models based on the analysis.
- Students will present the prototype at a "conference," discussing the merits of their design, and citing evidence in support of their design.
- Students will evaluate other designs and will describe the features of a successful truss.

Guiding Questions: What are the guiding questions for this lesson?

What guiding questions for students should the teacher use? Guiding questions are broad questions that students and the teacher can come back to throughout the learning experience. A good guiding question is (a) thought-provoking, counterintuitive, and/or controversial, (b) requires students to draw upon content knowledge and personal experience, and (c) can be revisited throughout the lesson to engage students in an evolving discussion.

- How successful do you think your truss design will be in supporting weight?
- How will you design your truss to support weight? What geometric shapes might be used in your design?
- What is the truss beam of the International Space Station and what is its purpose?
- How would not having the truss beam affect the International Space Station?

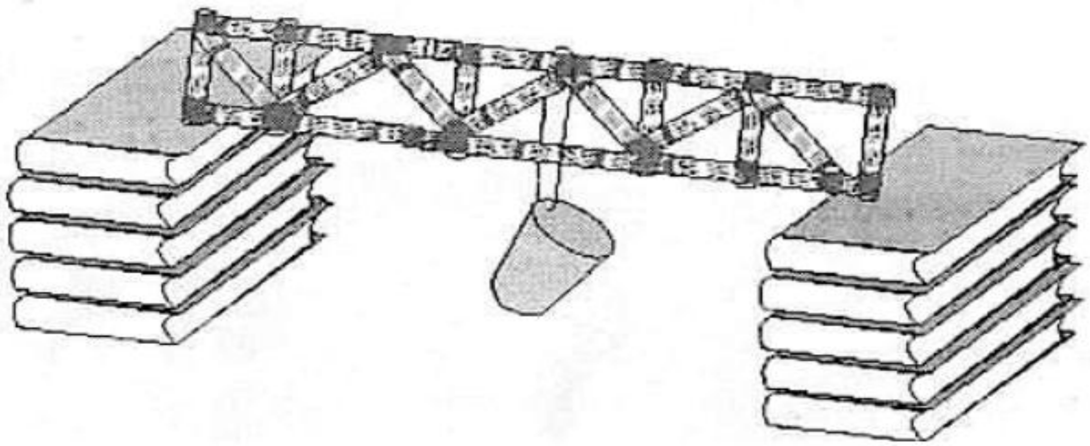
Prior Knowledge: What prior knowledge should students have for this lesson? How might prior knowledge be assessed?

Space Knowledge:

The International Space Station consists of approximately 100 major components. They are joined together to produce a habitat for teams of up to seven astronauts to live and work in space for months at a time. The largest components of the ISS are the truss beam and solar panels. The truss beam extends to the right and left of the station as it orbits around Earth. It is joined to the U.S. Destiny Module, a cylindrical laboratory in which astronauts do their work. Attached to the ends of the beam are large solar panels for making electricity from sunlight. Also attached are thermal radiators for exhausting waste heat from the modules into space. The truss beam also holds the robotic system that can travel its length.

The truss beam consists of an open structure of girders that are arranged in the shape of a hexagonal prism. Diagonal girders crisscross the structure to form many rigid triangles. It is 100 meters long. The open structure reduces the weight of the truss beam and the triangles give it strength to maintain its shape. Strength is important for the beam but not because of the weight of the structures it has to support. In space, these structures are virtually weightless. However, the structures still have mass and mass resists changes in motion. The beams have to be able to maintain the position of the solar panels and other structures during thruster firings when the ISS orbit or attitude is changed.

Tell the groups they will be planning and testing a truss using newspaper in class, a truss made of K'NEX at KSC and then a K'NEX truss in class after the trip.



Part 1: Pre-KSC Trip Activity: Paper Truss Design Challenge

(Adapted from Brevard Space Week Lessons: Building Trusses)

Introduction: *How will the teacher inform students of the intent of the lesson? How will students understand or develop an investigable question?*

Day 1

1. Show the students the pre-trip PowerPoint that was provided by KSC Educators.
2. For additional information, show students one or more of the following videos and/or website:
   - NASA: Station Assembly Animation
   - European Space Agency: International Space Station
   - Brain Pop: International Space Station
   - Discovery Education: Space Exploration: International Space Station (2:00)

Discuss the structure of the International Space Station. Talk about the importance of the truss and how it supports weight. Discuss the fact that the ISS truss does not support a great deal of weight due to microgravity; however, the truss helps the ISS stay rigid and resist bending where there is a change in motion due to a thruster, etc.

