DOCUMENT RESUME

ED 383 539 SE 055 880

AUTHOR Crismond, David; And Others
TITLE Technology for Science: Overview of the Project.
INSTITUTION TERC, Cambridge, MA.
SPONS AGENCY National Science Foundation, Arlington, VA.
PUB DATE 94
NOTE 9p.
PUB TYPE Guides - Classroom Use - Teaching Guides (For Teacher) (052)

EDRS PRICE MF01/PC01 Plus Postage.
DESCRIPTORS *Electricity; Grade 9; *Heat; High Schools; Learning Activities; *Magnets; *Measurement; *Motion; Science Activities; Science Curriculum; Science Education
IDENTIFIERS Hands on Science

ABSTRACT

Technology for Science is a National Science Foundation funded program that is developing and testing curriculum units for teacher materials built around a series of design-oriented science problems called "challenges," mainly for ninth-grade general and physical science classes. Technology for science challenges have a clear connection to science concepts, allow for multiple solutions, engage, and motivate students. Solutions must be low-tech and easy to make. Three-to-six week curriculum units have been created around the following topics: Motion and Measurement, Electricity and Magnetism, and Heat. In each unit, students define and research problems, collaboratively design and build solutions, present plans and results to classmates, and reflect upon their work. Each activity contains: concepts, materials, design challenges, and student assessment. (MKR)

Technology for Science
OVERVIEW OF THE PROJECT

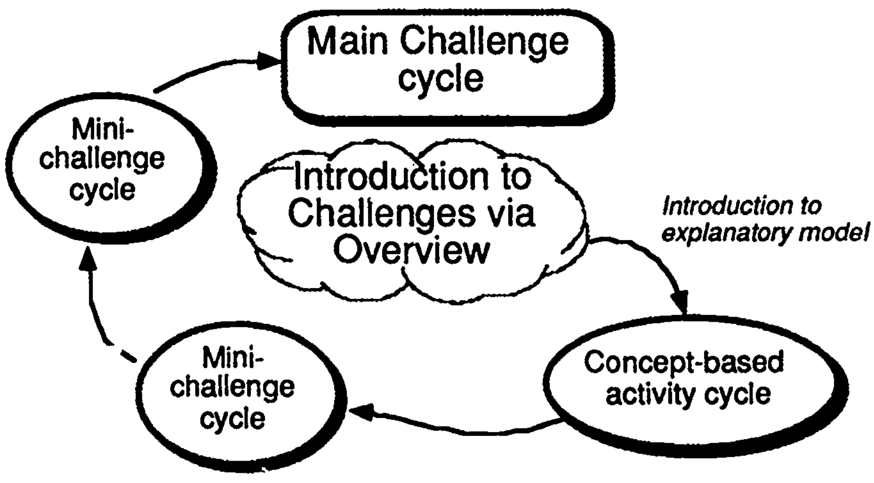
Contributors: David Crismond, Earl Carlyon, Jerry Touger, and Riley Hart.
For more information contact: David Crismon (David_Crismond@terc.edu)

Technology for Science is an NSF-funded program that is developing and testing curriculum units and teacher materials built around a series of design-oriented science problems called "challenges," mainly for ninth grade general and physical science classes. In each unit, students define and research problems, collaboratively design and build solutions, present plans and results to classmates, and reflect upon their work. In the service of learning science, students do four kinds of designing: they design measuring instrument, testable models, "fair test" experiments, and solutions to challenges. Teachers assess students' work through small and large group oral presentations, product evaluation, and written responses to student activity sheets, as well as more traditional testing methods.

Design challenges provide motivation for students and a meaningful context for grappling with key ideas in science. Technology for Science challenges have a clear connection to science concepts; allow for multiple solutions; engage and motivate students. Solutions must be low-tech and easy to make. Three-to-six week curriculum units have been created around the following topics: measurement & motion ("Paper Helicopter"); heat ("Emergency Solar Shelter"); electricity & magnetism ("Electric Capacitor Car").

WHAT IS CONTAINED IN A UNIT?

