SUMMER INSTITUTE FOR ENGINEERING AND TECHNOLOGY EDUCATION

ENGINEERING DESIGN - TEACHER MODULE 1

SPACE STATION PLATFORM

CONCEPT

This module allows the student to use their creativity and ingenuity to design a working prototype while applying the real world engineering constraint of *manufacturing cost* to their design.

OBJECTIVES

The students will investigate the benefits of planning a design before starting to build the prototype. They will start with a set of specifications, design a cost effective solution, and then build the prototype.

SCIENCE PROCESS SKILLS

- Observing
- Questioning
- Experimentation
- Evaluation
- Organizing Information
- Analyzing
- Practicing Group Decision Making
- Measurement
- Understanding
- Modeling and Predicting
- Designing
- Identifying Structure, Function, and Relations
- Computation and Estimation

AAAS SCIENCE BENCHMARKS

- 2B Mathematics, Science, and Technology
- 3A Technology and Science
- 3B Design and System
- 3C Issues in Technology
- Technology and Science

SCIENCE EDUCATION CONTENT STANDARDS (NRC)

- Science Inquiry
- Design and Systems
- Interaction between Science and Technology
- Models

STATE SCIENCE CURRICULUM FRAMEWORKS

1.1.2, 1.1.3, 1.1.4, 1.1.11, 1.1.12, 1.1.14, 1.1.15, 2.1.8, 2.1.10, 2.1.14

MATERIALS

Per class:

Long Straws
Short Straws (long Straws cut in half)
Scissors
Scotch tape
Paper and pencil to keep track of materials purchased by groups
Weight (easily balanced object between 3 and 5 kg, e.g. a light book.)

Per group:

Paper and pencil to write out design
Ruler to make measurements and draw an accurate design

KEY QUESTIONS

1. What are the benefits of having a thorough design beforehand?
2. How did your final prototype differ from your team's original design?
3. How does the cost of the design influence how the structure performs its job?
4. Is it more cost effective to over-purchase straws and have wasted money on unnecessary supplies, or to pay an increased cost if you need to purchase more straws than your original design called for? Explain.
5. What was more important in your design: simplicity of construction, cost of construction, overall performance of structure, or out-bidding your competitors? Why?
6. What are the benefits of testing your model before the demonstration? Did testing increase the cost of your design? Explain.
7. As a consumer, what attributes of a product's design are most important to you (i.e. cost, performance, ...)? Why?

MANAGEMENT SUGGESTIONS

- Divide into groups of three or four students to do the activities.
- Use assigned roles within the groups to facilitate cooperative learning. Suggested roles that might work well for this exercise:

  design engineer - leads the team in drawing an accurate schematic of the prototype,

  materials engineer - in charge of materials required by the team,

  quality assurance engineer - makes sure prototype meets specifications while keeping the cost low,

construction engineer - leads team in construction and testing of the prototype according to team's design.

PROCEDURE

Introduction Phase

Ask the students if a straw can hold up a book. Let the students answer. You may try and balance a book on a straw.

Ask them if two straws will work any better. Again try and balance the book on two straws.

Ask them, "How many straws would it take to hold up a book?" Let them answer, and then bring out a column of 200 straws held together with a rubber band as an example of an inefficient design of a platform. "What is wrong with this design? Is it efficient?"

Explain about the Space Platform contest that you are about to have.

Setup Phase

Divide the students up into teams. Emphasize that every team member is important and that everyone needs to help in designing the space platform. Explain how the structures will be tested.

Hand out one copy of the student module to each team. Instruct the Quality Assurance Engineer to read the description of the project to everyone.

Design Phase

Give the teams about 10 minutes to create a design on paper. If teams are stuck, you might suggest that they think about how bridges are made to distribute a load over all their trusses (straws). Some teams may wish to skip the design phase and start experimenting with the straws. This is up to them, but remind them that the price of straws goes up after the initial purchase.

DESIGN SPECIFICATIONS

At least 19 cm tall.

Wide enough to support the weight selected for the test.

After the team has determined the initial number of straws and tape that they need in their design, they may purchase their supplies.

Purchasing Phase

You should oversee the purchase records for the teams. Record the quantity of materials bought by each team, and the current price of the materials at the time of purchase. Sharing or scalping of excess materials between teams should not be allowed. After the initial purchase the price of straws goes up 50%.