3. **Form teams of 5. *Students will be working in groups of 5 during the trip to KSC. It is recommended that you form the groups of 5 now and have the students remain in the same groups for the pre-activity and the post-activity as well as for the day of your trip.***
4. Explain that they are engineers working for NASA. They have been hired to design a new truss section to be added to the ISS. Each team should decide upon a name and design a team logo.

Optional: Create mission patches using the team logos for the teams to wear as buttons on their visit to KSC.

5. Display and explain the Engineer/Design Challenge Process graphic (refer to chart of graphic, if posted), Phase 1.
6. Explain that students are now in **Phase 1: Identifying the Problem**. In this stage, engineers identify the problem and identify areas they need to consider when they design their solution. These considerations are part of the "specifications" for the solution.
   a. After they identify the specifications, they brainstorm possible solutions. Engineers usually brainstorm many solutions before they settle on the best one to build. Stress that they shouldn't stop at the first idea they get—they should think of several ideas before choosing the one that best fits the specifications.
   b. After they decide on a solution, engineers make a drawing of their idea so they can begin to work out the details of the design (material needed, size, etc.).
   c. Once they have a plan approved by the Project Head (teacher), they build a model of their design to test it. This model is called a "prototype."

   d. Briefly show them Phases 2 and 3 of the Engineer/Design Challenge Process graphic, but explain that they will be getting more details about those later in the challenge.

Investigate: *What will the teacher do to give students an opportunity to develop, try, revise, and implement their own methods to gather data?*

7. Pass out the Pre-KSC Trip: Paper Truss Engineer Reports (See Accommodations for options).
8. Guide the class in developing the question:

How can you build a truss that will support the greatest amount of weight?

9. With the class, develop the specifications of the problem:
   a. Teams must create a truss using the materials provided.
   b. The truss must be designed with increasing the added weight as the primary goal.
   c. Additional specifications suggested by the group.
10. Students get back into their teams and complete Phase 1 (Steps #1-5 above) on the Engineer Report. (*Hint: Tell students that, as Project Head, you cannot give them ideas, but you can help clarify. One idea is to tell them that you will only be able to ask questions, not answer any. For example, if a student asks if you think their design will work, respond with, "Does it meet our specifications?"* Educative assessment*)*
11. Once the teams have a design and materials list (selected from the list on the Engineer Report), they will bring the report to you for approval. As students bring you their plans, ask:
    a. How does your design increase the amount of weight supported? *Formative assessment—does the student understand that geometric shapes (i.e., triangles) placed closely together increase the amount of weight supported?*
    b. Does your design take into account the use of materials that will work best to increase the amount of weight supported? *Educative assessment*
12. After teams receive approval for their designs, they can collect their materials and build their prototypes.

Analyze: How will the teacher help students determine a way to represent, analyze, and interpret the data they collect?

<u>Day 2</u>

1. Gather the student teams together and tell them that we are moving into **Phase 2: Testing**.
   a. Refer to the Engineer/Design Challenge Process graphic (if posted). Explain that engineers test their prototypes before they present them. The purpose of testing is to work out all the "bugs" in a design before showing it to others.
   b. So, they test the design under the conditions of the challenge, analyze the results of the test to see what worked well on the design and what needs to be improved, then they modify their design to fix the things that need to be improved while keeping the things that worked well.
   c. After modifying, they go back to test again, continuing the test—analyze—modify cycle until they feel their solution is complete.
2. With the students, discuss the testing they will use. Ask, "How will we test our designs?" *(Set up a testing area using books to elevate the truss on both ends. If the truss is 2-dimensional, set up a way to hold the truss in place.)*
   a. Discuss safety rules to be followed.
   b. Lead them into a discussion about controlling the tests for valid results. Consider these variables:
      i. How do you make sure you have the same conditions for each test? *(Lead the students into deciding that trusses must be elevated to the same height. Hang a paper cup from the truss and add weights.)*
      ii. How do we measure the quality of the prototype? *(The amount of weights added before it bends and/or breaks).*
      iii. Any other variables that come up during the discussion.
3. In their engineering teams, students develop a way to record the data from their tests.
   See Engineer Report, Phase 2. A chart might look like this:

	Mass of the Weights (in grams)
Truss Prototype #1	
Truss Prototype #2	

4. Students bring their prototypes to the testing. Test according to the conditions outlined by the class.
5. Students record their data, and then complete the Test Analysis section on Engineer's Report.
6. Students bring Test Analysis section to Project Head for approval signature BEFORE they modify. Discuss the students' finding with each engineer team (*Educative Assessment*).
   NOTE: Some students may have a hard time with modifying their current design and instead want to start over with a new design. There is usually something that works in every design—help the team find those things that they can build on. Starting over with a new design each time defeats the purpose of the Engineer Design Process.
7. Encourage all teams to complete at least 2 test—analyze—modify cycles. Remind them that they need Project Head approval at the end of each analysis.

