Teacher Edition

HOW DOES IT WORK?

Biology / Structure / Compression

Overview : *How Does it Work*?

How Does it Work? consists of a series of modular, hands-on, activities designed for high school science classrooms and laboratories. The modules are designed to expand on basic science principles and technologies as presented in the *How Does it Work*? poster series developed by United Technologies, Inc. A unifying goal of the project is to provide activities that illustrate how basic science principles span the broader science disciplines of earth science, biology, chemistry and physics.

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Compression

Introduction

One of the distinguishing features of human beings is our ability to build things. We have built cities, roads and machines. Nature has also built living things -- from plants to animals to even our own bodies -- using exactly the same construction principles and overcoming the same obstacles. All around us are forces that can destroy what we and nature have built. The most common of these is the constant pull of gravity that can bring our buildings down. In this activity, students will investigate how changes in the shape and thickness of a material can affect the structural compression strength of an object and how this knowledge can be used to make buildings or living things that can withstand the forces of nature. They will also learn how these scientific principles relate to both natural systems and to the technologies shown in the *How Does It Work?* poster called "Straight Up."

Methodology

Before the students begin this activity, they should take a few minutes to read this section which describes the philosophy of learning which is the basis of this program. If they understand why this program was developed, it will be a better educational tool for both teachers and students.

Hands-On

This is essentially a program of experimental physics. There are practically no equations or theories given. It is assumed that any theory needed can be obtained in the student's regular class textbook. Rather, this book attempts to help students learn physics the way Archimedes, Galileo, Newton, Franklin and Edison learned physics, i.e., by experimentation.

These experiments are meant to be hands-on projects that are actually performed by the students themselves and not done as a classroom demonstration by the teacher alone. The goal is to have students actively participate by doing the experiments, not just by watching them.

Learning By Doing

Students should not intellectually assume what an answer might be nor should they be allowed to just think about what will happen if an experiment were done. They should actually perform each and every experiment. There will be plenty of surprising answers that will pop up, which would remain undiscovered if merely thinking about what might happen were the only activity.

Students also should keep a notebook for recording observations, data and conclusions on each experiment.

The Value Of Mistakes

We don't learn how to ride a bicycle by watching someone else ride. We only learn by getting on and trying it for ourselves. Of course, as part of the learning process, we will fall off the bike a few times. Errors and mistakes are an important part of the learning process. The students participating in this activity will make lots of mistakes in their experimental setups, procedures and observations. It is hoped that the teacher will not just give students the correct answers, but will allow them slowly to work their own way to the truth. This is the only way to truly understand what is happening. It is not enough to merely know the answer: You must understand it.

The Process, Not The Facts

Science teachers have a serious problem. They cannot merely teach students what they learned when they were in school, because so many of the science "facts" have changed since then. New technologies, new methods, new theories and new explanations are constantly emerging. Teachers cannot even teach students what they need to know today, because in the few years until they get out of school, things will probably have changed again. What teachers must teach students are not facts, but the processes of learning and solving problems. With those skills, then, no matter how the world and technology change, the students will be able to adapt, survive and succeed. Science is not a collection of facts. It is a process, and it is that process that we must be teaching our students.

Concepts

Students will learn the basic principles governing the structural strength created by using materials of different geometric shapes and what other factors contribute to that strength. They will use the data collected to draw conclusions about the relative importance of these factors, how they relate to each other and the impact of each on real-world constructions. The skills and knowledge the students learn in this activity will be invaluable to them in their future lives both as workers and citizens.

Competencies

At the completion of this activity, the students will have gained experience in the following areas:

Science

- set up an experimental system
- collect data from an experiment
- analyze data sets
- understand the relationship between dependent and independent variables
- modify variables in an experiment
- compile the data collected

Mathematics

- make graphs of the collected data
- interpret the graphs
- draw conclusions from the data and graphs
- extrapolate the information into new areas
- explain the difference between linear and non-linear relationships
- understand the difference between analog and digital information

Language Arts

- listen to presentations and collect relevant information
- read and follow written directions
- write a report presenting conclusions and analysis
- present a verbal explanation of the experiment and their results
- defend their conclusions from the experiment

Critical Thinking Skills

- draw conclusions from data
- interpret data to explain situations
- use information to solve problems
- test suppositions and challenge assumptions
- understand diagrams and the use of diagrams

Interpersonal Skills

- evaluate the relative skills in a group
- understand the division of labor in a project
- determine the most effective leadership roles
- realize the need for teamwork in a group
- understand and follow instructions

Relationship to Technology Education

This module relates to the following standards for Technology Education.

