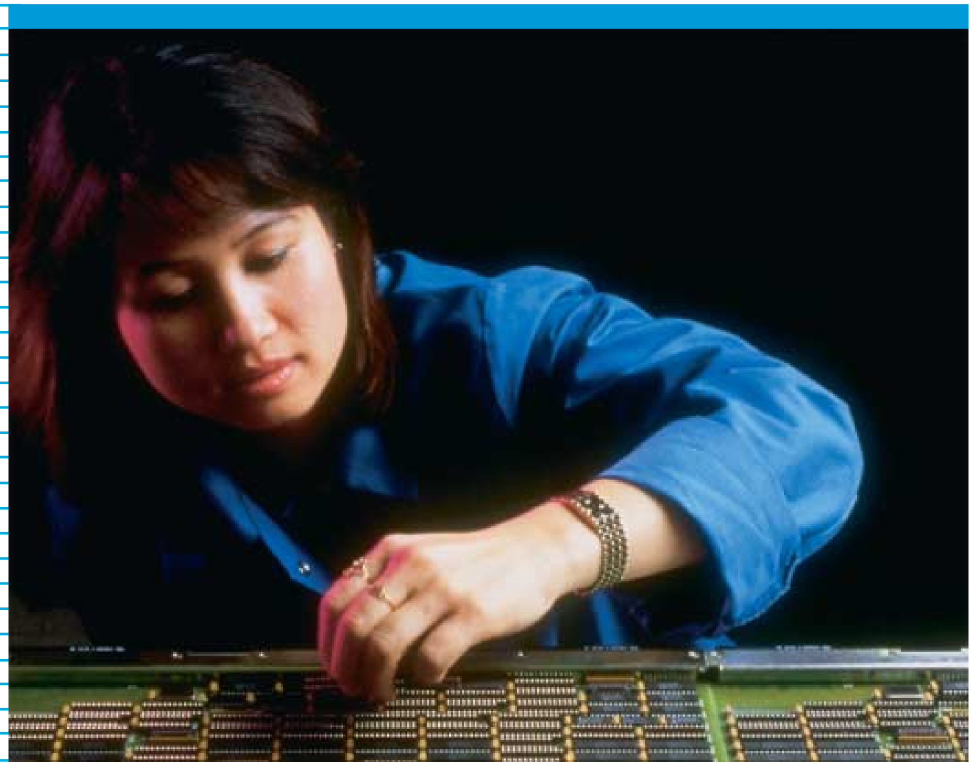
Teaching Technology: High School

Strategies for Standards-Based Instruction



Advancing Technological Literacy: ITEA Professional Series

Addendum to Standards for Technological Literacy: Content for the Study of Technology

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Table of Contents

Preface

This guide presents strategies and activities to aid teachers in preparing their students to be technologically literate. It is not intended to be a comprehensive high school curriculum. This guide is based on *Technology for All Americans: A Rationale and Structure for the Study of Technology* (*Rationale and Structure*) (ITEA, 1996) and *Standards for Technological Literacy: Content for the Study of Technology* (*Standards for Technological Literacy/STL*) (ITEA, 2000). Further guidance is provided through *A Guide to Develop Standards-based Curriculum for K-12 Technology Education,* (ITEA, 2000). Because these documents contain the fundamentals of technological literacy, teachers, supervisors, and teacher educators are encouraged to review them prior to using this guide.

Rationale & Structure for the Study of Technology

The *Rationale and Structure* provides a new vision for the study of technology. It addresses the power and promise of technology and the need for every American student to be technologically literate by the time he/she graduates from high school. Understanding the nature of technological advances and processes and participating in society's decisions on technological issues is of utmost concern. The document, prepared by the International Technology Education Association's (ITEA) Technology for All Americans Project (TfAAP), outlines the knowledge, processes, and contexts for the study of technology.

Executive Summary of Standards for Technological Literacy

What is *Standards for Technological Literacy*?

ITEA and TfAAP published *Standards for Technological Literacy* in April 2000. It defines what students should know and be able to do in order to be technologically literate and provides standards that prescribe what the outcomes of the study of technology in grades K-12 should be. It does not, however, put forth a curriculum to achieve these results. By setting forth a consistent content for the study of technology, *Standards for Technological Literacy* provides a structure to help educators deliver an effective education about technology for all students.

Why is *Standards for Technological Literacy* important?

- Technological literacy enables people to develop knowledge and abilities about human innovation in action.
- *Standards for Technological Literacy* establishes the requirements for technological literacy for all students — kindergarten through grade 12.
- *Standards for Technological Literacy* provides qualitative expectations of excellence for students.
- Effective democracy depends on all citizens participating in the decision-making process. Because so many decisions involve technological issues, all citizens, therefore, need to be technologically literate.
- A technologically literate population can help our nation maintain and sustain economic progress.

Who developed *Standards for Technological Literacy*?

Teams, committees, and various groups of educators, engineers, technologists, and others appointed by ITEA developed *Standards for Technological Literacy*. This process spanned more than three years and produced six drafts of a document, which was reviewed by educational professionals using mail and the Internet, as well as hearings at workshops around the country. Additionally, the document was submitted for field review to more than 60 schools nationwide. More than 4,000 people were involved in this review process. The National Research Council and the National Academy of Engineering contributed significantly to the review process for *Standards for Technological Literacy*. After an extensive review process, members of these organizations provided feedback that added important credibility to the document.

What is the vision of *Standards for Technological Literacy?*

All students can become technologically literate.

What are the guiding principles behind *Standards for Technological Literacy?*

The standards and benchmarks were created with the following guiding principles:
- They offer a common set of expectations for what students should learn in the study of technology.
- They are developmentally appropriate for students.
- They provide a basis for developing meaningful, relevant, and articulated curricula at the local, state, and provincial levels.
- They promote content connections with other fields of study in grades K-12.
- They encourage active and experiential learning.

Who is a technologically literate person?
A person who understands — with increasing sophistication — what technology is, how it is created, how it shapes society, and in turn is shaped by society is technologically literate. He or she can hear a story about technology on television or read about it in the newspaper and evaluate the information intelligently, put that information in context, and form an opinion based on it. A technologically literate person is comfortable with and objective about the use of technology — neither scared of it nor infatuated with it.

Technological literacy is important to all students because they need to understand why the study and use of technology is such an important force in our economy. Anyone can benefit by being familiar with it. Everyone — from corporate executives to teachers, from farmers to homemakers — will be able to perform their jobs better if they are technologically literate. Technological literacy benefits students who will choose technological careers — future engineers, aspiring architects, and students from many other fields. They can have a head start on their future with an education in technology.

What should students know and be able to do?
Standards for Technological Literacy presents the content (knowledge and abilities) needed by students in grades K-12 to become technologically literate.

What is included in *Standards for Technological Literacy*?
The document includes 20 standards that specify what every student should know and be able to do in order to be technologically literate. The benchmarks that follow each of the broadly stated standards at each grade level articulate the knowledge and abilities that will enable students to meet the respective standard. A brief summary of the content standards and benchmarks is presented in the Compendium of Major Topics for *Standards for Technological Literacy* .

ITEA Center to Advance the Teaching of Technology and Science (ITEA-CATTS)

The International Technology Education Association-Center to Advance the Teaching of Technology and Science (ITEA-CATTS) was created in July 1998 to provide professional development support for technology teachers and other professionals interested in technological literacy. ITEA-CATTS initiatives are directed toward four important goals:

1. Development of standards-based curricula
2. Teacher enhancement
3. Research on teaching and learning
4. Curriculum implementation and diffusion

The Center addresses these goals to fulfill its mission to serve as a central source for quality professional development support for the teaching and learning of technology and science. Teachers, local or state supervisors, and teacher educators are encouraged to become familiar with the offerings of ITEA-CATTS and how the organization will provide additional support as *Standards for Technological Literacy* is implemented.

ITEA-CATTS Consortium

The ITEA-CATTS Consortium, which was established as part of ITEA-CATTS, forms professional alliances in order to enhance teaching and learning about technology and science. Consortium members receive quality products and services specific to their local and professional development needs.

Using this Guide

This guide contains a compilation of strategies, activities, and resources for teaching technology at the high school level. The document will assist teachers in preparing to implement *Standards for Technological Literacy.* In addition, state, provincial, and local curriculum developers can use it for creating standards-based curricula.

Chapter 1 will help teachers understand and use strategies that are basic to technological studies, many of which are used frequently throughout the study of technology.

Chapter 2 contains a variety of student activities that may be used in any laboratory-classroom setting, including a general laboratory-classroom, a modular laboratory-classroom, or any combination thereof. Some activities are designed to last from two to three weeks, while others require four to six weeks to complete. The use of alternative assessments is discussed in Chapter 1 as a method, while Chapter 2 offers suggestions to help guide teachers as they implement the activities.

Chapter 3 contains descriptions of resources, materials, and references that teachers may obtain as they develop curricula and instructional materials. Summaries of other activities developed through major research projects funded by NASA, NSF, and other agencies are also included.

Technological Studies and Technology Education

The term "technology education" is often misunderstood or not completely recognized as the study of technology as presented here and in *Standards for Technological Literacy*. The use of the term "technological studies" is, therefore, intended to help bring clarity to the study of technology in technology education laboratory-classrooms. The use of the term "technological studies," which has proven to be effective in explaining the subject matter, is not intended to replace or supplant the term "technology education."

Compendium of Major Topics for Standards for Technological Literacy: Content for the Study of Technology

Standard	Benchmark Topics Grades K-2	Benchmark Topics Grades 3-5	Benchmark Topics Grades 6-8	Benchmark Topics Grades 9-12
Nature of Technology				
Standard 1: The Characteristics and Scope of Technology	• Natural world and human-made world • People and technology	• Things found in nature and in the human-made world • Tools, materials, and skills • Creative thinking	• Usefulness of technology • Development of technology • Human creativity and motivation • Product demand	• Nature of technology • Rate of technological diffusion • Goal-directed research • Commercialization of technology
Standard 2: The Core Concepts of Technology	• Systems • Resources • Processes	• Systems • Resources • Requirements • Processes	• Systems • Resources • Requirements • Trade-offs • Processes • Controls	• Systems • Resources • Requirements • Optimization and Trade-offs • Processes • Controls
Standard 3: The Relationships Among Technologies and the Connections Between Technology and Other Fields	• Connections between technology and other subjects	• Technologies integrated • Relationships between technology and other fields of study	• Interaction of systems • Interrelation of technological environments • Knowledge from other fields of study and technology	• Technology transfer • Innovation and Invention • Knowledge protection and patents • Technological knowledge and advances of science and mathematics and vice versa
Technology and Society				
Standard 4: The Cultural, Social, Economic, and Political Effects of Technology	• Helpful or harmful	• Good and bad effects • Unintended consequences	• Attitudes toward development and use • Impacts and consequences • Ethical issues • Influences on economy, politics, and culture	• Rapid or gradual changes • Trade-offs and effects • Ethical implications • Cultural, social, economic, and political changes

Standard	Benchmark Topics Grades K-2	Benchmark Topics Grades 3-5	Benchmark Topics Grades 6-8	Benchmark Topics Grades 9-12
Technology and Society, continued				
Standard 5: The Effects of Technology on the Environment	• Reuse and/or recycling of materials	• Recycling and disposal of waste • Affects environment in good and bad ways	• Management of waste • Technologies repair damage • Environmental vs. economic concerns	• Conservation • Reduce resource use • Monitor environment • Alignment of natural and technological processes • Reduce negative consequences of technology • Decisions and trade-offs
Standard 6: The Role of Society in the Development and Use of Technology	• Needs and wants of individuals	• Changing needs and wants • Expansion or limitation of development	• Development driven by demands, values, and interests • Inventions and innovations • Social and cultural priorities • Acceptance and use of products and systems	• Different cultures and technologies • Development decisions • Factors affecting designs and demands of technologies
Standard 7: The Influence of Technology on History	• Ways people have lived and worked	• Tools for food, clothing, and protection	• Processes of inventions and innovations • Specialization of labor • Evolution of techniques, measurement, and resources • Technological and scientific knowledge	• Evolutionary development of technology • Dramatic changes in society • History of technology • Early technological history • The Iron Age • The Middle Ages • The Renaissance • The Industrial Revolution • The Information Age
Design				
Standard 8: The Attributes of Design	• Everyone can design • Design is a creative process	• Definitions of design • Requirements of design	• Design leads to useful products and systems • There is no perfect design • Requirements	• The design process • Design problems are usually not clear • Designs need to be refined • Requirements
Standard 9: Engineering Design	• Engineering design process • Expressing design ideas to others	• Engineering design process • Creativity and considering all ideas • Models	• Iteration • Brainstorming • Modeling, testing, evaluating, and modifying	• Design principles • Influence of personal characteristics • Prototypes • Factors in engineering design

Standard	Benchmark Topics Grades K-2	Benchmark Topics Grades 3-5	Benchmark Topics Grades 6-8	Benchmark Topics Grades 9-12
Design, continued				
Standard 10: The Role of Troubleshooting, Research and Development, Invention and Innovation, and Experimentation in Problem Solving	• Asking questions and making observations • All products need to be maintained	• Troubleshooting • Invention and innovation • Experimentation	• Troubleshooting • Invention and innovation • Experimentation	• Research and development • Researching technological problems • Not all problems are technological or can be solved • Multidisciplinary approach
Abilities for a Technological World				
Standard 11: Apply the Design Process	• Solve problems through design • Build something • Investigate how things are made	• Collecting information • Visualize a solution • Test and evaluate solutions • Improve a design	• Apply design process • Identify criteria and constraints • Model a solution to a problem • Test and evaluate • Make a product or system	• Identify a design problem • Identify criteria and constraints • Refine the design • Evaluate the design • Develop a product or system using quality control • Reevaluate final solution(s)
Standard 12: Use and Maintain Technological Products and Systems	• Discover how things work • Use tools correctly and safely • Recognize and use everyday symbols	• Follow step-by-step instructions • Select and safely use tools • Use computers to access and organize information • Use common symbols	• Use information to see how things work • Safely use tools to diagnose, adjust, and repair • Use computers and calculators • Operate systems	• Document and communicate processes and procedures • Diagnose a malfunctioning system • Troubleshoot and maintain systems • Operate and maintain systems • Use computers to communicate
Standard 13: Assess the Impact of Products and Systems	• Collect information about everyday products • Determine the qualities of a product	• Use information to identify patterns • Assess the influence of technology • Examine trade-offs	• Design and use instruments to collect data • Use collected data to find trends • Identify trends • Interpret and evaluate accuracy of information	• Collect information and judge its quality • Synthesize data to draw conclusions • Employ assessment techniques • Design forecasting techniques

Standard	Benchmark Topics Grades K-2	Benchmark Topics Grades 3-5	Benchmark Topics Grades 6-8	Benchmark Topics Grades 9-12
The Designed World				
Standard 14: Medical Technologies	• Vaccinations • Medicine • Products to take care of people and their belongings	• Vaccines and medicine • Development of devices to repair or replace certain parts of the body • Use of products and systems to inform	• Advances and innovations in medical technologies • Sanitation processes • Immunology • Awareness about genetic engineering	• Medical technologies for prevention and rehabilitation • Telemedicine • Genetic therapeutics • Biochemistry
Standard 15: Agricultural and Related Biotechnologies	• Technologies in agriculture • Tools and materials for use in ecosystems	• Artificial ecosystems • Agriculture wastes • Processes in agricul-ture	• Technological advances in agriculture • Specialized equipment and practices • Biotechnology and agriculture • Artificial ecosystems and management • Development of refrigeration, freezing, dehydration, preservation, and irradiation	• Agricultural products and systems • Biotechnology • Conservation • Engineering design and management of ecosystems
Standard 16: Energy and Power Technologies	• Energy comes in many forms • Energy should not be wasted	• Energy comes in different forms • Tools, machines, products, and systems use energy to do work	• Energy is the capacity to do work • Energy can be used to do work using many processes • Power is the rate at which energy is converted from one form to another • Power systems • Efficiency and conservation	• Law of Conservation of energy • Energy sources • Second Law of Thermodynamics • Renewable and non-renewable forms of energy • Power systems are a source, a process, and a load
Standard 17: Information and Communication Technologies	• Information • Communication • Symbols	• Processing information • Many sources of information • Communication • Symbols	• Information and communication systems • Communication systems encode, transmit, and receive information • Factors influencing the design of a message • Language of technology	• Parts of information and communication systems • Information and communication systems • The purpose of information and communication technology • Communication systems and sub-systems • Many ways of communicating • Communication through symbols

Standard	Benchmark Topics Grades K-2	Benchmark Topics Grades 3-5	Benchmark Topics Grades 6-8	Benchmark Topics Grades 9-12
The Designed World, continued				
Standard 18: Transportation Technologies	• Transportation system • Individuals and goods • Care of transportation products and systems	• Transportation system use • Transportation systems and sub-systems	• Design and operation of transportation systems • Subsystems of transportation system • Governmental regulations • Transportation processes	• Relationship of transportation and other technologies • Intermodalism • Transportation services and methods • Positive and negative impacts of transportation systems • Transportation processes and efficiency
Standard 19: Manufacturing Technologies	• Manufacturing systems • Design of products	• Natural materials • Manufacturing processes • Consumption of goods • Chemical technologies	• Manufacturing systems • Manufacturing goods • Manufacturing processes • Chemical technologies • Materials use • Marketing products	• Servicing and obsolescence • Materials • Durable or non-durable goods • Manufacturing systems • Interchangeability of parts • Chemical technologies • Marketing products
Standard 20: Construction Technologies	• Different types of buildings • How parts of buildings fit	• Modern communities • Structures • Systems used	• Construction designs • Foundations • Purpose of structures • Buildings systems and sub-systems	• Infrastructure • Construction processes and procedures • Requirements • Maintenance, alterations, and renovation • Prefabricated materials

Chapter 1

Methods for Teaching Technology: High School

Strategies for Standards-Based Instruction

Chapter 1

Methods for Teaching Technology: High School

Introduction

The primary purpose of this chapter is to briefly describe some of the most important and effective strategies to use in teaching about technology. These strategies, which are ideal for delivering content and providing alternatives to written tests, go beyond traditional lecture, demonstration, and testing to allow students opportunities to perform at higher levels and grow in their technological literacy. The teaching strategies included will allow students freedom to develop insights and discover knowledge beyond what has been taught. As a result, they will develop the ability to think for themselves and apply their thinking skills to a lifetime of learning in a technological society. While some of the strategies in this chapter are not technically considered teaching methods, each section within this chapter and general references to this chapter will refer to them as *methods* for the purpose of organization.