Closure: *What will the teacher do to bring the lesson to a close? How will the students make sense of the investigation?*

Day 3

1. Gather the student teams together and tell them that we are moving into **Phase 3: Presentation**. Refer to the Engineer/Design Challenge Process graphic (if posted).
   a. Explain that, after testing is completed engineers present their final prototype for "public comment." This public comment could be with the customer who ordered the project, the people who will be using the project, or some other interested party.
   b. In our case, we are presenting our prototypes to NASA. *In an Engineers' Conference/Community Meeting, the teacher tells students that when another engineering team is presenting, the rest of the class will play the role of NASA.* Remind them that they need to listen carefully and critically to the presentations to determine which team offers the best design and what evidence is provided.
2. Students present their prototypes.
3. Have a question and answer period after each presentation:
   Project Head:
   - Prompt them to use their evidence to support their claims of effectiveness (Formative Assessment—Are students identifying how the placement of geometric shapes affects support?)
   - The teacher should also ask each team about benchmark concepts related to this lesson. (e.g., characteristics of scientific investigations, variables, defending conclusions, comparing methods and explanations, creativity, models, forces, etc.)

4. Have the students complete the Feasibility Report and Summative Assessment prompt in the Science Notebooks (See Summative Assessment #1, parts *a* and *b*):
   How can you increase the weight that is supported by your truss? Use evidence from the Engineers' Conference/Community Meeting to support your evaluation.
5. Students can self-assess or teacher can assess using the attached Engineering Design Process Evaluation Rubric.

Part II: KSC Trip: K'NEX Truss Design Challenge – at Kennedy Space Center

KSC Challenge Question: *How can you use K'NEX to build a truss that will support weight?*

NOTE: In order to maximize the engineering time at KSC, it is critical for teachers to properly prepare students for the Kennedy Space Center phase of the Engineering Design Challenge.

- Distribute 1 copy per team - of the **KSC Trip: K'NEX Truss Design Challenge: Engineering Report**. Groups will record the name of the student who will hold each position. This copy of the **KSC Trip: K'NEX Truss Design Challenge: Engineering Report** will be collected and brought to Kennedy Space Center on the day of the trip. (*Each student will get a copy of the report after the trip to be completed and secured in his/her interactive science notebook*.)
- Instruct the teams to decide which member of the group will hold each position and record on the report:
    1. Lead Engineer (Responsible for team cooperation and completion of truss according to design specifications.)
    2. Illustrator (Responsible for sketching the design of the truss before it is tested.)
    3. Data Collector (Responsible for documenting the length of the truss and how much weight the truss can hold.)
    4. Structural Engineer (Responsible for determining where the weight should hang from the truss for the testing phase.)
    5. Demolition and Clean up Supervisor (Responsible for making sure the truss is taken apart and putting pieces away.)

  All team members are responsible for working together to build the truss.
- Display and review the Engineer/Design Challenge Process graphic (refer to chart of graphic, if posted: **Phase 1: Identifying the Problem** and **Phase 2: Testing.** Explain to students that they will be in these phases at Kennedy Space Center.
- Students will follow up in the classroom after the trip by analyzing—modifying, then repeating the cycle.

Phase 1: Identifying the Problem and **Phase 2: Testing**
Engineering Design Challenge at KSC:

- Teams will have about 1 hour, for: Explanation, Building (about 20 min.), and Testing. (Safety goggles are not needed.)
- Students will work in already established teams (groups of 5 from Day 1).
- Trusses can be 2D or 3D. KSC has a wooden stand to hold trusses while testing. No one holds the trusses while being tested.
- Testing involves attaching milk bottles of sand weighing 4 lbs., 8lbs, or 12lbs (the 4 lb. and 8lb. together).
- Follow up questions on the Engineering Report can be completed at KSC if time allows, or they can be completed back in classroom during the Post-trip activity.
- Optional –Teachers or students may bring cameras to document the design, testing, and results.
- ***At the end of the activity and before moving onto the next KSC stop - teachers should collect the Engineering Report from each team so they don't get lost or misplaced. They will be redistributed back at school during the follow-up lesson.***