Technological Impacts

- describe cause and effect
- describe how technology is used in familiar surroundings
- describe the role of technology in their lives
- develop a criteria for evaluating technology.
- identify and describe how individual technological innovations may be combined to create new technologies.
- explore and identify the personal, societal, economic and environmental impacts of technological systems.
- describe the universal input, process, output, feedback (IPOF) systems model.
- employ the "input" "process" "output" system model, to their evaluation of technological impacts.
- evaluate technologies based upon their positive and negative outcomes.

Career Awareness

- describe how mathematics, science, language arts, social studies and the arts are related to technology
- define the role of mathematics, science, language arts, social studies the arts and
- technology education in preparing for various careers
- describe how technological development effects careers and occupations.

- prepare a preliminary career plan, with relation to high school course selections.
- understand the need to be a life-long learner.
- identify future labor market trends.

Problem Solving/Research and Development

- identify and define a problem
- describe different methods of problem solving
- gather, record and organize data, based on observations
  develop an action plan
- discuss how technological systems have been used to solve human problems.
- select and apply a general problem solving model in a laboratory setting.
- identify research methods, materials and techniques.
- apply cooperative techniques while engaged in a group problem solving activities.
- engage in an activity that requires creativity.
- apply appropriate and effective questioning techniques.
- describe and apply the processes used to make decisions.
- develop, test and modify a design idea through experimentation.
- use research techniques to support design development.
- apply the descriptive statistics of average, percentage, correlation and graphing to design outcomes.
- design and conduct a technical experiment.

Materials and Processes

- select the appropriate tool for a given need
- use tools and resources correctly and safely
- identify technological resources as materials, people, time, money, information, tools etc.
- describe how processing of resources can produce a more useful product
- use manual and electronic measuring devices accurately.
- describe the physical structures and properties of materials used in technological systems.
- experiment with the alteration of material characteristics.

Production Systems

- use a technological system
- describe the function of various systems
- describe the input, process, output, feedback (IPOF) system model
- define manufacturing terminology including interchange ability, automation, standardization, etc.
- identify the characteristics of sub and super structures.

Transportation Systems

- define technological system
- identify the parts of a system
- describe the function of various systems
- describe and be able to identify the transportation sub-systems of body/frame, propulsion, suspension, control, guidance and support in a variety of transportation devices.
- explore the characteristics of lighter than air, and heavier than air, atmospheric transportation systems.
- apply the concept of transportation sub-systems while solving transportation problems.
- identify and explore solutions to future global transportation problems.

Engineering Design

- construct, evaluate and modify a model or prototype
- discuss the differences between "problem solving" and "engineering design strategies.
- become aware of the role of creativity in the engineering design process.
- describe conceptual design, embodiment design and detail design and identify their role in the engineering process
- develop conceptual designs for transportation, communications, production and bio-related problems.
- differentiate between the problem solving and engineering design processes. understand the "detail design" phase of the engineering design process.

Relationship To Biology

The following biology topics are related to this activity:

- How does the force of gravity affect the shape of living things?
- How do living things overcome the force of gravity?
- What other natural conditions create compression forces?
- How to living things overcome those conditions?
- What compression forces are created when walking on 4 legs?
- What additional compression forces are created in walking on 2 legs?
- What compression forces are created by flying?
- What compression forces are created by swimming under water?
- What compression forces do plants encounter that animals generally do not?
- How does the shape of a bone tell you about where it was in a body?
- What can the shape of a bone tell you about the animal it came from?
- How are bird bones different from mammal bones?
- How do plants overcome gravity without bones?
- What other forces act on a skeletal system besides gravity?
- What animals don't have bones and how do they survive?
- What shapes are used in nature but not by humans in their constructions and why?
- What shapes are used by humans in their constructions but not in nature and why?