Scope of the High School Curriculum

Compared to middle school students, those in high school have the opportunity to study technology in more detail and with more sophistication. Certainly, students who enter high school without experience in technological studies will need an introduction to the general concepts of technology and its study. The curriculum and instruction in eleventh and twelfth grades generally provide more depth.

The breadth of the curriculum at the ninth grade level is a matter of articulation between the middle school curriculum and the high school curriculum. Much effort should focus on the school system's ability to document students' achievement of *Standards for Technological Literacy* throughout their school years. Such information is critical to the development of curriculum and instruction at the high school level. An introductory high school course is often offered to help ninth grade students learn about fundamental technological concepts. Just such a course has been recommended for the subject area of technology education. See *A Guide to Develop Standards-Based Curriculum for K-12 Technology Education.* Subsequent courses and instruction often become more detailed and specialized as depicted in Figure 1 below.

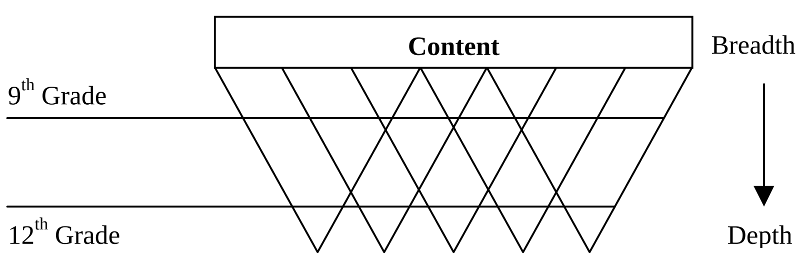


Figure 1: The scope of the high school curriculum.

Method 1— Achieving at Higher Levels

Overview

It is often difficult to "see the forest for the trees." Teachers who set out to help their students become more technologically literate set a course along which they may lead their students. With the publication of *Standards for Technological Literacy* and the related benchmarks, the job of the technological studies teacher becomes one of interfacing the curriculum with teaching and learning in the laboratory-classroom. In order to help students achieve higher levels of learning, objectives should be set for such achievement.

Suggestions for Achieving at Higher Levels

Indirect Instruction

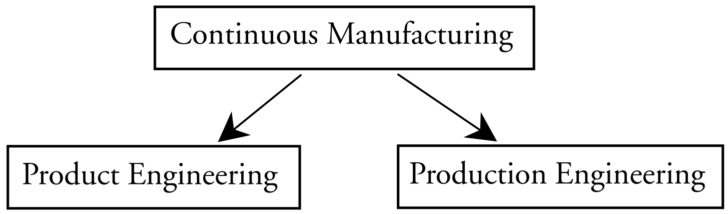
"Indirect instruction," a term that describes teaching for higher levels of learning (Borich, 2000), is very useful for teaching to the analysis, synthesis, and evaluation levels of learning. It leads to an understanding of concepts by generalizing and discriminating lesser concepts, information, and facts. While this is simply a reference to achieving at higher cognitive levels, the same can be said for higher-level achievement in the affective and psychomotor domains. All of the following are approaches to facilitating indirect instruction.

For more information on indirect instruction, see Borich (2000).

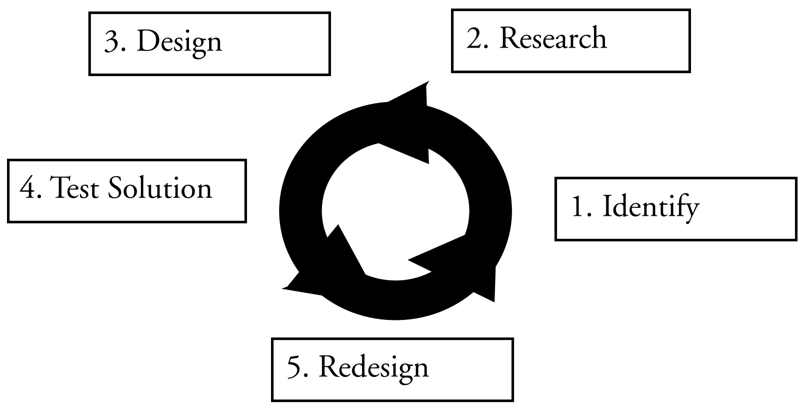
Advance Organizers

Advance organizers are graphics of what the class is going to learn in the lesson. The following three examples can be teacher-made, or students may develop them as lead activities.

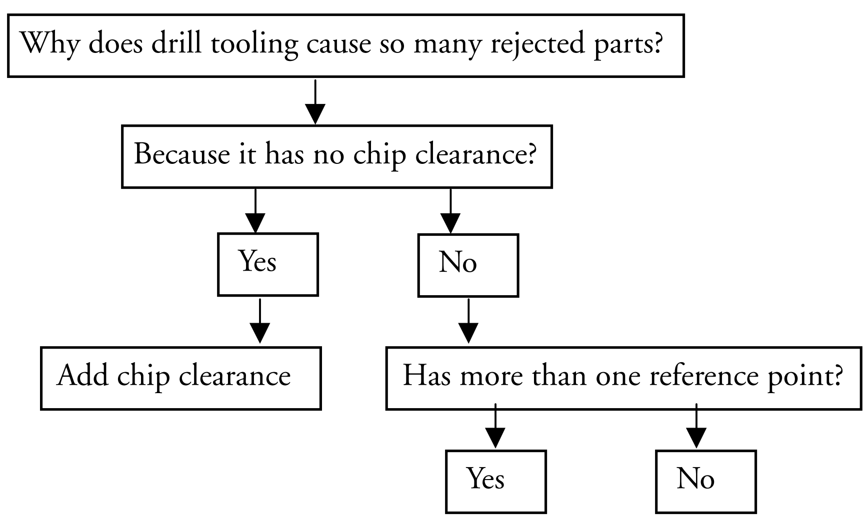
1. Conceptual



2. Problem centered



3. Decision making

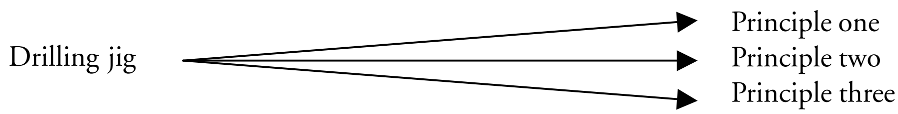


Reasoning

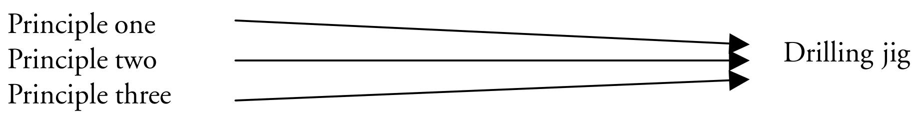
Encourage students to use reasoning by providing varied opportunities in the curriculum.

Types of Reasoning

Induction — using a specific instance to develop generalizations based on it. For example, students may study a drilling jig in *Engineering Design Fundamentals* and then identify some general principles of tooling design based on their observations, knowledge, and comprehension.

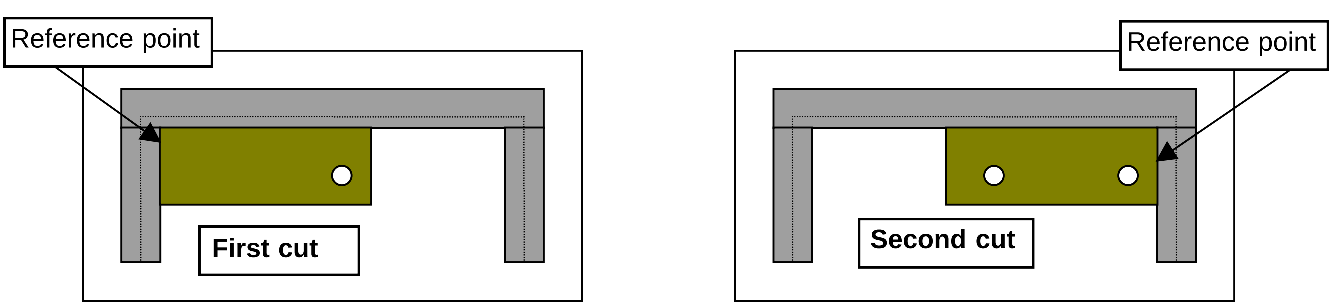


Deduction — involves relating generalizations to a specific instance. A manufacturing student might learn the principles of production tooling design and then synthesize them into a design for a specific operation—a drilling operation, for example.



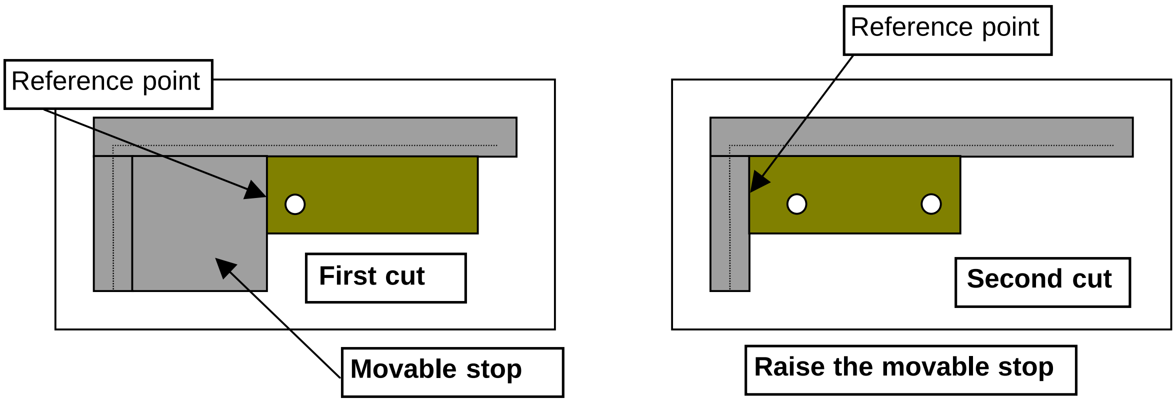
Examples and Non-Examples

Examples and non-examples help students sort through their knowledge by clearly differentiating what is correct and incorrect. The following drilling jig is poorly designed because it has two reference points. A reference point is the spot at which the product subassembly touches the stop on the jig. The stop allows a production worker to position a subassembly for cutting without having to measure. If the length of the parts varies slightly from product to product, and if two reference points are used, then the critical dimension, or the distance between holes, will also vary. If the distance between holes varies, other subassemblies cannot be fastened together with the holes.



The drilling jig above is a *non-example* because it is supposed to set the distance between drilled holes consistently. Two reference points will allow this distance to vary as the length of the stock varies from one product to the next.

The drilling jig below is correct and serves as the *example*. Because it has only one reference point, the distance between holes will not vary with the size of stock.



Questioning

Through questioning and discussion, teachers should encourage students to think. Since students are encouraged to think beyond simple facts and memorization, questioning used in indirect instruction is less structured and more open-ended than the questioning used in traditional instruction.

Traditional Instruction: "How can you tell that the tooling has more than one reference point?" By asking such a question, the teacher is actually giving away the answer or the most important or fundamental concept — the tooling has more than one reference point.

Indirect Instruction: "What seems to be wrong with the tooling?" With this type of question, the teacher was careful not to give away the answer.

When teachers are not sure that a student understands, they should ask guiding questions during indirect instruction.

Teacher: "What seems to be wrong with the tooling?"
Student: "The stop does not flip up for the second cut."
Teacher: "Why would the stop need to move for the second cut?"
Student: "So the product only touches one end of the tooling for drilling both holes."
Teacher: "Are there additional ideas to consider?"
Another Student: "It has two reference points at each end of the product. It should only have a stop at one end of the tooling."
Teacher: "Then what locates the second hole?"
Student: "The movable stop."

Capitalize on Student Ideas

Teachers can capitalize on what students know to move them to further learning. They should encourage students to focus on how much they know, rather than concentrating on where they are and where they need to go.

Student: "What if we put a hinge on the movable stop?"
Teacher: "Good thinking, this would reduce the time and skill required for a worker to drill the two holes. Let's design it."

Group Discussion

Group discussion can help students compare what they understand to what others understand.
It can give the teacher good opportunities to correct misconceptions and identify opportunities
to move students toward more sophisticated concepts. So that more students have opportunities to share ideas and compare understandings to others, teachers should use small group discussions. Students can form design groups using a list of design criteria in order to structure their deliberations about the production problem and examine possible solutions. Discussions may center on the application of tooling design principles to the tooling problem solution. Teachers should guide students in the use of the principles of tooling design in order to evaluate the feasibility of solutions. A representative from each group may present the group findings to the class, thereby providing for a more meaningful and manageable discussion as a larger group.

For more information on indirect instruction, see Borich (2000).

Purpose of Performance Assessment

Performance testing is perhaps the most authentic assessment method next to on-the-job performance and ultimately prospering as a citizen. Because students need to learn design concepts, they should participate in designing real-life products, processes, and solutions. By watching students use a given technology, teachers can determine their proficiency at using and controlling it. This performance assessment method allows teachers to get around typical problems associated with written testing — validity and reliability, for example. Performance can be measured during an activity that is set in a real-life context or in a formal setting. It can also be used to measure all levels of learning in the three domains of learning discussed in Chapter 1. Performance measures should initially center on that content (processes and products) specified in the standards and their related benchmarks.

Developing a Rubric

A rubric will provide teachers with an inventory of desired behaviors and guide them in making judgments regarding student achievement within a range of mastery. After developing the objectives and activities for a unit, teachers should develop a listing of desired behaviors and provide the performance criteria to students before starting instruction. The behaviors should be derived from the objectives considering the context of the activity and using the objective criteria (Custer, 1996).

The rubric illustrated on the next page uses the following objective examples:
Terminal Objective 1.1
Given necessary tools and materials, in addition to planning and background knowledge, the student will develop a working model of an aerodynamic vehicle that will improve in performance (speed) after it is analyzed and redesigned.

Enabling Objective 1.1
Given a piece of polystyrene, a piece of stock for a form, and a thermoformer, the student will form a vehicle body so that its surface is smooth and its profile is tapered and streamlined.

Enabling Objective 1.2
Given a computer controlled timing system, the student will measure the elapsed time required for the model vehicle to travel 25 feet according the testing protocol.