Part III: Post-KSC Trip: K'NEX Truss Design Challenge

Day 1

1. Display and review the phases of the Engineer/Design Challenge Process that were completed at KSC. Have a general class discussion about the truss building done at KSC. Share pictures if cameras were used to document. Reflecting on the event together before writing, will help students with the benchmark concept - *"Discuss, compare, and negotiate methods used, results obtained, and explanations among groups of students conducting the same investigation."*
2. Redistribute the team copy of the Engineering Report completed on the trip to KSC. Distribute individual copies of **KSC Trip: K'NEX Truss Design Challenge: Engineering Report** to <u>each</u> student. Give students time to discuss and record information from the testing at KSC into their individual reports. Reports should be glued or taped into science notebooks.
3. Remind students they are still in **Phase 2.** Students analyze their data, and then complete the Test Analysis section on the Engineering Report. Students should record what modifications they want to make and why they think the modifications will work.
4. Students bring their modification section to the Project Head for approval signature BEFORE they modify. Discuss the students' ideas for modification with each engineer team (*Educative Assessment*).
   NOTE: Some students may have a hard time with modifying their current design and instead want to start over with a new design. There is usually something that works in every design—help the team find those things that they can build on. Starting over with a new design each time defeats the purpose of the Engineer Design Process.
5. <u>Using the K'NEX kit provided to each school</u>, encourage all teams to complete at least 1 more test—analyze—modify cycles. Remind them that they need Project Head approval at the end of each analysis. Complete Phase 2 questions on the **Post-KSC Trip: K'NEX Truss Engineering Report.**

Day 2

6. Gather the student teams together and tell them that we are moving into **Phase 3: Presentation**. Refer to the Engineer/Design Challenge Process graphic (if posted).
   c. Explain that, after testing is completed engineers present their final prototype for "public comment." This public comment could be with the customer who ordered the project, the people who will be using the project, or some other interested party.
   d. In our case, we are presenting our prototypes to NASA. *In an Engineers' Conference/Community Meeting, the teacher tells students that when another engineering team is presenting, the rest of the class will play the role of NASA.* Remind them that they need to listen carefully and critically to the presentations to determine which team offers the best design.
7. Students present their prototypes.
8. Have a question and answer period after each presentation:
   Project Head:
   - Prompt them to use their evidence to support their claims of effectiveness (Formative Assessment—Are students identifying how the placement of geometric shapes affects support?)
   - The teacher should also ask each team about benchmark concepts related to this lesson. (e.g., characteristics of scientific investigations, variables, defending conclusions, comparing methods and explanations, creativity, models, forces, etc.)

9. Have the students complete the Feasibility Report and Summative Assessment prompt in the Science Notebooks (See Summative Assessment #1, parts *a* and *b*):
   How can you increase the weight that is supported by your truss? Use evidence from the Engineers' Conference/Community Meeting to support your evaluation.
10. Students can self-assess, or teacher can assess, using the attached Engineering Design Process Evaluation Rubric.

IV. <u>Accommodations and Recommendations</u>

Accommodations

Describe how to accommodate students with special needs and how to differentiate instruction.

- Students with physical impairments will be on teams with non-disabled peer to enable them to construct the prototype.
- The teacher may choose to have a student complete each section of the Engineer Report and Summative Assessment orally.

Extensions

Describe possible extensions of this lesson.

Have students conduct research about different types of trusses. Students will identify one type and will build a model of a bridge using materials of their choice (i.e., toothpicks, craft sticks).

Suggested Technology

- Document Camera
- Computer for Presenter
- Internet connection

Special Materials Needed

Describe what special materials or preparations are needed for this lesson.

<u>Materials</u>

Materials for Paper Truss Design Challenge

- old newspaper (Roll and tape newspaper girders for truss beams.)
- masking tape
- paper cup
- string
- weights such as coins or washers

Materials for K'NEX Truss Design Challenge

- K'NEX kit (provided by BPS Science Department)
- Weights to test truss (i.e., milk jugs filled with sand in increments of 4 lbs., 8 lbs., and 12 lbs. to remain consistent with testing procedure at KSC)
- Stand or other device to hold truss for testing

- Copies of **<u>Pre-KSC Trip: Paper Truss Design Challenge Engineering Report</u>** (one for each student)
- Copies of **<u>KSC Trip: K'Nex Truss Design Challenge: Engineering Report</u>** (one for each team to bring to KSC; one for each student during the follow-up lesson back at school)
- Copies of **Post-KSC Trip: K'Nex Truss Design Challenge Engineering Report** (one for each student)
- **Engineer/Design Challenge Process graphic** (to post/display or use with document camera)
- **Engineering Design Process Evaluation Rubric** (to use for evaluation)