Construction Phase

Allow the teams about 15 to 20 minutes to construct their designs. (This will depend on how much time is available.) Circulate among the teams and ask questions about their designs to encourage them to analyze what they are creating. Many teams will discover that a design with only horizontal and vertical beams will not be able to support a load very well. Diagonal trusses are almost essential to stop the structure from twisting. Allow the students to discover this, through experimentation. Ask questions about how their design is behaving that will lead them to examine their design more closely.

> **SOME EXAMPLE HELPING QUESTIONS:**
>
> What forces will the load (weight) apply to your model?
>
> What happens when a force is applied to a straw?
>
> Why were 200 straws able to accomplish what one or two straws were not? The weight being applied to the model is the same, so what is different about the force being applied to each straw?
>
> In your design, what function does a straw positioned in the vertical direction perform? In the horizontal direction? What about other directions?

Allow the teams to test their design with the weights as much as they would like to. (If straws are destroyed in the pre-tests, the teams may have to purchase replacement supplies, but at the elevated price.) Many prototypes will fail and have to be redesigned. It is everyone's goal to come up with a working prototype that meets the specifications. Testing is an important part of engineering design. Many times designers will learn more from their failures than their successes.

Demonstration and Testing Phase

When all prototypes are finished and the teams are happy with their prototype (or you are out of time), have each team bring their model to the testing area. Invite the students to speculate on which structure should be the strongest. Have each team in turn demonstrate their model to the class. Have the team disclose the amount of their bid and present their initial paper design. Then have them demonstrate that the structure meets the height and weight bearing specifications. Ask the teams how their original design differed from their final model and why.

The team that completes the design with the lowest bid wins the competition. If there is a tie, then the design that supports the most weight wins the competition.

TEACHER NOTES

Free straws might be obtained from local fast-food restaurants. Contact the manager of your local stores.

EVALUATION

Students will include their work as a portfolio entry to be evaluated using the portfolio rubric.

REFERENCES

CORNWELL, PHILLIP J., "Engineering Students Visiting Grade School Classrooms," *1992 Frontiers in Education Conference*, IEEE, 1992.

OTHER RESOURCES

SIMON, HAROLD A., *A Student's Introduction to Engineering Design.* New York: Pergamon Press Inc., 1975.

BEAKLEY, GEORGE C. AND H. W. LEACH, *Engineering: An Introduction to a Creative Profession, 4th Edition.* New York: Macmillan Publishing Co., Inc., 1982.

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ENGINEERING DESIGN - MODULE 1

SPACE STATION PLATFORM

Engineers design and direct the construction of structures, products, and devices. They need to apply principles of science in their design, yet consider the cost of manufacturing or constructing their design.

Engineers will start with a set of requirements and specifications of their structure/product, and create a detailed design of the end result. Often they need to build a *prototype*, or practice structure/product, to examine and test their design. This exercise is an example of the design and prototype steps in engineering.

You are part of an engineering design team that has been assigned to build a platform for a space station on the moon. It is your task to make the framework as strong and as light as possible. You will be given about 10 minutes to come up with a design (detailed drawing).

Once you have a design, you will purchase the materials you need (straws and tape) from the warehouse. Each long straw represents a cost of $10,000,000 and each short straw represents a cost of $5,000,000 in materials and labor. Each centimeter of tape represents an investment of $100,000. If you discover that you need more straws than your original design called for after you have made your initial purchase of straws, then the cost goes up 50% (that is, each long straw is $15,000,000 and each short straw is $7,500,000.)

Construct a model of your framework to be used for testing its strength. For the test, the framework should stand on one end. The frame should be at least 19 **cm** tall and must be wide enough at the top to balance a weight selected for the test.

As you construct your framework, keep track of the materials you use. Total the cost of the materials. If your framework is able to support the weight, the cost of your materials will be your bid. The successful team with the lowest bid will win the competition.

COST:

Number of long straws x $10,000,000	= ____________________
Number of long straws purchased late x $15,000,000	= ____________________
Number of short straws x $5,000,000	= ____________________
Number of short straws purchased late x $7,500,000	= ____________________
Number of centimeters of tape x $100,000	= ____________________
TOTAL COST	= ____________________