Enabling Objective 1.3
Given guidance on how to control variables in an experiment, students will change vehicle design parameters in a manner that will enable them to determine what change in design affected vehicle performance.

Technological Studies Performance Assessment

Foundations of Technology

Teacher: ______________________________ **Student:** ______________________________

Rubric for Aerodynamic Vehicle Design and Testing

Behavior	**Criteria Range**				
The Student:	**2**	**1**	**0**	**Weight**	**Subtotal**
Incorporated aerodynamics…	whenever possible	in some parts of vehicle	into no aspects of the design	x10	10
Incorporated thermoformed polystyrene…	whenever possible	in some parts of vehicle	into no aspects of the design	x15	30
Controlled testing procedure…	throughout time trials	during part of time trials	during none of time trials	x10	10
Controlled variables during redesign…	by changing one variable at a time	by changing 2 variables at a time	by not implementing changes	x10	20
Improved vehicle speed…	by more than one second	by less than one second	not at all	x5	10
				Total:	**80**

Teacher Comments:
Sherry, I was really proud of the way your design used streamlining in the front of the vehicle. Keep in mind, however, that you should also consider the turbulent flow that we detected in our wind tunnel. It revealed that streamlining the back of the vehicle body might also have been needed. Good work, though. Keep it up.

Developing Rubrics for Other Assessments

Portfolio Assessment
Teachers should develop rubrics to use when assessing students' portfolios. Some considerations for developing criteria for portfolio assessment are outlined in Chapter 1, Method 3: Design. Technological studies teachers and their students could adapt the portfolio assessment rubric below. The rubric should suit the content being studied and problems being solved.

Scale Criteria	1 Beginning to Attain Standard	2 Nearly Attained Standard	3 Achieved Standard	4 Exceeded Standard
Portfolio is aesthetically appealing.	Portfolio unit has few unintended mistakes in the way it is decorated and appears.	Portfolio unit has extra graphic and text elements that *accent* contents, provide an interesting look.	Portfolio unit has extra graphic and text elements that *accent* contents, provide an interesting look, and establish a format that carries over from one unit to the next.	Portfolio has format elements that improve the look and interest of the portfolio are drawn well, maintain the overall format, and are mistake free.
Portfolio is effectively organized.	Portfolio unit has broad categories that help the student to group design processes.	Portfolio unit has subheadings that further organize the design process.	Portfolio unit is organized in a way appropriate for the content being studied and has an appropriate amount of narrative explanation.	Portfolio is organized by a design process sequence, has appropriate narrative explanation, and is appropriate for the content being studied.
Portfolio includes thumbnail sketches of various design solutions to the problem.	Thumbnail or rough sketches are evident.	Portfolio includes thumbnail sketches of various design solutions to the problem at hand.	Portfolio includes thumbnail sketches of various design solutions, and at least one is related to the final solution.	Portfolio includes thumbnail sketches of various design solutions, and they illustrate a progression of idea development.
Portfolio includes technical sketches.	Technical sketches are evident.	Technical sketches are related to subsequent technical drawings.	All of those technical sketches necessary to communicate the solution idea are included and are scaled and proportional.	Portfolio has a complete *set* of sketches and each sketch is complete and follows conventions appropriate to the content area.
Portfolio includes orthographic drawings or those appropriate to the content.	Orthographic drawings are evident.	Orthographic drawings are related to subsequent pictorials and renderings.	All of those orthographic drawings necessary to communicate the solution idea are included and are scaled and proportional.	Portfolio has a complete *set* of orthographic drawings and each drawing is complete and follows conventions appropriate to the content area.
Portfolio includes pictorial drawings or those appropriate to the content.	Pictorial drawings are evident.	Pictorial drawings are related to subsequent pictorials and renderings.	All of those pictorial drawings necessary to communicate the solution idea are included and are scaled and proportional.	Portfolio has a complete *set* of pictorial drawings and each drawing is complete and follows conventions appropriate to the content area.
Portfolio includes a rendering of the solution.	Rendering is evident.	Rendering obviously depicts the actual solution.	Rendering obviously includes consideration of shape, form, color and texture.	Rendering looks realistic.

Physical Products

Teachers should develop rubrics or checklists to assess student projects. The criteria for the assessment are often determined, in part, by students when they set criteria for their developmental work.

Other Alternatives to Written Tests

Self-Assessment
Teachers should encourage their students to reflect on their own performance. For student self-assessment, teachers should ask individual students to compare perceptions of their own work to the guidelines and criteria that have been established. These criteria are those same elements that are identified by students as requirements. This process provides the teacher with an opportunity to "get inside" the

student's mind to assess things like creativity and metacognition. Self-assessment can be made a regular part of the student's portfolio, and teachers can include a checklist component or rubric, as well as a written narrative component.

Group and Peer Assessment

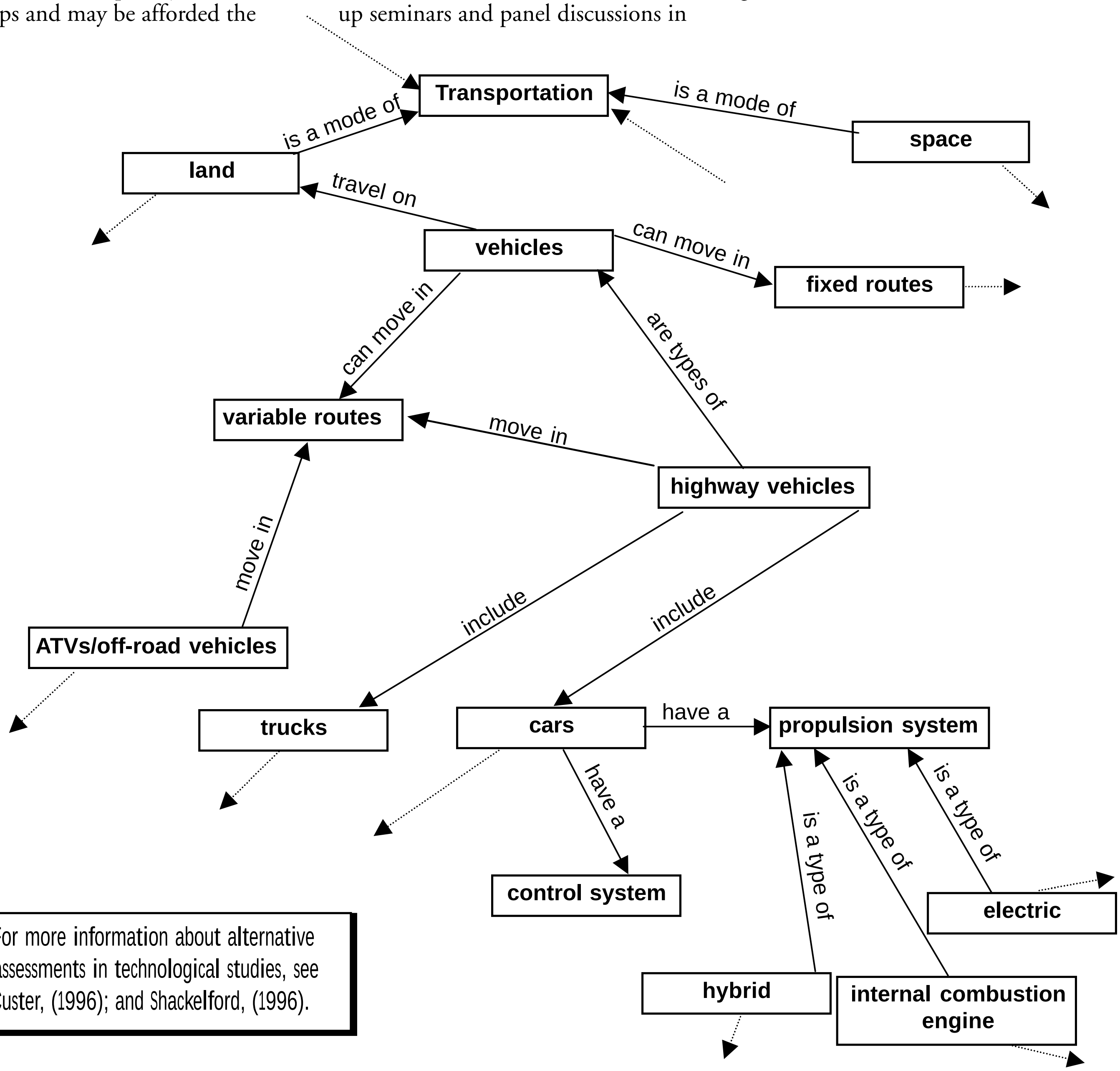
Students will frequently work in groups and may be afforded the opportunity to assess the achievement of their own groups. The criteria for assessment would focus on group dynamics, responsibility, organization, strategies, and presentations.

Seminars and Discussions

Teachers may also want to conduct informal assessments such as follow-up seminars and panel discussions in which students share their understandings and give everyone else a feel for the progress of the group as a whole.

Concept Mapping

Concept mapping may be used to determine students' understandings of the relationships within an area of study or across several fields. See Figure 2.



For more information about alternative assessments in technological studies, see Custer, (1996); and Shackelford, (1996).

Figure 2. Part of a concept map that students may develop in order to show their teacher how well they understand the world of transportation.

Method 2 - Cooperative Learning

Overview

Like most of the methods discussed in this chapter, cooperative learning is appropriate for advancing student understanding. In addition to helping students develop skills for social interaction, group planning, and decision making, cooperative group learning provides them with opportunities to apply strategies for research and problem solving. Cooperative learning occurs in small groups of four to six students, and classes may be divided into four or five separate groups. Depending on the assignment, all groups may work on the same task, or each individual group may work on slightly different tasks.

Characteristics of Cooperative Group Learning

Social Development
When students work together to solve a problem, demonstrate their learning, or research a question, they will build on their ability to collaborate within a team to work toward a common goal. Using cooperative group learning offers more authentic experience than does repeatedly making assignments to individual students. Furthermore, students will start to identify themselves as part of a group.

Synergy and Responsibility
Each group may have a specific task that contributes to a problem shared by the whole class. However, each student within a given group may have additional tasks for which he or she is responsible. The group members should consider each student's skill level in determining individual responsibilities to a group. For example, one student may be particularly good at computer aided design, a second student could be the group "expert" on library research, and yet another might be good at programming the CNC milling machine. By pooling their talents and by being accountable to each other, the cooperative group forms a synergy and is able to achieve at a higher level than one student may have achieved alone. The opposite approach could also have advantages. Students might be delegated responsibilities based on their individual limitations. This method would provide them with the chance to address their current weak points with their peers and the teacher.

Freedom to Think and Interact with the Content and Each Other
Cooperative group learning is an effective method to use when students conduct technological problem solving. Ill-structured, real-life, or other open-ended problems require students to reason with each other and to share their thoughts about identifying, implementing, and evaluating solutions. In the beginning, the teacher may provide guidelines and handouts to steer student interaction within groups. As students become accustomed to the cooperative process, the teacher should encourage them to develop their own group rules and strategies.

For further reading on cooperative group learning, see Borich, 2000 and Henak, 1988.

Suggestions for Conducting Cooperative Group Leaning

The following are some questions that will help in planning for cooperative group learning (Nickolai-Mays & Goetsch, 1986):

1. What abilities and knowledge do students have? What standards have students met?
2. What abilities and knowledge do they need? What standards do they need to meet?
3. How many students should be in each group?
4. How should students be selected? Is a synergy needed? Would simple groups be adequate?
5. How much guidance will students need to manage group interaction?
6. What documentation will be required of students?
7. What means of assessment will be employed?

The following are a few guidelines to follow when conducting cooperative group learning (Nickolai-Mays & Goetsch, 1986):

1. Provide each group with its own space to meet and work as a group.
2. Provide or require something for students to submit that provides frequent or intermittent feedback to the teacher regarding students' progress.
3. Begin each class with a review of the previous day's progress and provide an advance organizer or anticipatory set of expectations for the day's work. End each class with a summary of progress. Provide a seminar intermittently for groups to

summarize their progress, share findings, make suggestions, and get feedback.

4. Although open-ended and real-life problems require more time to solve than do structured, simple problems, the teacher should not allow too much time for the assignment at hand. Students will tend to lose direction and purpose.
5. Move from one group to another frequently.
6. Work with each group and each individual within a group to emphasize the curriculum content related to the standards and the instructional objectives. It is important that teachers explicitly teach students to transfer what they learned in the past to what they are currently learning. Teachers should not expect students to automatically apply concepts or to completely transfer knowledge on their own (Johnson, 1995).
7. Allow adequate time at the end of the class for cleaning and reorganizing the laboratory-classroom.

> For further reading on teaching for transfer, see Johnson (1995).

The following are some assessment considerations to make prior to cooperative group learning (Nickolai-Mays & Goetsch, 1986). (What means will be needed to observe, measure, and document students' achievement of specific objectives and standards?)

1. Consider individual, group, self, and peer assessments.
2. Consider how to assess group interactions and group processes, hands-on artifacts and products, actual problem solutions, and student presentations and demonstrations at the conclusion and during seminars.
3. Have students use a design portfolio for long-term assessment that will show the current cooperative learning assignment as a step in their pursuit of technological literacy.

Looking Inside the Classroom: A Cooperative Learning Snapshot

Ms. Thompson wanted her technological studies students to develop an understanding of the interaction of technology and an aging society. The first task that she presented to her students was to identify some of the problems that senior citizens face as they move from their 60s into their 70s. Before the students divided into their assigned groups, Ms. Thompson provided them with a handout that explained each group member's responsibilities.

- The **group leader** manages group discussions and delegates research assignments to the group members.
- The **recorder** keeps notes on the group's deliberations and research findings, and he or she helps the group members organize their work into portfolios.
- The **analyst** helps group members implement strategies for finding information about aging.
- The **presenter** helps summarize the research findings and presents a summary to the rest of the class.

The handout also gets the students started on the right track by suggesting some first steps for the way the group members interact. It suggests questions that the group can ask to decide how to continue with their research. For example:

- What sources should they use to find research?
- What terms should they use that will lead them to articles, books, and websites?
- What are some of the issues that relate to the aged?

> For further reading on teaching cooperative learning, see Nickolai-Mays & Goetsch, 1986.

Once they understood what their roles would be within the group and how they would get started, each group assembled at an assigned table in the laboratory-classroom.

In one group, for example, Adrianne was the leader. She went over the rules for planning discussion and said, "Speak one at a time, and be patient with each other." She started reviewing the list of responsibilities with the group. Because Caleba was the last person to complete the World Wide Web module in the technological studies laboratory-classroom, the group decided quickly that he would serve as the group's analyst. Cameron had just completed the multimedia module, so he was elected as the presenter, and because Davin had just finished a keyboarding class last semester with an "A," the group chose him as the recorder.

To get started with a research strategy, the students began going through the questions listed on Ms. Thompson's handout. Davin recorded the group's ideas on some notepaper. Then Ms. Thompson said, "Davin, once you all are finished recording your strategies, you might want to slide your table closer to computer number five. It's hooked up to the Internet." While she looked around the laboratory-classroom at the other groups, she asked, "Adrianne, what are some of the issues that your group has identified that relate to aging?"

Adrianne replied, “Well, we are just getting to that part of the work, but the one thing we thought of so far is that it is a problem if you are elderly and poor. Some elderly people get put in homes. Cameron was saying that when his grandmother was sick, they put her in a nursing home, and she got totally depressed.” “That’s exactly the sort of thing you should be researching,” replied Ms. Thompson, and then she went across the room to check on another group.

With their worktable pulled up right next to the computers, the group had room to spread out. Davin was at computer number four recording notes on the word processor, and Caleba was on computer number five browsing through the public library’s online catalog. He noticed one book on aging. Because her father did not mind taking her to the library, Adrianne volunteered to check the book out that evening. She also volunteered to interview her grandmother. Caleba began using a search engine to find more information on the World Wide Web, and he hit a “gold mine”— a website dedicated to designing housing for retired and elderly people. During this process, Cameron used some of the terms he and Adrianne identified to search in Ms. Thompson’s database of resources that are kept in the laboratory-classroom. He was able to find an article on community design in one of Ms. Thompson’s teacher journals.

Next, Caleba worked with Davin to get their notes recorded, and Adrianne took over the Web search. She found a site with an article about integrating medical technology into the houses of the elderly, the terminally ill, and patients who live in remote locations. “Telemedicine sounds like one possible solution,” exclaimed Adrianne. Ms. Thompson told Cameron that he should start taking notes on the community design article. She suggested that their group’s focus for the next step in the unit could be designing suitable living space for senior citizens.