Every unit being produced by the Technology for Science team starts with a design sheet or "brief" that introduces students to the context, constraints, and goals of the challenges students will attempt to solve.



After encountering the challenges, students learn the concepts they need to solve them through a wide range of early activities, including mini-challenges, student-designed experiments, a "catalog of experiments," taking-things-apart activities, explain-it and explore-a-home activities, as well as teacher-led lessons. The series of mini-challenges leading to the main challenge that then follow are designed to reach a middle ground between student-defined projects, which tend to lack closure and be divergent, and traditional teaching, which often is restrictive for students. All activities are meant to focus on concepts, not on products or process skills alone. Students get feedback from peers and the teacher, and through self-reflection. Assessment is on-going, using non-directive, open-ended questions to identify prior conceptions and to monitor conceptual growth and change.

THE MOTION AND MEASUREMENT UNIT

This three-week unit immerses students in the practice of taking responsibility of asking and answering their own questions, making careful measurements, designing "fair test" experiments, and making alterations in the design of a engaging yet simple device. Students develop positive habits of mind as they work together designing ways to measure speed in a variety of contexts — water running from a tap, the swaying hands of different people while they walk, the descent of a paper helicopter students have built, and a speed of a living "critter" students have brought in to school. Students change the design of the paper helicopter so that it descends with reverse spin, and can operate under water. Throughout these activities, they are compelled to defend the meaning and accuracy of the numbers they obtain as they compare their values to those of their classmates.

CONCEPTS

The primary focus of this unit is on measurement -- how we find ways of measuring in open-ended situations and how we make sense of the numbers we obtain. Speed plays a central role as a concept that is easy to define but often substantially more difficult to measure in real-world contexts. Specific concepts covered include:

- unit conversion
- measurement, and limitations of measurement
- speed
- graphing
- orders of magnitude and significant figures
- estimation

MATERIALS

The Measurement and Motion unit has students working with common and inexpensive materials: rulers, timers, ticker tape, etc. We will provide you with a template for the paper helicopters.

THE DESIGN CHALLENGES

Four mini-challenges hone students' skills in measuring and thinking-about-numbers in anticipation of the main challenge. The mini-challenges are:

Tile City: Students are put in the position of an employee of a floor-tiling company who, lacking time for accurate measurement, must quickly assess the area of a space in order to give a customer an estimate. Calibrating one's pace is part of the task.

Running Water Speed: Students must find a way to measure the speed of running water from a faucet.

Hand Speed: Students must measure the speed of their hands as they walk, using PSSC-type ticker tape. They plot their data and look at the variability in speed versus time graphs.

Critter Speed: Students bring their own critters (insects, turtles, gerbils, etc.) to class and design experiments to measure their critter's speed. They must defend their observations to the class.

Paper Helicopter: In the main challenge, student groups are provided with a template on paper of a paper helicopter that they cut out and assemble. Students are intrigued by the fact that after initial instability, each descending helicopter quickly levels off to a steady speed. They are required to find a way of determining this speed, reach consensus on its value, identify factors (wing length, number and size of paper clips, etc.) that affect the speed, and see how the speed changes as each of these factors varies. They also modify the helicopter to reverse its direction or to have it perform underwater.

STUDENT ASSESSMENT

This unit's activities provide the teacher with multiple opportunities to obtain a detailed learning profile of each student: initial understandings, learning style, skills, mathematical strengths and weaknesses, etc. In addition to this *baseline assessment*, each activity is an opportunity to assess the students' progress. In this sense, the unit provides for *embedded assessment*. Beyond this, specific assessment tools include:

- **Student presentations** of their design solutions to challenges;
- Students provide **peer review** to each other with structured feedback after teams present their designs. The teams must then reflect upon and respond to their peers' comments and questions.