Relating To The How Does It Work? Poster – "Straight Up"

This activity will help students answer the following questions about the technologies shown in the poster:

- For each of the following sections of the helicopter, explain:
- Where is that section on the helicopter?
- What is the function of that section?
- What are the forces acting on that section and when do they act?
- What structural features would you expect to find in the construction of that section to withstand those forces?
- What factors besides structural compression strength are important in that section?

Sections:

- Main rotor blade
- Tail rotor blade
- Helicopter body
- Tail section
- Wheel supports
- Tail airfoil

Materials

Each team will need the following materials:

- Light-weight paper with grid lines
- Medium-weight paper with grid lines
- Heavy-weight paper with grid lines
- Scissors
- Weight set (kilogram)
- Weight set (grams)
- Support plate
- Scotch tape
- Marking pen
- Lab notebook
- Graph paper
- French curves
- Transparent ruler

Additional Research Topics

Research, either before or after the activity, can be done into the following topics:

- Work, force and energy
- Vectors and scalars
- Static mechanics
- Strength of materials
- Extension and compression
- Stress factors
- Gravity
- Mass and weight
- Force and gravity
- Stability

Vocabulary

- **Deformation -** A change in shape caused by pressure or stress
- **Force -** The capacity to do work or cause physical change
- **Torque -** A turning or twisting force
- **Mass -** A characteristic of matter which is different from, but proportional to its weight
- **Column -** A beam of material used for vertical support
- **Cross-section -** A graphic representation formed by a plane cutting through an object, usually at right angles to an axis
- **Compression -** The condition of being made more compact by being pushed together
- **Linear -** Described by or related to a straight line
- **Non-linear -** Not straight or linear
- **Variable -** A quantity or condition that is likely to change or vary
- **Dependent variable -** A quantity or condition that relies on another quantity or condition to determine its value
- **Independent variable -** A quantity or condition whose value is not determined by another quantity or condition

Management

It is very important to keep students on track and focused during this activity. They need to fully understand all of the basic principles presented here to get the most out of this activity.

While none of the materials used are inherently dangerous, there is always the potential for misuse and inappropriate behavior. Although students will be working as independent teams, as always, discipline and control must be maintained.

This module requires students to read, understand and perform various experiments. Although they will be working in teams, it would be best if all members of each team got a chance to perform each of the different operations. For example, one student could initially read and explain the instructions from the manual while another student actually assembled the components to do the experiment. A third student could read the various instruments while the last records the data. After a while, they could switch roles and perform the other functions. This would give all the students an opportunity to learn each of the different skills involved in this activity.

In the first class (1.5 to 2 hours) the students will design, prepare and perform the experiments and collect the appropriate data. They will then make the appropriate graphs and charts from the data collected and draw conclusions. In the second class (45 to 60 minutes), each team will work together to present its results and conclusions to the rest of the class as a whole.

Since the class has a number of teams, each having performed the same experiments, there may be some repetition in the reports given. In fact, if all the experiments and analyses were done correctly, all the presentations should be almost identical in content. However, in most cases they won't be, and this is another area where learning can take place. After all the teams have presented their reports of data and conclusions, they can then be allowed to critique each other's results, conclusions and presentations. If some teams got unusual results or reached different conclusions than others, explore why this is so! In this way all the students can learn from seeing how others did it to understand how they reached their particular conclusions and what differences, which may be errors, in measurement or logic got them there.

Future Activities

Here are some topics that can be explored in future experimental activities:

- What other factors besides those investigated here may affect the compression strength of shapes?
- How do the demands on vertical supports differ from those on horizontal supports?
- What characteristics of a cross-sectional shape make it stronger?
- What other cross-sectional shapes are used in construction and when are they used?
- What characteristics of a material make it stronger?
- What is the relationship between flexibility and strength?
- What are other ways to increase the stability of a support besides making it thicker?
- How much do economic issues affect the selection of construction materials?
- What other considerations besides strength must be taken into account when designing building and bridges?