Ms. Thompson then warned the groups that they had five minutes remaining before they had to arrange the furniture, computers, and books. She wanted to leave sufficient time at the end of class for each group to share their preliminary findings. Davin printed out the notes he kept of the work they accomplished in the last 40 minutes and let Cameron look over them. “In the next unit, someone else gets to be recorder,” Davin said. Adrianne reminded Cameron that he should be ready to develop the group’s brief multimedia presentation the next day, and she promised to have the results of the library research and interview. In the last five minutes of class, when it was Cameron’s turn to share, he told the rest of the class that his group had discovered that two big concerns for some poor seniors citizens were inadequate housing and lack of health care.

The next day Ms. Thompson led a discussion on the ways technology may cause problems for senior citizens and ways that technology might also improve or solve problems for senior citizens. She gave the groups 30 minutes to complete their research. After that point, she asked the groups to decide how to organize their findings for a formal presentation. During each presentation, Ms. Thompson led discussion on the problems that the groups identified. After she helped summarize the findings for the whole class, she announced that each group should take five minutes to decide what problems they would like to solve. Adrianne’s group decided to find ways to improve the housing problem of the elderly by trying to design a retirement community complete with telemedicine in each senior citizen’s home. During the rest of class that day, Ms. Thompson went from one group to the next to help each write design briefs that students would use in managing their technological problem-solving activity.

See Chapter 2 – all of the activities provide examples for opportunities to use cooperative group learning.

Method 3 - Design

Overview

A wide range of people conduct design activities throughout the course of any given day. Teachers frequently design instructional activities based on the learning objectives their students are expected to achieve. Engineers, for example, design new products, processes, and solutions based on the requirements, criteria, or parameters of the job. They apply mathematics and scientific principles to the development of a design. Frequently, they will use mathematical and computer models that inform the development process and predict the behavior of what is being created. Like most designers, engineers use iteration in the design process when they add an element to a design and then check the results against the parameters. Although the design processes used in various fields are very similar, a particular field may have unique standards and practices that need to be incorporated. For example, when production engineers design production tooling, they will apply a set of tooling design principles.

Any designer would be wise to consider the "big picture" when developing a design. Because designers can pool their expertise, working in groups can help to ensure that both *form* and *function* are considered. While a product can be made to look appealing, if it does not do what it is supposed to, no one will ultimately buy it. Sometimes people's lives depend on this balance. In architecture, for example, a beautiful balcony could be pleasing to the overall look of an auditorium, but if that balcony were to collapse during a movie, the results could be deadly. Architects and structural engineers often work together on such large projects.

Characteristics of Design

Design — a special form of communication, planning, reasoning and creativity — is an iterative developmental process and an inherent part of technological problem solving. Designers must consider many aspects of the design process and subsequently make some tradeoffs. Some considerations include:

- Functional requirements of the final process or product
- Aesthetic requirements of the design
- Standard weights and measures
- Standard specifications such as tolerances and allowances
- Conventions and styles that are unique to the field, such as can be seen in the differences between mechanical and architectural drawings. Regulations, such as zoning ordinances
- The amount of time and money that is dedicated to the design
- How the products of design will be used in the development process
- Technicians' use of the plans on the production floor (blueprints)
- Salespeople's use of plans to pitch an idea (renderings)
- Impact or interaction of the design on individuals, society, and the environment.

Suggestions for Teaching Design

Design will have more meaning for students if it is taught in the context of solving problems. In technological studies, design and technological problem-solving approaches go hand-in-hand.

1. Teachers should start with simple problems and work up to more complex, open-ended problems. Along the way, they may ask students to focus on how different design abilities help lead to an acceptable solution to the problem.

2. Designers must be able to work well with others. Because they must be able to focus their thoughts, designers typically apply specific techniques for focusing on a problem (Hutchinson & Karsnitz, 1997). Brainstorming, making preliminary sketches, and even "walking away" from a problem when stuck, are methods that help in generating design ideas. During the time when students are forming ideas about a solution, others should avoid criticizing strange sounding ideas. One student's idea may sound outlandish, but in the final analysis, part of his or her idea may have been a key to success. While some ideas may not be plausible, they may lead to others through association and analogy.

3. Students must have a certain level of understanding about the processes that characterize the context of the design problem. For example, if the students are

designing a new product to sell to consumers at department stores, they need to know how materials are changed using tools and machines, and they may need to understand concepts like "design for assembly." Students should be aware of a variety of materials and their various properties that are typically used in the field. If, for example, students are designing a residence for people with physical disabilities, they need some knowledge of medicine and ergonomics. Students acquire such knowledge in the context of design and technological problem assignments.

Communicating Designs

4. Students should develop over time the abilities and knowledge required to communicate their design.
   - Sketching is used in many ways. Casual doodling can be used at first to help remember ideas and to show others understanding of the basic concept. A progression of more sophisticated sketches follows this process. Techniques for good sketching are used, such as box construction.
   - Students should eventually be able to make a variety of pictorial drawings that help others visualize a design and to give the design form. Oblique, isometric, and perspective drawings depict a physical design in three dimensions.
   - For the purpose of providing a clearer idea of what a product will look like aesthetically, students can develop renderings using various sizes of markers and pens to give a design form, some color, and texture.
   - Students will need to learn basic orthographic drawing that will often provide a technician or an engineer with a clear understanding of a product's size and the locations of its details such as drilled holes and screw holes. They can learn techniques such as sectioning and auxiliary views, tolerances and allowances, etc. The same can be said for developing an understanding of architectural drawings. Floor plans, elevations, and other detailed drawings are combined into a package referred to as "working drawings," which contain all of the information needed to build something.
   - Students will also benefit from understanding three-dimensional modeling, various computer simulations, and various forms of technical and scientific visualization.
   - Students must develop verbal presentation skills. Group presentations of design processes can serve as culminating activities.

5. Students, like designers, will become better able to solve design problems if they can make models that represent products and processes. For example, if automobile designers want to see how a new car will look, they will develop a mockup. This kind of model does not function; it merely represents the form and appearance of the design. Several developmental models can be worked out, and students will apply a troubleshooting approach in trying to get the design to work like it is supposed to. Finally, when a design is chosen, a prototype will be made. The prototype looks and behaves exactly like the actual designed product once it goes into production.

Portfolio Development

6. Finally, students develop design portfolios. Their portfolios are not notebooks in which they write every thought or note. These notebooks do not necessarily have to be as appealing as one used by designers to show their best work. Students' portfolios may be a combination of a design portfolio and a means of communicating their achievement, growth, and insights to the teacher and their parents, in addition to future colleges and employers. The portfolio can show the processes that students conducted and the products they produced.
   - Establish a format for the portfolio. Each page can

For more information on design and portfolio development, see: Hutchinson and Karsnitz, (1997); Denton and Williams, (1996); Hutchinson, Davis, Clarke, and Jewett, (1989);and Singer and Ritz, (1995).

have a similar border, color, and title style.

- Students will need time to revise their portfolio organization and add their most recent work.
- The portfolio should look good.
- Portfolios may be organized by learning units or activities.
- Within the unit, some pages should represent the order and processes that students employed in developing design solutions. A separate page could be set up for each step in the process.
- Within the unit, the rest of the pages can show all of the outcomes and products that students developed through design, research, and other cooperative work.
- The portfolio will become a valuable reference for students over the span of their technological studies course.
- The portfolio should be evaluated after each unit of instruction.
- The portfolio should be maintained over the long term so that the students' growth can be observed.

See Chapter 1, Performance Assessment, for an example of a portfolio assessment rubric.
See Chapter 2, Activity 6 for a portfolio assessment rubric, but see all activities for examples of content that should be included in portfolios.

Method 4 - Technological Problem Solving

Overview

Any discussion of technological problem solving should also include ideas, such as discovery, research and development, and the use of design briefs. These methods should be planned to consciously address *Standards for Technological Literacy*. While a comprehensive system of teaching technological problem solving is useful in any technological studies course, such a practice will prove especially important in *Foundations of Technology* and *Engineering Design Fundamentals.*

Characteristics of Technological Problem Solving

Setting an activity in context is one of the most important characteristics of technological problem solving. The problem should be chosen based on its ability to address relevant standards that students need to learn. The context should not be fanciful or farfetched; rather, it should be based on real technology content. The idea behind using technological problem solving as a method of instruction is that students are provided the opportunity to apply, analyze, synthesize, and evaluate what was learned during previous activities. Using this method allows students the opportunity to *discover* new knowledge, develop critical-thinking skills, and manage their own learning. Also, it is a practical method for teaching very abstract concepts from other disciplines — science and mathematics, for example.

> For more information on technological problem solving in general, see Komacek (1995).

Suggestions for Conducting Technological Problem Solving

Many teaching materials and methods textbooks provide a variety of problem-solving models that teachers and students may follow. One model is shown in Figure 3 below. This stage model of problem solving shows in detail how the technological problem-solving process is iterative. Many of these models are linear and lead one to believe that problem solving is a lockstep process. However, this is not necessarily the case in real life. For example, an engineer might become involved in solving a problem related to a particular product at any point in the product's lifecycle. Perhaps a designer and an engineer conceptualized a passenger seat for an automobile. Later a problem is found with the design. A second engineer will have to fix the problem now that the seat is already installed in 100,000 automobiles.

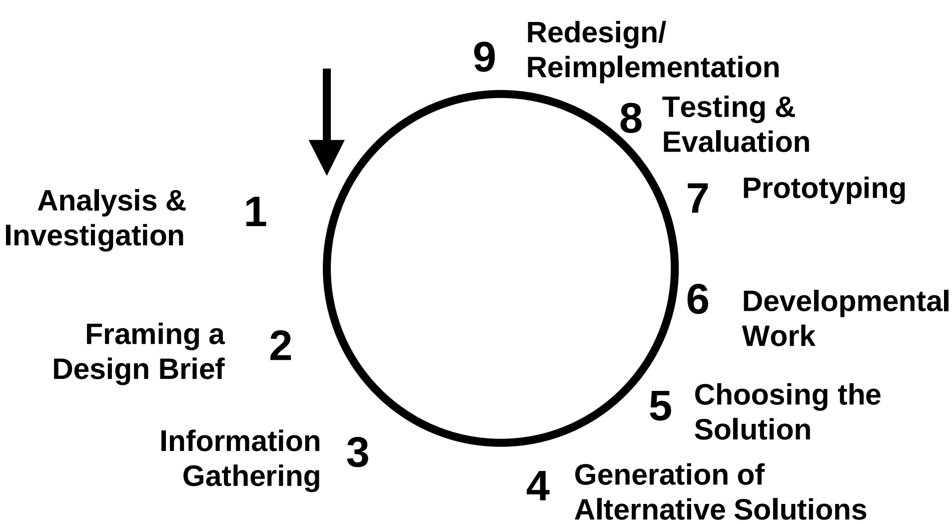


Figure 3: One Design Loop (Hutchinson, P., 1986).

> For more information on the design loop and technological problem solving, see: Hutchinson & Karsnitz (1997) and all Hutchinson references. Also, Todd, Todd & McCrory (1996).

For the model shown in Figure 3, the *first* step in the problem-solving process may be *redesign* or perhaps *testing and evaluation,* depending on the second engineer's point of view.

> For more information on what to explicitly teach students in technological problem solving, see Johnson (1994).

It is important for educators to encourage students to go beyond simply memorizing problem-solving steps. They need to reflect on their own thinking or develop strategies for navigating from one part of a problem to another. Following are suggestions on what to *explicitly* teach students in order to help them improve their problem solving (Johnson, 1994):

- Determine and sort information provided about the problem and information that may be missing about the problem.
- Encourage students to employ their senses in gaining information about the problem.
- Use a variety of resources to determine information that is relevant to the problem.
- Develop and/or use instruments to collect problem data and data from possible technological solutions.
- Make graphical models to simplify the problem.
- Plan and predict the behavior of solutions prior to implementing them.
- Encourage students to use inner speech and metacognition to control and be aware of their own logical thoughts and creative ideas.
- Identify and control variables to the problem.

A simple and effective model for technological problem solving proceeds in three phases: the **design** phase, the **construction** phase, and the **evaluation** phase (LaPorte & Sanders, 1996). If teachers use this basic procedure when their students are *engineering* various technological solutions to problems, they may provide continuity for students with problems that they will attempt throughout the school year.

> Examine *The Technology, Science, Mathematics Connection Activities* for a sample three-phase model for technological problem solving. See:
> LaPorte & Sanders (1996),
> LaPorte & Sanders (1995),
> LaPorte & Sanders (1993).

The design phase of technological problem solving emphasizes an engineering concept referred to as "design under constraint" — a recognition that real solutions to real problems must succeed in the face of limitations. Students conduct research, generate alternative solutions, and determine the criteria by which technological solutions will be judged.

The construction phase of technological problem solving involves students' implementation of their solutions. Students should have access to well-equipped technological laboratory-classrooms in which they are actively *doing* technology with tools and materials, as opposed to merely talking about their solutions.

The evaluation phase involves the collection of data through the observation of working solutions. Students should be afforded the opportunity not only to test, but also to *retest* their solutions after they have redesigned them. Because the main reason to test a solution is to improve and implement it, such an approach to technological problem solving is authentic. All too often, teachers stop after the first evaluation of the solution, which denies students the opportunity for an authentic experience, increased motivation, and learning across the curriculum.

The following is a checklist of some questions that may be used to help determine whether a technological problem and related instruction are feasible and appropriate to use with students (LaPorte & Sanders, 1993):

- Is the technological problem-solving activity directly correlated with specific curriculum content (and *Standards for Technological Literacy*)?
- Is the problem more practical than theoretical?
- Will students need to "design under constraint?"
- Will students have the opportunity to apply concepts throughout the process?
- Will students need to use tools and materials to implement

> For a more in-depth discussion on engineering and its relationship to technological studies, see Dugger (1994).
>
> For more information about engineering design related specifically to the teaching of science, mathematics and technological studies, see Frye (1997).

working technological solutions to the problem?
- Can there be several "right" answers to the problem?
- Are the requirements of the problem within the ability range of the students?
- Can the teacher manage the process and activity?
- Will students have time to test, redesign, and retest their solutions?

Many approaches to problem solving as a teaching method rightly emphasize cyclical processes, but they may also appear to over-emphasize that problem solving is a divergent thinking process *per se*. In order to develop creative thinking, divergent thinking should be emphasized. However, technological problem solving as it relates to engineering design processes is not strictly divergent in terms of student thinking. While the problem-solving process requires divergent thinking in the beginning, convergent thought and strategy are more appropriate once a plausible solution is developed and implementation is at hand. It is systematic and has a purpose.

Discovery

Discovery is the process of identifying new knowledge, insights, and realizations in the context of active modes of inquiry. For example, a discovery approach is used when students apply the scientific method to learn something new about the world.

When students do, in fact, have the freedom to explore learning beyond the explicitly taught content, they will learn additional concepts and skills with some guidance and structure. But students have to be active to accomplish this. Teachers should encourage them to "think outside the box." Discovery is a major recommended outcome for technological studies.

Research and Development

Research and development, a principal method used in technology education, became popular for the middle school when Maley (1973, 1986) described the processes of research and experimentation. However, this method may also be appropriate for high school students who have sufficient maturity and depth of knowledge to pursue specific areas of study related to the interests they have developed throughout their education. Research and development may be conducted in cooperative groups or as independent studies for individual students. One typical way to implement the method is through a capstone course in a technological studies program. The research and development method is a natural fit with courses such as *Engineering Design Fundamentals* and *Issues in Technology*.

All aspects of the processes used by students should be shared with the rest of the class in a regular seminar with a purpose similar to that described in a previous section of this chapter on cooperative learning. Research and development provides a means of discovering and observing technological content through the process of inquiry. The method emphasizes the importance of the inquiry process as a major focus of learning objectives for students.

In research and development, a student works with the teacher to establish a set of criteria to determine whether a problem or investigation chosen by the student will be appropriate. Two of the most important criteria in selecting a study are:

1. Will the student and the rest of the class benefit educationally from the student's study?
2. Does the study topic fit into the scope of the technological studies curriculum?

With the development of standards-based curriculum, an additional criterion should be:

3. Does the study topic address *a content standard* that has not yet been met or standards that have not been adequately met?