THE ELECTRICITY AND MAGNETISM UNIT

The five-to-six-week Electricity and Magnetism unit provides a hands-on, design-oriented approach to three main content areas: electrostatics and capacitors, electrical circuits, and generators and motors. Students design and build homemade capacitors, mystery circuits, and homemade generators. Finally, students build and attempt to optimize the performance of a motor-driven vehicle or "electric capacitor car" that uses a charged, high-capacitance capacitor as its only power source.

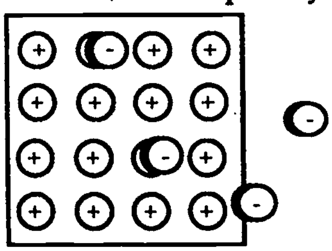
CONCEPTS

In preparing to solve the series of design challenges in the unit, students conduct a wide variety of activities to address the following specific concepts:

- a charged-particle model of matter;
- electrostatic forces, and how they determine the behavior of charged particles in conductors and insulators;
  the behavior of capacitors, batteries, bulbs, and switches in simple series and parallel circuits;
- magnetic induction;
- converting between mechanical input and electrical output in generators, and reversing the process in motors.

MENTAL MODELS

Electric Charge Bingo Cards: Manipulating Electric Charge Bingo Cards (pictured below) , developed by the Operation Physics program, helps students to picture the movement of charges in materials. Negative "electron" chips can be moved on and off the fixed sites of positive ions. Cards represent various elements in an electric circuit, and "electrons" can be moved between them. Especially powerful is the use of two Bingo cards to represent the two plates of a capacitor.



Role-Playing: Students take on the roles of electrons and circuit elements to experience kinesthetically the unseen events underlying their observations of circuits. Scenarios that students act out include charging a capacitor with a battery, then discharging the capacitor to light a bulb. After they act out each scenario, they write a description of an electron's experience. (See sample Activity Sheet: "Travels of Tron.")

MATERIALS

• The E&M unit uses primarily common, inexpensive materials: rulers, combs, fur, flashlight batteries, wires, magnets and simple construction materials.
• Technology for Science will provide tests sites with high-capacitance capacitors (0.5 F and 1.0 F), which discharge slowly enough to visibly light small bulbs. Also provided will be bulbs, sockets, LEDs, motors and a template for the Electric Bingo Cards.

DESIGN CHALLENGES

Four mini-challenges help prepare students to tackle the Electric Capacitor Car main challenge. They provide students with several design experiences and focus on a subset of the concepts that students will draw upon in solving the main challenge. The mini-challenges are to design and build a:

Capacitor: Each student group designs and builds a large capacitor, which they charge and discharge.

Special-Purpose Switch: Students choose to design and build either a switch for a sump-pump turned on at a particular water level, a switch activated by the step of a heavy person—but not a light person—, or a switch that turns on and off twenty times per second.

Mystery Circuit: Student groups design and build a complex, largely hidden circuit and then challenge other groups to identify the arrangement of all the components, based on the behavior of the visible components.

Generator: Students follow instructions to build a baseline generator; then they design and implement improvements to increase the current they can generate, to light an LED.

Electric Capacitor Car : In this main challenge, student groups are provided with plans and some materials for a model car, as well as a motor that can be run by a charged capacitor. Generators that the groups have built earlier will charge the capacitors. Groups design and implement improvements to their generators and cars so that the cars climb a ramp or travel a certain distance.

STUDENT ASSESSMENT

The multi-faceted student activity sheets are designed to provide teachers continually with information about students' understandings. They include the following assessment tools:

- Imaginative writing assignments emphasizing understanding of underlying models, for example describing the travels of an electron;
- Performance tests, such as designing new circuits and explaining what happens in them;
- Student presentations of their design solutions to challenges;
- Peer review: (see sample Activity Sheet) Students provide each other with structured feedback after teams present their designs. The teams must then reflect upon and respond to their peers' comments and questions.

THE HEAT UNIT

The five-to-six-week long Heat unit engages students in planning and a conducting experiments involving heating and cooling, and design-and-build a variety of devices, all with functions related to heat transfer and thermodynamics, including a winter glove, box for keeping hot food hot, a solar mirror and shower, and an emergency solar shelter. Students also work with a variety of measuring instruments, including thermally sensitive liquid crystals, bulb thermometers, and learn about and then use the kinetic theory to explain real-world events involving the flow of thermal energy.