In the course, ***Issues in Technology***, students may conduct case studies of important technological innovations, disasters, or attempts at solving technological problems, such as Super Fund Clean Up. In ***Engineering Design Fundamentals***, students may conduct experiments and quasi-experiments which they can control, and they can manipulate variables to gain information about the behavior of a technology or system in order to improve it.

Design Briefs for Technological Problem Solving

Using design briefs is an effective way to introduce or frame a problem as an assignment. While design briefs may be highly structured and specific when they are used with a new class of students, they may provide less structure as students become more sophisticated. Students may even write their own design briefs. For example, a difficult-to-machine product in a manufacturing production run illustrates a very specific problem with a narrow scope. While there may be more than one correct solution to the problem, the exercise provides an example of a teaching method for a specific type of content. On the other hand, an example of a broad problem might involve the lack of adequate housing in a community, which could be solved by the application of broad content.

Suggestions for Writing Design Briefs

Background
Teachers should provide background information that helps provide a setting for the problem. While the background might include previously learned ideas and concepts, it might also include some things that students have not learned and need to know to understand the problem.

Context
Teachers are encouraged to provide a context in which the problem will exist. The context helps to answer a typical student question: "Why do we have to know this?" It provides relevance for the problem and the learning associated with solving it.

Problem Statement
The design brief should state a problem. Often solution ideas are confused with problems. For example, a problem occurs when a student confined to a wheelchair wants to gain access to a building with stairs only. A problem is often stated in these terms, "Build a ramp so that people in wheelchairs can gain access to a building." Such a statement implies a solution, not a problem.

Challenge
Teachers should present students with a challenge — a suggested course of action in solving the problem that may imply a direction for some solutions. Some design brief formats use the word challenge to describe the way in which students will test their technological solutions.

Requirements
The design brief may describe any limitations, constraints, and other requirements that the teacher wants placed on the problem solution. Design under constraint is a real-world skill that students should develop. Setting constraints is also useful in controlling an activity — setting size limitations on solutions or specifying ways in which solutions should be designed for safety, for example.

Objectives
The design brief should list objectives that identify the concepts students will learn as a result of the activity.

Assessment of the Solution
The design brief should either provide some description of how students should assess or test the success of their solutions or communicate that students are responsible for designing the assessment process.

Resources
The design brief may list various resources that are available to the students.

Assessment of Students
The design brief should list the ways in which students will be assessed on their performance and could include any assessment rubrics.

See Chapter 2, Activities 1, 2, 3, 4, and 5 for example activities that can capitalize on technological problem solving and see Activities 3 and 4 for design briefs that will help to structure technological problem solving.

Method 5 - Curriculum Integration

Overview

Curriculum integration is reported to have a number of benefits, and there is evidence that this method makes instruction and the curriculum more relevant for students (Brusic, 1991). The mathematics instructor who teaches concepts without setting their purpose in a real-life context will fail to show students how useful and important a subject can be. The same principle applies when students are developing technological literacy. Technology provides a good foundation for curriculum integration with other school subjects because it is easily related to real life and demands the use of knowledge and skills from many disciplines. Students are motivated in mathematics class when they learn the Pythagorean Theorem to estimate the altitude at which their model rockets flew. It is, therefore, important that technological studies classes be viewed as an equal partner in any curriculum integration effort.

Characteristics of Curriculum Integration

Curriculum integration can be approached in several basic ways. One approach is when technological studies teachers integrate the other subjects into their own instruction. The teachers are responsible for delivering the content — mathematics, social studies, science, language, etc. — that is relevant to the technology content. Teachers also deliver entire courses that are integrated with other subject areas. *Principles of Technology*, for example, is an entire course that integrates physics and technology. Materials that support the course are published, and teachers receive formal training to obtain certification to teach it. At the high school level, it is difficult for one technological studies teacher to successfully deliver sophisticated concepts from subject areas that are not part of his or her field of expertise or without considerable formal training. The total school approach is another method to accomplish curriculum integration. Every teacher in the school teaches lessons related to the theme that the school has chosen. Such approaches are effective for developing awareness and interest, although they may not be as effective for subject areas with little relevance to the chosen theme (Vars, 1987).

Although curriculum correlation is often the most viable approach for the high school level, it is not without obstacles. Correlation involves teachers from various subject areas addressing related concepts in their respective classes at approximately the same time (Vars, 1987). For example, in the *Engineering Design Fundamentals* course, technology students are learning about manufacturing and quality control. While they are learning about sampling products and analyzing the results of quality control, they are simultaneously learning about averaging, charting data, and interpreting statistics in their mathematics class. This approach requires the mathematics and technological studies teachers to plan what concepts will be taught. Ideally, they should have most students in common, and each teacher may need to alter the sequence of course instruction. Additionally, the teachers need support from the school administration to achieve the most favorable effect on student performance (LaPorte & Sanders, 1993). There are many ways to overcome correlation constraints. Some teachers may visit other classes when too few students are shared in common, while others may meet for planning after school or over the Internet. To optimize curriculum integration, planning should generally begin one year in advance and be supported by the administration.

> Examine The Integrated Mathematics, Science, and Technology Project's Teacher's Resource Binder for modules that facilitate curriculum correlation activities and are characterized as a "curriculum." See: IMAST

Suggestions for Conducting Curriculum Integration

Curriculum correlation is also an ideal approach for teaching *Foundations of Technology*. Teachers are encouraged to start curriculum integration with modest goals and then supplement the plan after the process gets going. This method, which will help teachers avoid frustration with logistical concerns and extra work, may include the following actions:

1. Begin by approaching one or two other teachers who teach related subjects and work well with others. Perhaps the mathematics and science teachers would be good partners for the first attempt.
2. Approach the principal and guidance department about arranging common planning

Examine *The Technology, Science, Mathematics Connection Activities* for planning models that facilitate curriculum correlation activities. See:
LaPorte & Sanders (1996)
LaPorte & Sanders (1995)
LaPorte & Sanders (1993)

time among the teachers involved, and make arrangements for two or three classes of students to be shared in common.

3. In deciding what concepts to begin teaching, teachers might identify concepts that students have had trouble learning in the past. If learning a specific mathematics concept will help technology students perform better at solving a particular technological problem, then that may be the starting point.
4. Choosing a theme is another way to begin planning curriculum correlation. A planning web or wheel (as well as other planning models) can be used to show how each subject's content relates to the theme. See Figure 4 below. (See also webbing to extend modules.)

A Planning Web for a Thematic Unit

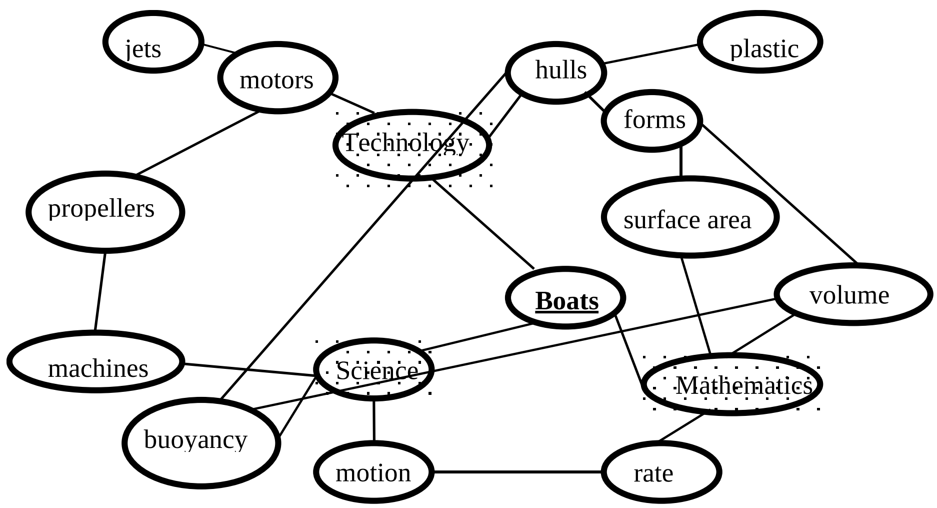


Figure 4. Planning Webs Help Teachers Identify Areas Where Content Overlaps.

In the figure above, the *Foundations of Technology*, mathematics, and science teachers have chosen a central topic or theme. They have included concepts from each subject that relate to the theme, and they have found where their subject areas overlap. In this case while the technology students are learning about boat hulls, the mathematics teacher can help them gain a better understanding of volume, and the science teacher can teach them about buoyancy. (Notice that the web implies that students could design better boat hulls if they understand these concepts.) Likewise, they will understand the concept of buoyancy if they also understand the concept of volume.

5. After identifying overlapping content, teachers should establish the sequence in which it should be taught. For example, if students need to know volume to understand buoyancy, the mathematics teacher should teach volume a couple of weeks before the science teacher addresses buoyancy. The technological studies teacher could begin instruction on boat hulls just after the science teacher begins teaching buoyancy, and the technology students could be learning other concepts about boat transportation along the way.
6. The teachers involved in curriculum correlation should meet regularly to monitor the progress of instruction related to the theme and to determine student achievement.

See Chapter 2, all activities provide examples of an activity that can be improved through curriculum integration.

Method 6 - Simulations, Games, Models, and Role Play

Overview

One criticism that John Dewey expressed was that education is very removed from real life. Most instruction in school is less authentic than many educators would prefer, and this characteristic applies even within the area of technological studies. There are several methods that teachers can use to make instruction more realistic. For example, when a student learns about manufacturing through an internship with a local manufacturer, the learning is based in a real life situation. Simulations, games, models, and role-play are methods that teachers can use when they are unable to provide real life activities such as internships. In addition to providing students with safe, affordable, and manageable experiences related to the learning at hand, these approaches can provide some concrete experience in the midst of abstract concepts. Simulations, games, and role-play are useful methods for *Technology Assessment* and *Issues in Technology*, while modeling is an excellent choice for teaching *Foundations of Technology* and *Engineering Design Fundamentals*.

Characteristics of Simulations, Games, Models, and Role-Play

Although educational games teach concepts, they are typically not authentic. Games usually have some context in which the players operate. For example, students can play the role of an entrepreneur and buy properties in a popular board game. Rules govern the way players perform in the game, including a set sequence of play and a points system to measure success. In the board game mentioned above, the amount of money acquired measures the degree of success. In such a context, games involve more than merely quizzing student teams on memorized facts while keeping score. Among other advantages, games can be useful in helping students learn processes and sequences related to the technological concepts they are studying (Johnson, 1988).

Although simulations are more lifelike than games, students are not actually conducting the process under simulation (Johnson, 1988). For example, many computer numerical control (CNC) systems provide graphical simulations that show how students' computer programs (G code) will machine the product without actually cutting any material. In such an instance, the simulation provides economical and safe feedback for students as they learn to operate a CNC machine. Students can run the simulation as many times as needed without spending too much time or money and without damaging the machine. Simulations can be physical and virtual, and they can include role-play in which students assume the responsibilities of people involved in the real-life process. By physically acting out the process in the class, for example, students across the country may simulate space travel without ever leaving the laboratory-classroom. The manufacturing enterprise is another important simulation offered by technological studies courses. Students might form a manufacturing company, raise capital, research and develop products, create packaging and marketing plans, develop production tooling, and produce and sell real products. Likewise, computer simulations can be used in electronics classes to simulate the behavior of circuits and in transportation classes to simulate flight.

> For a further explanation of games and simulations see: Johnson, I. H. (1988).

Like simulations, models take many forms. In mathematics, particular formulas and functions model both pure mathematical patterns and patterns that are observable in nature. Students can use modeling to represent biological processes. Models can be represented in graphic form such as charts and three-dimensional wire frame or solid images on a computer. Popular computer aided design (CAD) software packages now feature 3-D solid modeling. Many combinations of software can be used to represent models by applying several media — sound, color, and animation. Both computer simulations and computer models are convenient ways to see the results of design changes or changes to variables that students deduce are necessary in solving a technological problem. Finally, working models and prototypes are made from authentic materials to represent the way a technological solution will operate in the real world. For example, a student who is developing a safer automobile may design and construct a scale model of an automobile and use sensors and videotape to analyze its behavior during a crash test.

Suggestions for Conducting Simulations, Games, Models, and Role-Play

Games, simulations, and models provide students with a safe and economical opportunity to apply, analyze, synthesize, and evaluate concepts they have learned. These activities allow students to control variables in an experiment and to change design parameters with relative ease.

1. Depending on the instructional objective and the content that students are learning, a simulation, model, or game may be more appropriate than attempting the real-life process.
2. Simulations and models may be more appropriate when time and safety are concerns.
3. Using a simulation or model may not *necessarily* be the instructional objective over the long term; rather, these tools help students understand technological concepts.
4. Role-play is an effective way to encourage students to synthesize what they have learned about a process. For example, students learn how a manufacturing company functions through a series of learning activities. They could then role-play the running of a manufacturing enterprise. This is a good activity to simulate how all of the departments in a company work in unison.

For more ideas on how to incorporate models into technological studies, see the North Carolina Department of Public Instruction's Scientific and Technical Visualization I and II.

5. Finally, the teacher should assist students in developing a structure or means for relating the results of the simulation or model to the concepts they were supposed to learn.

See Chapter 2, Activities 1, 2, 3, 4, and 5 for examples of how simulations and models can be incorporated into technological studies.

Method 7 - Modular Instruction

Overview

Many technological studies programs use modular instruction as an instructional delivery system. In modular instruction, students are guided through a series of instructional units and conduct learning activities that are related to the units. A program that applies modular instruction as the primary means of instruction may provide students with an excellent opportunity to enjoy curriculum exploration, which develops interest and motivation. Typically, the units, referred to as "modules," are self-contained because the instructional materials contain everything that students may need through the sequence of instruction. In this environment, the teacher is more a facilitator of learning than the source of knowledge. Modular instruction is a reasonable approach for teaching *Foundations of Technology* at the high school level.

Characteristics of Modular Instruction

Because each module is different, modular labs may provide good curriculum exploration, which is very appropriate for first-year technology students. Typically, all of the media, tools, materials, supplies, and work areas are located in close proximity to the module in the laboratory-classroom. Teachers commonly purchase all of the modules and the associated resources from an educational vendor. The vendor typically provides the instructional materials that interface learning with the curriculum. A technological studies program may start out purchasing enough modules to allow as many as 10 pairs of students to study something different simultaneously. As student pairs rotate from one module to another on scheduled intervals, the teacher is able to monitor each pair and to provide guidance and feedback about research and problem solving.

While modular labs may provide excellent opportunities for exploration, they can lack sufficient depth and sequence needed for advancing students' technological literacy. Instruction in modular labs may not provide an adequate depth of knowledge, especially at the high school level. However, technological studies teachers can provide extensions to existing modules by developing materials that provide greater depth and sophistication, and they can add culminating activities that give student groups opportunities to apply what they learned in regular modules earlier in the school year. This approach would make modular laboratory-classrooms more appropriate for teaching the other three technological studies courses recommended by ITEA-CATTS.

Suggestions for Conducting Modular Instruction and Culminating Activities

1. Organization is the key to successfully teaching so many different areas of content to so many different students. Teachers must organize classes so that one student is responsible for each area of the laboratory-classroom. For example, each student pair would check the inventory of supplies and tools for their module at the end of each class, and then they would post the inventory at each module station. The resource area containing references and books would have an inventory that a student should check at the end of each class. The system must establish the sequence by outlining how students rotate through the modules and how each student's achievement is assessed and documented.
2. If teachers are providing instruction in previously developed modular laboratory-classrooms, they may have identified opportunities for enhancing, extending, adding, or changing modules. This may especially be true if they are in the process of implementing instruction that addresses *Standards for Technological Literacy*. Generally, a module is divided into "frames" of instruction — small sections or sub-units that address an objective. Each frame provides most of the information that a student needs to proceed with the unit. Typically, modules should:
   - Address one area of specific content
   - Divide a large topic into sub-topics or frames
   - Address a topic that lends itself to *how to* or sequential type activities
   - Take about two to five hours for an average reader
   - State an objective for each frame
   - Use terms the students understand
   - Use active terms (verbs, *doing* words)
   - List needed materials and supplies and where they are found

- Provide a brief introduction stating importance/relevance
- Have each frame organized in step-by-step fashion
- Prompt students on note taking for details/principles
- Provide graphics if necessary
- Provide videos to help guide students and provide content
- Provide audio prompting for computer-based modules that will help poor readers
- Provide self-evaluation at the end of each frame
- Prompt students to demonstrate skills to the teacher when needed
- Provide a brief summary
- Be easy to use
- Use 14 point type or larger
- Have numbered pages or slides
- Be durable
- Use correct grammar, spelling, etc.

Bridge Building Tips
by John Daly

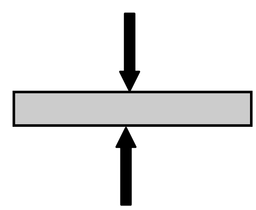
This presentation will give you some tips for designing and constructing your bridge.

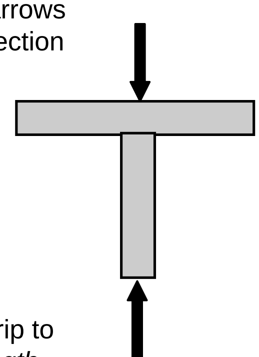
The first section explains the forces that will act upon your bridge. You need to understand those forces so you can design your bridge to handle them.

The second section gives you tips for cutting and gluing together the pieces of your bridge.

The force of
Compression

Compression is a force that squeezes. In the examples below the red arrows show the location and direction of the forces.

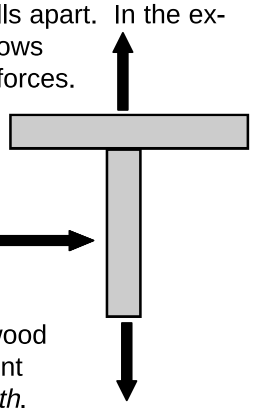




Squeeze a balsa wood strip to test its *compressive strength.*

The force of
Tension

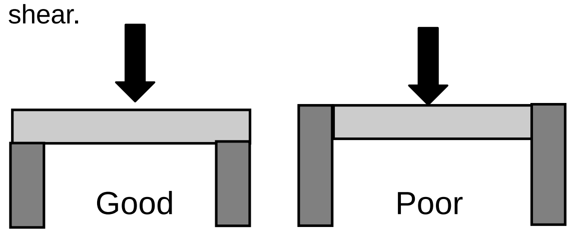
Tension is a force that pulls apart. In the examples below, the red arrows show the direction of the forces.



Try to pull apart a balsa wood strip and balsa wood T joint to test their *tensile strength*.

Tip: Think about ways to make your joints stronger.

When you plan how to glue a joint together, consider the forces that will act on the joint. In the examples below, the red arrow represents a load on the roadbed. The example on the left has the roadbed resting on the wood. That's stronger than the example on the right - where the roadbed will collapse when the glue joints shear.



John Daly (1999), a technology education teacher in North Carolina, developed the preceding as media slides in order to supplement the material included in an existing module. Daly developed about 19 slides for this supplement with a relatively easy-to-use presentation software package. While each slide is not numbered, students can use navigation buttons to move from one slide to the next.

3. The teacher can design culminating activities that require students to pool the talents and knowledge that they developed as a result of studying the modules. Teachers could begin to plan for such an activity using the webbing idea that was discussed in the curriculum integration section of this chapter. For example, in an *Engineering Design Fundamentals* problem to design and manufacture a product, one member of a cooperative group would have learned CAD at the CAD module. Another member would have learned CNC at the CNC module, and yet another group member may have studied an engineering design process at the engineering module. The students could have developed these capabilities in *Foundations of Technology*.
4. If the laboratory-classroom has only one round of modules, teachers can design and add a second level to a couple (or eventually all) of the modules. They can design each new module to take the student to a higher level of sophistication. Such a new module could borrow from the existing materials in the first module and use the same hardware.

See Chapter 2, Activities 1, 2, and 5 for examples of culminating activities and extensions to modular activities.

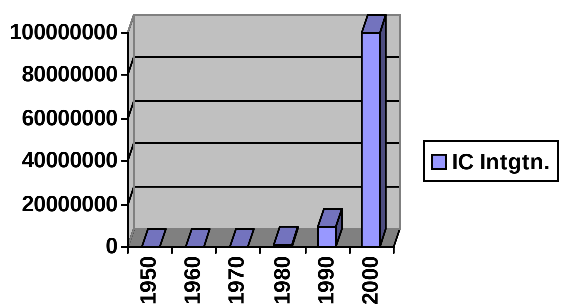
Method 8 - Technology Assessment

Overview

One of the fundamental purposes of technological studies is to help students develop technological literacy. Part of that literacy includes the ability to participate in the development and management of technology. "Technology assessment" is a term that describes a variety of techniques for determining the effects of the interaction of technology and society. Because the impacts of technology profoundly affect people's lives, it is important to be able to identify desirable and undesirable consequences of technological decisions. A prime example is the impact of the semiconductor on society and the spawning of the Information Age. People have used techniques for forecasting the influences of technological innovation for years. *Megatrends*, a popular book in the 1980s, used excerpts from newspapers to predict changes in the later years of the twentieth century (see also *Megatrends 2000*). Forecasting can focus on intended and unintended outcomes and emphasize both negative and positive outcomes. Two of the many techniques used to forecast the paths of technological development include normative forecasting and exploratory forecasting, both of which are highly appropriate for *Technology Assessment*.

Characteristics of Forecasting

Normative forecasting helps people determine a path to take in the development of technology in order to arrive at an ultimate goal. Basically, the path is comprised of a series of subordinate goals to achieve the ultimate goal. These subordinate goals may also branch off into alternative paths to the same destination (Whaley, 1987). The normative technique helps research and development teams, engineers, executives, and technologists make decisions and plan future strategies.



Exploratory forecasting helps people look into the future by using past and present conditions to predict future events and developments. The predictions in *Megatrends* were based on this basic approach (specifically content analysis) (Naisbitt, 1982). Exploratory forecasting involves identifying trends and extending them into the future (Whaley, 1987). Forecasting could certainly be accomplished by *drawing a graph* that shows the growth of the number of electronic components that can be placed inside of an integrated circuit. Such an exponential relationship can be based on past and present circuit integration, and the trend can be extended into the future right on the graph. Sometimes less statistical and mathematical approaches are used that depend on the expertise of people in the field. A Delphi Study is an example of an exploratory forecasting technique that depends on the professional opinions of experts in a given field.

Technology assessment may also involve the history of technological innovation. Creating a historical timeline of the development of various technologies is one conventional activity for students. Such a timeline should describe the product or system that the student has chosen to research, in addition to reporting the various influences of the innovation on society.

For more information on Technology Assessment see:
Naisbitt (1982),
Tidewater Technology Associates (1991),
Virginia Department of Education (1992),
Whaley (1987).

Suggestions for Conducting Technology Assessment

Before conducting a normative forecast, there must first be a reason to conduct it. Perhaps the students are researching the problem of urban sprawl, and they want to develop a sociological/technological solution to the problem. The primary goal is to reduce a city's geographic growth.

Normative Assessment Procedures

1. Identify the ultimate future goal.
2. Identify the relevant issues associated with the goal, which might be accomplished by pinpointing some of the problems associated with urban sprawl — gridlocked highways, abandoned buildings, etc. These problems suggest primary courses of action to take in reaching the ultimate goal.
3. Primary goals or courses of action, in turn, suggest additional secondary goals or courses of action, sometimes referred to as a "relevance tree" (Whaley, 1987). In a way, students work in reverse to establish a course of action for the future in order to reach the ultimate goal. Secondary goals are prerequisite to achieving primary goals as seen in Figure 5 below.
4. Developing a matrix will help students make decisions about what paths are feasible (Whaley, 1987). (See Figure 6.) Students may develop certain paths more than others. Depending on the instructional objectives or the scope of the lesson at hand, students working in cooperative groups may choose to focus on a specific technological course of action. One student group might work on the transportation-related part of the problem above, while another group might work on the building-related part of the urban sprawl problem. Developing additional paths can provide excellent opportunities to integrate technological studies with other subject areas.

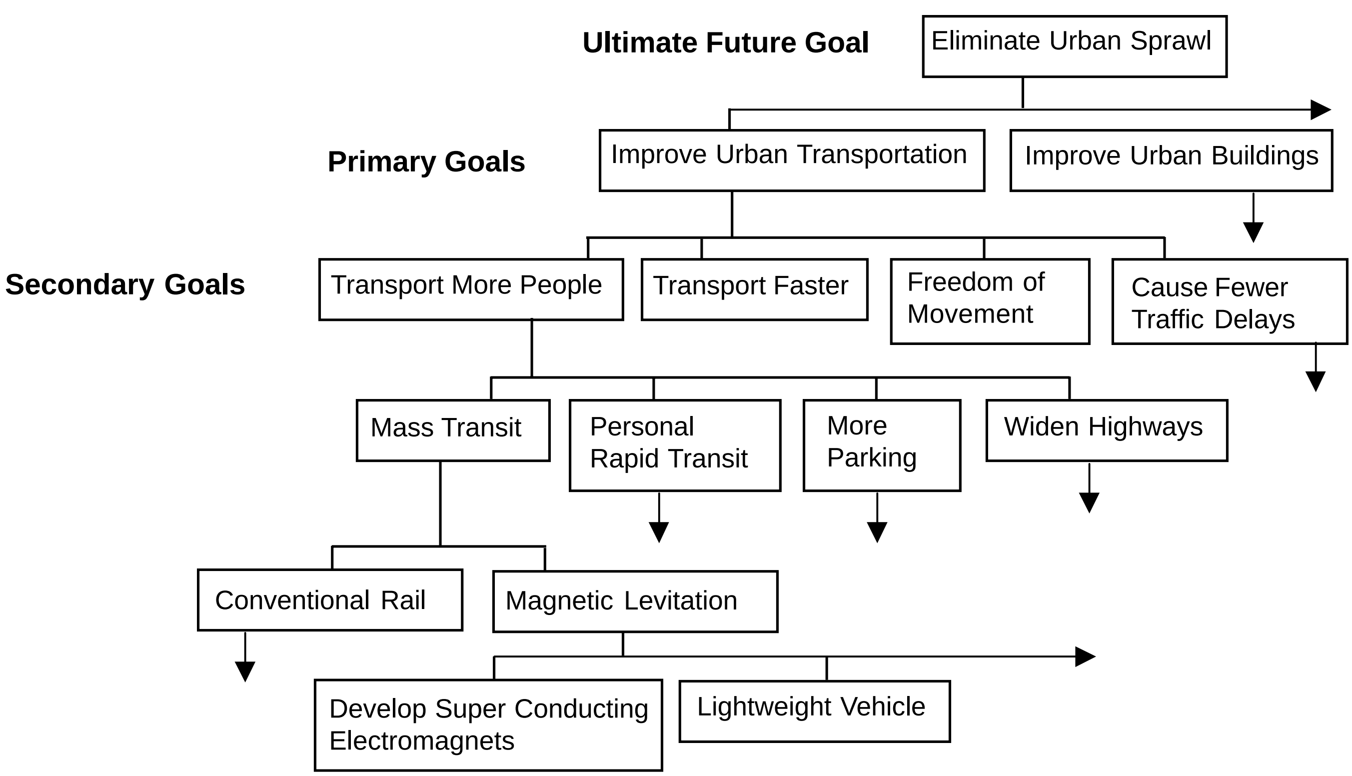


Figure 5. A Relevancy Tree With an Ultimate Goal, Primary Goals, and Secondary Goals.

Eliminate Urban Sprawl By Improving Urban Transportation

	Mass Transit	Personal Rapid Transit	More Parking	Widen Highways
Move More People	**yes**	**no** (limited passenger capacity)	**no** (would attract more cars to city)	**no** (would attract more cars to city)
Move People Faster	**yes**	**yes**	**no** (cars have lower speed limits)	**no** (cars have lower speed limits)
Freedom of Movement	**no** (go along track only)	**somewhat** (PRT vehicles can go to many different buildings)	**somewhat** (cars can go on any but must tear down buildings for parking lots)	**somewhat** (only so many highway routes can be constructed)
Fewer Traffic Delays	**yes**	**yes**	**no** (traffic jams)	**no** (traffic jams)

Figure 6. Students Develop a Matrix to Help Them Make Decisions About What Future Paths Are Feasible.

5. A flow diagram is developed from the relevance tree. It shows the steps needed to achieve the ultimate future goal via a path (Whaley, 1987). (See Figure 7 below.) It could be extended to include *intended, unintended, negative*, and *positive* outcomes.

Exploratory

Because there are many techniques for exploratory forecasting, teachers should choose the most appropriate one for the circumstances. However, a Delphi study will provide students with the chance to practice a statistical method, integrate with other subject areas, use an authentic practice, and correspond with experts in the field of study. For technology assessment, a Delphi study is used to survey a panel of experts regarding their professional opinions about future trends for the technology in question. Following are suggestions

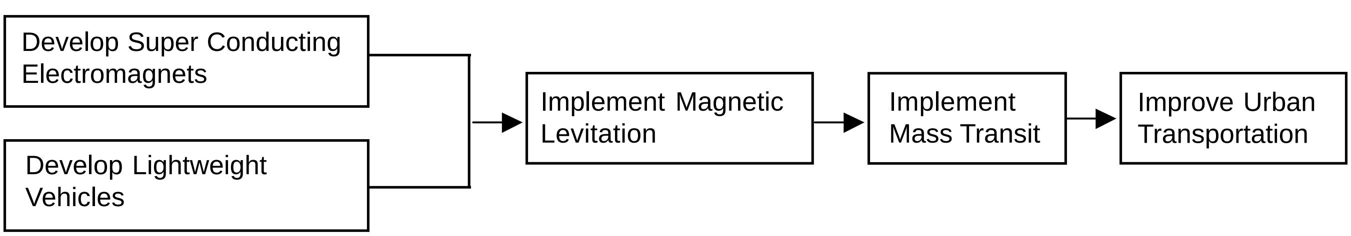


Figure 7. The Flow Diagram Shows the Steps to Take to Achieve the Future Goal.

on conducting the Delphi study (Whaley, 1987):

1. Develop an instrument or questionnaire that poses a number of questions related to the technology under assessment. Students will need to conduct research in order to be well educated on the past and current nature of the technology being assessed. Lead the students in some discussions that will help them construct understandings of the technology and the issues that are associated with it.
2. Ask a small team of people in the field to review the instrument to be certain that the questions are not too ambiguous or specific.
3. Through research and recommendations, identify the panel of experts and ask them to participate in the assessment. Such a panel should be comprised of at least ten people.
4. Send the instrument to the panel with a deadline for their responses — the first round of the study. The teacher may instruct the panel to make changes to the questions and suggest edits and additional questions that may be considered more relevant to the topic.
5. Implement the changes recommended by a majority of the panel members.
6. With the revised instrument, have panel members answer the questions or respond to the items.
7. When the panel returns its responses, each instrument is checked to see if some responses are similar across various items. If a majority of the panel members respond in the same manner, certain questions can be combined into one. Based on the responses, alter questions to make them more precise, and ask panel members to clarify their responses if necessary.
8. Send the questions out to be answered by the panel again. As the panel's responses become more consistent or some trends of agreement begin to emerge, list their predictions and ask the panel to rank them from most to least probable. This might happen as early as the fourth round.
9. Conduct discussions that help students relate the resulting predictions to their original understandings of the technology.
10. Have students present their results in a seminar.

Students may conduct Delphi Studies in cooperative groups that meet, perhaps, once a week as a long-term assignment. By providing students with access to experts in a particular field of interest, such an assignment would afford them an opportunity to conduct science in the context of technology. Correspondence with the public provides an opportunity to demonstrate the importance of good writing and language skills. Finally, correspondence could be conducted using the Internet, and alternatives to national experts could be used — local government officials, local industry leaders, local technicians and engineers, parents, and teachers in school.

See Chapter 2— all activities, and especially Activity 6, provide examples that could include technology assessment

Method 9 - Community-Based Learning

Overview

In some subject areas, community-based learning involves providing a real-life context to an activity. It can be much more than a context, however, because community-based learning can provide a real-life setting for learning. Community-based learning begins by establishing relationships with community partners — those people and organizations that share an interest in the success of the technological studies program. Such relationships will help to improve the program in every aspect. Field trips become more meaningful. Advanced students can gain access to internships. Resources for the program will begin to appear, and industry-based internships can be arranged to sharpen the teacher's skills and breadth of knowledge during the summer break. Although potential partners might include nationally known museums like the Henry Ford Museum or large corporations like Duracell, most will be local organizations. In either case, both will prove to be an ongoing benefit to the program.