CONCEPTS

This unit covers the concepts addressed in a traditional heat-and-temperature unit and some concepts related to solar energy. It also includes a brief treatment of optics related to the design of the solar collector. Specific concepts covered include:

- the fundamental elements of kinetic theory;
- the difference between heat and temperature;
- graphs of characteristic cooling and warming data;
- conduction, convection, radiation, and thermal equilibrium; and
- the relationship between surface-to-volume ratio to rates of cooling or warming.

THE DESIGN CHALLENGES

Four mini-challenge help prepare students to tackle the main challenge. They provide students with several design experiences and focus on a subset of the concepts that students will draw upon in designing their solar shelter. The challenges include:

Design a Glove: Students design a glove using two or more one-size-fits all vinyl gloves and insulating with various materials; they then develop a test to assess the effectiveness of this glove as compared to a traditional winter glove.

Design a Hot Food Storage System: Students design and build a storage system which will slow the cooling of hot food for as long as possible; they again test their system to evaluate its effectiveness.

Design a Solar Mirror: Students design and build a device which allows them to collect and concentrate the sun's energy for storage and later use.

Design a Solar Shower System: Students design a shower with a reservoir of water which will support a 3-minute shower, as well as a way to warm the reservoir to an acceptable temperature.

Emergency Solar Shelter System: In the culminating challenge of this unit, students design and build an emergency shelter system that will keep a single occupant warm and dry overnight, one that might be distributed by a relief organization like the Red Cross or Red Crescent in the wake of a disaster such as the 1994 Los Angeles earthquakes. In preparation for designing their shelter, students research the climate of the locale to which they will be tailoring their design. An effective shelter must rely upon the sun for all necessary energy; be cheap to make; be portable and easily assembled; and remain comfortable for its user both day and night.

STUDENT ASSESSMENT

Because the materials in the unit are rich and multi-faceted, the student assessment pieces aim to provide teachers with information about students' understandings of process skills and the design process as well as concepts. They include the following assessment tools:

- "Thought experiments," traditional tests which emphasize application of concepts and can be used as performance tests: For example, students answer questions about characteristic warming curves, matching descriptions of different situations in which a hot cup of liquid warms (e.g., in a cold room, in a warm room, etc.) to characteristic graphs.
- Performance tests: Students develop a "heat audit" of their school to determine how heat energy may be conserved more effectively.
- Student portfolios: Students individually analyze the physics of their "Hot Food Storage System"; this sheet is be compiled with other student work to provide an overview of each student's work over the course of the unit.
- Peer review: Students provide each other with structured feedback after teams present their designs. The teams must then reflect upon and respond to their peers' comments and questions.

MATERIALS & TECHNOLOGY

Students use fairly common materials when working through the heat unit: bulb thermometers, buckets, hot and cold water, empty soda containers of different sizes, candles, foil, small strips of different kinds of metals, vinyl gloves.

Technology for Science will provide test sites with "postcard thermometers," which contain liquid crystals that turn different colors at different temperatures. Because it is a two-dimensional rather than a one-dimensional measuring instrument, it can provide information not only about temperature but also about temperature gradients over its surface, helping to make the process of heat transfer visible.

FOR TEACHERS

We hope teachers will be able to use these materials to elicit and identify students' existing ideas about the phenomenon at hand. The materials are designed to be flexible enough to be easily adapted or adjusted to match the students' level of thinking about the phenomenon. They can be used to support students in a variety of ways which help them to re-think their understandings to take into account and explain new observations and experiences.

TEACHING STRATEGIES USED IN THESE MATERIALS

The emphasis of these materials is on close observation of phenomena, followed by testing of ideas and by small and large group discussions which help students to make sense of what they have experienced and to re-think past experiences in this context. Techniques include: teacher lecture; individual paper-and-pencil work; small and large group discussions; group work; and team presentations.