Suggestions for Conducting Community-Based Learning

1. Develop a list of ways that community partners can help the program. These activities could range from having experts visit classes in order to help teach students and prepare them for student competitions to seeking funding for supplies and professional development.
2. Begin identifying potential partners through colleagues, parents, students, student club activities, and by networking in civic organizations and associations like the chamber of commerce.
3. Establish an advisory committee that includes parents and students, in addition to leaders from business, industry, academia, and the local government.
4. Identify the services that partners are willing or are able to provide for the program and take advantage of them.
5. Publicize the partnerships in the school newspaper, on the program's website, at parent visitation functions, in the state association newsletter, and in the local newspaper.
6. There is a variety of learning activities to conduct.
   - If funding and regulations prohibit students from visiting partners for a field trip, then arrange a virtual field trip via the World Wide Web. Whether students are visiting in person or over the Web, the teacher will want students to study the related technological concepts ahead of time and to develop a list of questions to be answered during the field trip. Students might organize a structure for quickly jotting down notes during their visit. Many potential partners will provide formal instruction and instructional materials during visits. NASA, for example, has a number of learning centers around the U.S.,and many local museums and industries provide fineprograms.
   - Guest lecturers and teaching experts can be invited to lend assistance and technological expertise. The partners can act as judges and assistants for student competitions related to technological studies, and they can sponsor a contest by providing funding and advertising their organization on site.
   - When students interact with community partners, they will experience a wonderful opportunity to learn about the values of a particular field. A community of partners can reinforce the development of workplace and community values.
   - Community partners can also provide the *Issues in Technology* classes with opportunities to conduct community-based service projects. Projects that reinforce content standards and instructional objectives should be chosen. Students should be able to relate what they learned in class to what they accomplished in the service project.
   - Through partnerships, the teacher can arrange or learn about special programs such as technology camp and other summer learning opportunities.
   - Having established relationships with the community partners, teachers may also find it beneficial to arrange internships for themselves and the students. Mentoring and job shadowing could also be arranged.

Teachers should keep in mind that formal arrangements for off-campus programs should be made through the school system's administration.

- Community partners react favorably to programs that offer student clubs that relate to the curriculum. Co-curricular student organizations provide an excellent way to attract community support.
- Students should compile portfolios of their experiences with community partners in order to relate their learning to the curriculum content and to develop a resource or inventory of job experience and knowledge that they can use for job hunting and for applications to post-secondary institutions.
- Debrief students following these interactions to help them sort out their experiences and make sense of them to enhance learning.

See Chapter 2, Activities 1 and 5 for extensions of activities that include community-based learning.

Notes on Other Instructional Considerations

Overview

While an exhaustive presentation on teaching methods cannot be covered in this document, a few issues can be addressed before considering the activities in Chapter 2.

Suggestions for Managing Other Aspects of Instruction

Embracing Student Equity and Diversity — Accommodating Students with Special Needs
Although all students should have opportunities to develop technological literacy, the education system sometimes fails to make all students feel that they are an important part of classes. To better reach all students, educators might consider the following suggestions about adapting teaching and the laboratory-classroom for the needs of special students.

1. Because female students and minorities are underrepresented in the field of technology, it would be encouraging to set some assignments in contexts that relate to various cultures and backgrounds. It is not difficult to plan activities that not only teach technology, but also appeal to the interests of women and minorities.
2. Female students benefit by having mentors who encourage them to undertake non-traditional experiences and roles. Both men and women make good mentors for female students as long as the mentors have time to spend with the students and share some of the same values.
3. Minority students tend to benefit from the freedom to apply concepts in the laboratory-classroom and learn well from experiences and hands-on instruction. Cooperative learning is an excellent approach to use.
4. Gifted students may be provided with slightly altered technological problems and other assignments that are more challenging than regular assignments. Because individualizing instruction for gifted students keeps them engaged, adopting a teaching assistant or protégé to help with instruction should be considered. Such an opportunity could encourage a student to become a technological studies teacher.
5. For some students, English is a second language. If there are problems with language in the laboratory-classroom, non-verbal communication is possible by using demonstrations, role-play, design processes, and visuals.
6. For students with learning and emotional disabilities, the following procedures should be considered:
   - Maintain an orderly, safe environment where students treat each other with respect.
   - Consult the student's individual education plan (IEP) for required and suggested accommodations.
   - Participate in the development of students' IEPs.
   - Frequently consult with students' special education teachers.
   - Provide a place in the laboratory-classroom for "time out" when things are not going well.
   - Appeal to all of the senses by using computers, sound, videos, bulletin boards, pictures, graphics, etc., in addition to traditional discussions, lectures, and written assignments.
   - Team students with special needs with students who do not have the same requirements.
   - Use behavior and home work checklists to communicate with parents daily.
   - Be consistent in the way laboratory-classroom activities and discipline are structured.
   - Provide an abundance of references and resources in the laboratory-classroom.
   - Help students take small steps toward success to prevent frustration with learning.
   - Provide frequent opportunities for group interaction.

See Chapter 2, Activity 6 for an example of an activity that gets students to focus on diversity.

Documenting Student Achievement of Content Standards across Grade Levels and Courses

In order to completely address students' technological literacy and effectively document their achievement, teachers will have to articulate *Standards for Technological Literacy* with their curriculum. They will need to develop activities beyond those presented in the next chapter in a way that will allow their students to address all 20 standards and their related benchmarks. While this curriculum development process will be time consuming, it will not be as difficult as documenting student achievement across the standards from year to year.

While using portfolios is an obvious long-term solution, a matrix can be used to document that a particular benchmark has been addressed. The teacher passes the checklist to the student's next teacher as the student matriculates through the school system. This process will be most easily accomplished on a computer database.

Student Articulation Chart for Student Achievement of *Standards for Technological Literacy* and Benchmarks

Student: ______________________________ Student Identification Number: ______________________________

Indicate with a K, 1, 2…12 the grade in which the student achieved the benchmarks within each standard.

Standard **Benchmark**

	a	b	c	d	e	f	g	h	i	j	k	l	m	n	o	p	q	r	s	t	u	v	w	x	y	z	aa	bb	cc	dd	ee	f f
Std 1														-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Std 2																																
Std 3											-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Std 4												-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Std 5													-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Std 6											-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Std 7																-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Std 8												-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Std 9													-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Std 10													-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Std 11																		-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Std 12																	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Std 13														-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Std 14														-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Std 15															-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Std 16															-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Std 17																		-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Std 18														-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Std 19																			-	-	-	-	-	-	-	-	-	-	-	-	-	-
Std 20															-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-

Chapter 2

Activities for Teaching Technology: High School

Strategies for Standards-Based Instruction

Chapter 2

Activities for Teaching Technology: High School

Introduction

The primary purpose of this chapter is to provide robust examples of activities that reflect the *variety* of instructional strategies discussed in Chapter 1 and that reflect *Standards for Technological Literacy*. While the activities included in Chapter 2 are as detailed as practical, they may not necessarily include every detail that a technological studies teacher may ideally need to implement them in particular circumstances. They do, however, provide outstanding guidance for the technological studies teacher. It is important to keep in mind that *Standards for Technological Literacy* is just a beginning. School systems may use the standards as a beginning point for establishing or revising their technological studies curricula. One should think of these activities as representative of what technological studies teachers will want to do with their students once their technological studies curriculum is in place.

Components

The activities contained in this chapter follow a similar format. They begin with a brief statement of purpose followed by a list of standards to be addressed in a given activity. However, the exact standard(s) a teacher selects to address depends entirely on the local curriculum and choices made by teachers and their students. Students should not be expected to master more than one standard and its related benchmarks in a single activity. The same principle applies to teaching strategies and methods listed at the beginning of each activity. Technological studies teachers should decide to use those strategies and methods that are best suited to their students' needs. Most prerequisite concepts and teaching resources are listed, and each activity describes how to approach teaching the activity. Extensions, or variations on the activities, are listed at the end of the description. Finally, a brief section called "Addressing Benchmarks" is intended to help teachers consider the extent to which students have addressed a particular standard and benchmarks. Students may, however, ultimately address more than the standard or benchmarks described. For the teacher's convenience, the next three pages provide a cross-reference of technology, mathematics, and science content standards and the six activities provided in this chapter.

Standards for Technological Literacy*

Return to Method 5 Curriculum Integration

Chapter 2 Activities	Designing and Manufacturing Products	Designing and Producing Video Communication	Reclaiming the Soil	Aquaponics: Growing Plants and Animals	Assisted Living	Forecasting the Future of Transportation Systems
Selected Technology Content Standards That Could Be Addressed Depending on How the Activity Is Conducted						
Understand …	The Nature of Technology					
1. Characteristics and scope of technology						
2. Core Concepts						
3. Relationships and connections among technologies and other fields	X	X	X	X		
Understand …	Technology and Society					
4. Cultural, social, economic, and political effects of technology					X	X
5. Effects of technology on the environment			X	X		X
6. Role of society in development and use of technology		X	X	X		X
7. Influence of technology on history						X
Understand …	Design					
8. Attributes of the design process	X	X	X	X	X	
9. Engineering design	X		X	X	X	
10. Troubleshooting, R&D, invention, innovation, and experimentation	X	X	X	X	X	
Ability to …	Abilities for a Technological World					
11. Apply the design process	X	X	X	X	X	
12. Use and maintain technological products and systems	X	X				
13. Assess impact of products and systems	X	X	X	X	X	X
Understand, select, and use …	The Designed World					
14. Medical technologies					X	
15. Agricultural and related biotechnologies			X	X		
16. Energy and power technologies			X			
17. Information and communication technologies		X				
18. Transportation technologies						X
19. Manufacturing technologies	X					
20. Construction technologies					X	

*Adapted from *Standards for Technological Literacy*, International Technology Education Association, 2000

Standards for Mathematics*

Chapter 2 Activities	Designing and Manufacturing Products	Designing and Producing Video Communication	Reclaiming the Soil	Aquaponics: Growing Plants and Animals	Asisted Living	Forecasting the Future of Transportation Systems
Selected Mathematics Standards (K-12) That Could Be Addressed Depending on How the Activity Is Conducted	Standards for Mathematics					
NUMBERS & OPERATIONS: Understand numbers, their meanings, and compute them fluently	X	X	X	X	X	X
ALGEBRA: Understand patterns, represent and analyze using symbols, use mathematical models, and analyze change	X		X	X	X	X
GEOMETRY: Analyze characteristics and properties of 2- and 3-D shapes, specify locations and spatial relationships, apply transformations and use symmetry, visualization, spatial reasoning, and geometric modeling to solve problems	X	X			X	
MEASUREMENT: Understand measurable attributes of objects and the units, systems, and processes of measurement; apply appropriate techniques	X	X	X	X	X	X
DATA ANALYSIS & PROBABILITY: Formulate questions that can be addressed with data and collect, organize, and display relevant data to answer them; select and use appropriate methods; develop and evaluate inferences; understand and apply basic probability	X		X	X	X	X
PROBLEM SOLVING: Build new knowledge, solve problems in mathematics and other contexts, apply and adapt a variety of strategies, monitor and reflect on the process	X	X	X	X	X	X
REASONING & PROOF: Recognize reasoning and proof as fundamental aspects, make and investigate conjectures, develop and evaluate arguments and proofs, select and use various types of reasoning and methods of proof	X				X	X
COMMUNICATION: Organize and consolidate mathematical thinking, communicating coherently and clearly, analyze and evaluate thinking and strategies of others, use the language of mathematics to express mathematical ideas precisely	X		X	X		X
CONNECTIONS: Recognize and use connections among mathematical ideas, understand how mathematical ideas interconnect and build on one another to produce a coherent whole; recognize and apply mathematics in contexts outside of mathematics	X	X	X	X	X	X
REPRESENTATIONS: Create and use representations to organize, record, and communicate mathematical ideas; select, apply, and translate among mathematical representations to solve problems; use representations to model and interpret physical, social, and mathematical phenomena	X	X	X	X	X	X

*National Council of Teachers of Mathematics, 2000

Science Content Standards*

Chapter 2 Activities	Designing and Manufacturing Products	Designing and Producing Video Communication	Reclaiming the Soil	Aquaponics: Growing Plants and Animals	Assisted Living	Forecasting the Future of Transportation Systems
Selected Science Content Standards (K-12) That Could Be Addressed Depending on How the Activity Is Conducted	Unifying Concepts and Processes					
SYSTEMS, ORDER, AND ORGANIZATION: "The natural and designed world is complex; it is too large and complicated to investigate and comprehend all at once. Scientists and students learn to define small portions for the convenience of investigation" (p. 116).	X			X	X	X
EVIDENCE MODELS, AND EXPLANATION: "Evidence consists of observations and data on which to base scientific explanations…Models are tentative schemes or structures that correspond to real objects, events, or classes or events, and that have explanatory power… Scientific explanations incorporate existing scientific knowledge and new evidence" (p. 117).	X	X	X	X	X	
CONSTANCY, CHANGE, AND MEASUREMENT: "Although most things are in the process of becoming different-changing-some properties of objects and processes are characterized by constancy…" (p. 117).	X		X	X	X	X
EVOLUTION AND EQUILIBRIUM: "Evolution is a series of changes, some gradual and some sporadic, that accounts for the present form and function of objects, organisms, and natural and designed systems" (p. 119).	X		X	X		X
FORM AND FUNCTION: "Form and function are complementary aspects of objects, organisms, and systems in the natural and designed world. The form or shape of an object or system is frequently related to use, operation, or function. Function frequently relies on form" (p. 119).		X		X	X	
Selected Science Content Standards (K-12) That Could Be Addressed Depending on How the Activity Is Conducted	Science Content Standards					
SCIENCE AS INQUIRY: "In the vision presented…inquiry is a step beyond 'science as a process,' in which students learn skills, such as observation, inference, and experimentation" (p. 105).	X		X	X	X	X
PHYSICAL SCIENCE: "Science subject matter focuses on the science facts, concepts, principles, theories, and models that are important for all students to know, understand, and use" (p. 106).	X	X	X		X	X
LIFE SCIENCE: "Science subject matter focuses on the science facts, concepts, principles, theories, and models that are important for all students to know, understand, and use" (p. 106).			X	X		X
EARTH AND SPACE SCIENCE: "Science subject matter focuses on the science facts, concepts, principles, theories, and models that are important for all students to know, understand, and use" (p. 106).			X			X
SCIENCE AND TECHNOLOGY: "The science and technology standards…establish connections between the natural and designed worlds and provide students with opportunities to develop decision-making abilities" (p. 106).	X		X	X	X	X
SCIENCE IN PERSONAL AND SOCIAL PERSPECTIVES: "An important purpose of science education is to give students a means to understand and act on personal and social issues" (p. 107).			X	X	X	X
HISTORY AND NATURE OF SCIENCE: "In learning science, students need to understand that science reflects its history and is an ongoing, changing enterprise" (p. 107).			X	X		X

*National Academy of Sciences, 1995

Activity 1

Designing and Manufacturing Products that Solve Problems

Purpose

This activity will help students understand and experience engineering design and manufacturing systems. As a result, they will be able to make more responsible decisions as consumers, to conduct manufacturing processes, to develop effective approaches to group problem solving, and to make career decisions.

Standards Addressed

Depending on how the content is emphasized, the following standards may be addressed:

The Nature of Technology

Standard 3. Students will develop an understanding of the relationships among technologies and the connections between technology and other fields of study.

Design

Standard 8. Students will develop an understanding of the attributes of design.

Standard 9. Students will develop an understanding of engineering design.

Standard 10. Students will develop an understanding of the role of troubleshooting, research and development, invention and innovation, and experimentation in problem solving.

Abilities for a Technological World

Standard 11. Students will develop the abilities to apply the design process.

Standard 12. Students will develop the abilities to use and maintain technological products and systems.

Standard 13. Students will develop the abilities to assess the impact of products and systems.

The Designed World

Standard 19. Students will develop an understanding of and be able to select and use manufacturing technologies.

Recommended Teaching Methods

Depending on how the instruction is structured, the following methods may be useful:

Method 2: Cooperative Group Learning

Students will work in small groups with each functioning as a department within a manufacturing enterprise. Each group will have specific responsibilities in order to develop, design, and produce an innovative product.

Methods 3 and 4: Design and Technological Problem Solving

Students will design marketing, financial, and labor relations systems for the manufacturing system. They will invent or innovate products, design product prototypes, and research and develop solutions to product, production tooling, and quality control.

Method 5: Curriculum Integration

You may correlate instruction with:

- **Mathematics** related to the statistics that students would develop from the data collected during market research and quality control.

- **Marketing education** related to all phases of marketing the product.
- **Art** related to advertising that students would design for marketing their product.
- **Business education** related to managing the financial affairs of the manufacturing company including the development of the necessary forms and financial systems.
- **Trade and industrial education** (if necessary) related to the processing of materials.

Every teacher involved should explicitly teach students how the fields that their classes represent are related to the other classes and to technology.

Method 6: Simulations, Games, Models, and Role-Play
By forming a manufacturing company, instruction becomes more authentic than by simply teaching about manufacturing. Students will role-play the different positions in a company, simulating the process.

Method 7: Modular Instruction
This activity serves as a culminating activity for students who have been building prerequisite skills in modular laboratory-classrooms. Some students will have developed abilities at various modules related to the "prior knowledge" items listed below. They can apply those abilities and knowledge to this manufacturing activity.

Method 8: Technology Assessment
Students will evaluate the quality of their manufacturing system and assess the impacts that it *could* have on "employees" and consumers.

Prior Knowledge

The prior knowledge and abilities needed for this activity include:
- Word processing
- Spreadsheet use
- Problem-solving techniques
- Desktop publishing and multimedia development
- Computer-aided design (CAD)
- Computer numerical controlled (CNC) machining
- Various material processes

Resources
- Computer with spreadsheet capabilities
- Computers with desktop publishing and word processing software
- Computers with CAD
- Computer with CNC software interfaced to a lathe or mill
- Laboratory-classroom space for several groups of students
- Variety of tools and materials
- Safety glasses and other lab safety equipment typical in technological studies labs

Time

High school technological studies classes will need from four to six weeks to complete this activity as described. However, some of the suggested extensions will require less time, while an especially robust approach to manufacturing education, for example, may be developed to last an entire semester.

Description

Forming the Company
Students will form a manufacturing company. Through group discussion or through an overview provided by the teacher, students will develop an understanding of how manufacturing companies are *basically* organized. Students will likely conclude that the company should be organized into the following departments:

- Financial Affairs — raises capital, purchases supplies, creates budgets, and tracks various costs
- Labor Relations and Training — trains employees, monitors safety, negotiates with employees regarding benefits, wages, and salaries
- Marketing — conducts market research, creates advertising, and distributes and sells products
- Research and Development — conducts research and development for product ideas and for methods of production
- Production — routes, schedules, dispatches, and expedites products through the plant

These departments represent the cooperative groups of students who will carry out the various responsibilities of the company. You might decide to group students according to their *expertise*. For example, some students in a modular laboratory-classroom may have performed well at CAD, while others excelled at CNC, and yet others stood out at desktop publishing and word processing. The class could elect company officers and submit employment applications that indicate their abilities and knowledge. The officers could help "hire" students into the appropriate "departments."

Running the Manufacturing System

1. Each group should research and establish department responsibilities, and each department should choose a department supervisor. Teachers should help each group design the forms, procedures, and systems that are needed to conduct business and communicate with the rest of the company.

2. Much of the preliminary work that departments need to do is not necessarily dependent upon knowing what product the company will produce. However, it is very important that the marketing department (and all students) begins to identify the wants and needs of the people around them so that they can generate product ideas and either invent or innovate a company product. Marketing should develop a survey or conduct focus groups about possible product ideas.

3. The financial affairs department can begin to sell stock in the company using real or imitation money. Either type will be very instructive.

4. The research and development department should develop engineering sketches and working drawings of products for the purpose of developing prototypes.

5. During this process, the labor relations department should be training employees to do various jobs. These jobs could relate to word processing programs for developing forms, to computer spreadsheets for calculating wages and other costs, and to CAD and machining prototypes for prototyping and production.

6. During product development, product and methods engineers should communicate with all departments, especially with marketing and production. The class could come together to help the engineers establish design criteria such as strength and durability and to help them design for assembly. Students should develop a systematic way of designing and checking their results against their criteria repeatedly through the process. Engineers and technologists must troubleshoot product designs before, during, and after mockups and prototypes are developed.

7. As a class or in groups, students should conduct an assessment of both the manufacturing system and the chosen product to determine what effects it could have on the community, the environment, the consumers, and the employees.

8. As soon as a product is chosen, methods or production engineers should work closely with production and R&D to develop the production tooling and quality control devices. Intermittent production will likely provide more opportunity for in-depth learning than will custom manufacturing. Like any other design and engineering process, students will need to design production tooling and quality devices based on the product *and* the principles of production tooling and quality design. Production tooling will assure that product subassemblies are interchangeable, and quality control will provide the feedback that the production system needs to correct itself and operate efficiently. This group will have to develop a variety of plans that range from assembly drawings, to operation process charts, to time-motion studies. Also, students will have to troubleshoot and experiment with the various tooling devices.

Safety Note:
Several safety issues should be considered when teaching manufacturing. Students should be thoroughly instructed on general safety, as well as particular safety for every tool and machine that they use. Each process, tool, and machine must be demonstrated for safety, and students must pass performance and written tests on the particular process/tool/machine in question with 100% accuracy. Teachers should use only those machines, tools, and processes that are appropriate for high school and in good condition. They should also conform to the policies and laws of respective states or provinces. Ensuring that students do not rush production because they feel hurried is another important consideration. Students must maintain appropriate behavior and judgment in the laboratory-classroom.

9. As one department becomes less busy and other departments become busier, the company officers and the teacher can relocate employees to other jobs where they are needed. This transferring will be especially important when it is time to *run* the production line. Workers, who were not originally hired for the production department, will be hired and trained to operate tools and equipment during production, and to assemble and package products.

Assessment

Students should develop an individual portfolio that demonstrates their understanding of the design concepts that have been emphasized, including the design process and manufacturing systems concepts. Use a rubric for portfolio evaluation.

Student self-evaluation and peer evaluation may also be appropriate for aspects of group work.

Additionally, to make the assessment more authentic, the entire company should compile a presentation representing all of its production development processes and products. For example, the drawings and sketches for all of the prototypes, tooling, and quality devices should be included, in addition to research statistics and sales reports. The G code program that was used on the CNC machine and the operation process charts, in addition to a prototype, product, and package should be included, to name just a few. Finally, the teacher and students should judge the quality of the products.

Extension 1
Competing designs and prototypes could be developed. In fact, teachers could divide their classes into two companies and have them compete.

Extension 2
The manufacturing enterprise can be developed into a community service project. Provided an adequate amount of *innovation* is required, students could mass-produce products that they then donate to civic causes. For example, some groups have donated toys to the U.S. Marines' "Toys for Tots" program.

Extension 3
The production run could produce popular and innovative products that are used for fund-raising. Proceeds could be used to support student clubs and activities or the technological studies program.

Extension 4
The production company does not have to physically machine a product from raw or processed materials such as wood or metal. The company's main product could be communication products or publications such as paper-based publications, radio or video broadcasts or tapes, or Internet-related publications.

Extension 5
As the primary manufacturer, students could contract with technological studies classes from other schools for a just-in-time supply of parts for the products they designed. By keeping a just-in-time inventory of parts, the technological studies teachers can demonstrate how leading manufacturers save money, and students will get a better idea of what it takes to manage a modern manufacturing enterprise in terms of transportation, scheduling, dispatching, purchasing, accounting, etc.

Extension 6
Students could learn many manufacturing concepts through various forms of community-based learning discussed in Chapter 1 such as internship and job shadowing.

Addressing Benchmarks

To illustrate how students will address the various benchmarks during this activity, educators can use the following examples.

Standard 9, Benchmark K:

A prototype is a working model used to test a design concept by making actual observations and necessary adjustments.

Standard 10, Benchmark I:

Research and development is a specific problem-solving approach that is used intensively in business and industry to prepare devices and systems for the marketplace.

For more information about teaching manufacturing systems concepts at the high school level, see Wright, 1990.

Standard 19, Benchmark P:

The interchangeability of parts increases the effectiveness of manufacturing processes.

Teachers should ask students to reflect on the R&D that they are conducting during the activity and relate it to similar problem-solving approaches used in former activities.

Most importantly, students should reflect on the R&D process and manufacturing content, such as prototyping, in their individual portfolios. Teachers should ensure that students relate their *authentic* activities to what they understand about research and development in real life.

Closing Comments

If teachers have little experience with running a manufacturing activity or conducting cooperative group activities, they may consider conducting only one or two aspects of the activity. For example, they might develop an innovative product with a marketing group and a research and development group only. Teachers could also consider asking guest speakers, specialists, and consultants to help them in conducting the activity. Local chapters of the Society of Manufacturing Engineers often help in this way, and the relationship could lead to a business and industry partnership with the program.

Activity 2

Designing and Producing Video Communication

Purpose

This activity will help students understand and experience the communication design process and electronic communication systems. As a result, they will be able to gain an appreciation for the process of communication and an understanding for communication as a system. They will be able to use communication technology to address their own interests by communicating a message effectively, developing effective approaches to group problem solving, and making career decisions.

Standards Addressed

Depending on how the content is emphasized, the following standards may be addressed:

The Nature of Technology

Standard 3. Students will develop an understanding of the relationships among technologies and the connections between technology and other fields of study.

Technology and Society

Standard 6. Students will develop an understanding of the role of society in the development and use of technology.

Design

Standard 8. Students will develop an understanding of the attributes of design.
Standard 10. Students will develop an understanding of the role of troubleshooting, research and development, invention and innovation, and experimentation in problem solving.

Abilities for a Technological World

Standard 11. Students will develop the abilities to apply the design process.
Standard 12. Students will develop the abilities to use and maintain technological products and systems.
Standard 13. Students will develop the abilities to assess the impact of products and systems.

The Designed World

Standard 17. Students will develop an understanding of and be able to select and use information and communication technologies.

Recommended Teaching Methods

Depending on how the instruction is structured, the following methods may be useful:

Method 2: Cooperative Group Learning
Students will work in small groups, each with the responsibility for a particular part of the video production. Each group will have specific responsibilities in order to develop, design, and produce a video program.

Methods 3 and 4: Design and Technological Problem Solving
Students will design the video program and troubleshoot video scenes and the editing process.

Method 5: Curriculum Integration
Instruction may be correlated with:

- **Performing arts** related to the screenplay or script that students write or to any acting they may perform
- **Art** related to the aesthetics of the *storyboard* and the set that students may need to develop
- **Language (English in the US) and composition** related to the mechanics of the script
- **Trade and industrial education** related to building props and sets (if needed)
- Every teacher involved should explicitly teach students how the fields represented in their classes are related to the other classes and to technology.

Method 6: Simulations, Games, Models, and Role-Play
Insofar as students are assuming the duties of people who produce videos, instruction should be more authentic than simply teaching about videography. Students will role-play the different positions required to produce a video.

Method 7: Modular Instruction
This activity serves as a culminating activity for students who have been building prerequisite skills in modular laboratory-classrooms. Some students, who will have developed abilities at various modules related to the "prior knowledge" items listed below, should use those abilities and knowledge in this activity.

Method 8: Technology Assessment
Students will evaluate the quality of their communication system and assess the impacts that it *could* have on society. Teachers could ask students to relate their assessment of this video communication system to similar assessments. For example, students may have assessed the influence of integrated circuit technology on the rise of the Information Age. Teachers might also ask students to consider the influence of society's norms and ethics on the production of televised programs.

Prior Knowledge

The prior knowledge and abilities needed for this activity include:

- Word processing
- Computer and traditional graphic design and imaging
- Multimedia development
- Desktop publishing
- Computer-aided design (CAD)
- Video editing

Resources

- Camcorder and tripod — for each student video production group of two or more
- Computer with video card and desktop video editing software
- Stand alone video editing system (Optional)
- Camcorder that is capable of simple video editing (Optional)
- Computers with graphics software (Optional — scanner)
- Computer with CAD (Optional — needed for props and set design and for shoot planning)
- Laboratory-classroom space for several groups of students
- Student-made boom with overhead microphone
- Lavaliere microphone

Time

High school technological studies classes will need from three to five weeks to complete this activity as described. However, some of the suggested extensions will require less time.

Description

Planning the Video
Students will need to divide the following responsibilities associated with designing and producing the video:

- Brainstorm ideas for the program and develop a storyboard for the program
- Outline and write the script
- Plan the types of shots for each scene in the program
- Provide training for operating the camcorder(s)
- Design and build any sets that may be needed
- Act out the script
- Direct and shoot the video
- Provide training for operating the video editing system

This list could represent the cooperative groups of students who will carry out the various responsibilities of the production. The teacher might decide to group students according to their expertise. For example, in a modular laboratory-classroom, some students may have performed well at CAD for the set design, others at video editing, and yet others at desktop publishing and word-processing. The class could elect production officers and submit employment applications that indicate their abilities and knowledge. The officers could help the teacher "hire" students into the appropriate "production departments."

It is also important that students understand how video equipment works as a communication system. Teachers may use the communication system model to teach students about the designed message, encoding, transmitting, receiving, storing, and decoding audio and video signals. They are encouraged to help students understand how human-to-human, human-to-machine, machine-to-human, and machine-to-machine communication are involved in the video communication system they are developing.

Shooting the Video
1. Although typical problems can occur with student-made video programs, many can be eliminated through good planning. Plans for various shots should be depicted in a storyboard showing each shot for each scene. Students often do the following:
    - Provide too much headroom and no lead room
    - Use the same type of shot repeatedly
    - Fail to use a tripod

- Fail to use an extra microphone (lavaliere or overhead)
- Fail to use an extra camcorder to shoot the same scene/subject
- Fail to use character generation or computer graphics to enhance their productions
- Use too many computer effects that distract from the program
- Violate continuity, such as changing clothes from one related scene to another
- Use poor lighting and/or have subjects with too much backlight

2. To generate ideas for a program, the entire class could brainstorm various needs. High school students and teachers typically have many ideas for video productions. For example, students like to depict student life around campus, and teachers like to promote their instructional programs through video.

3. The script has a particular format and provides all of the information needed by the director to complete the required shots. The script also describes the actors' movements and the setting of the stage and its props. The script should be outlined first.

4. The storyboard, which shows every shot for every scene, should be developed along with the script. The fact that students might not be good at drawing subjects with computer graphics should not dissuade them from making a good storyboard. Captions should be provided under each frame of the storyboard with each scene and shot identified.

   Teachers should encourage students to specify a variety of shots. For example, in an interview of a subject responding to an interviewer, a very tight shot of the person with lead room is an effective approach. This shot can be followed by a wide shot of both people followed by a tight shot of the interviewer, who should be nodding and looking interested. A reputable book on videography can provide suggestions for shot composition. For example, when actors are moving from one place to another and then exit on the right side of the screen, they should enter the next scene from the left side.

5. Important considerations include scouting locations and making props for the stage, in addition to arranging microphones and lights. Actors should not wear white shirts or clothing with white stripes. Subjects should have some back lighting and plenty of front light that does not reflect directly back into the camera lens. The iris and light balance should be calibrated with a sheet of white paper prior to shooting. Extra lighting can be made with inexpensive spotlights from a building supply store, and stands for lighting can be made with #10 coffee cans, concrete, and 2" x 2" beams.

   Lavaliere and boom microphones should be inconspicuous, but they should be positioned to catch enough sound to produce good quality.

   Students will have to troubleshoot and control the variables involved in developing a good scene, which will take some lead time. This characteristic is not significantly different from solving any other technological problem.

   Students should make sure that shots are ready before actors and other production people arrive on the set by using members of the camera, lighting, or sound crews to act as "stand-ins."

6. If possible, the director should see the scene the way viewers will see it on a monitor. Therefore, if the teacher is able to provide students with a monitor during a shoot, they will immediately know whether the shot is good. After each shot, the director and the teacher should review it before moving on to the next.

   Teachers may also find that shooting the same scene with two or more camcorders simultaneously from different angles will help provide a variety of shots for the editing room. There is a general practice for using different camera angles for the same shot. If, for example, two subjects are talking to each other in a scene, one camera may be positioned to shoot over the shoulder of the actor who is listening toward the actor who is talking. That camera will be focused on the director's side of the two characters. Likewise, if the other camera is shooting over the shoulder of the talking subject toward the one who is listening, then that second camera is also positioned on the director's side. As illustrated in the figure below, there is an imaginary line going through the subjects, and the cameras may be positioned anywhere as long as they stay on one side of the line or the other.

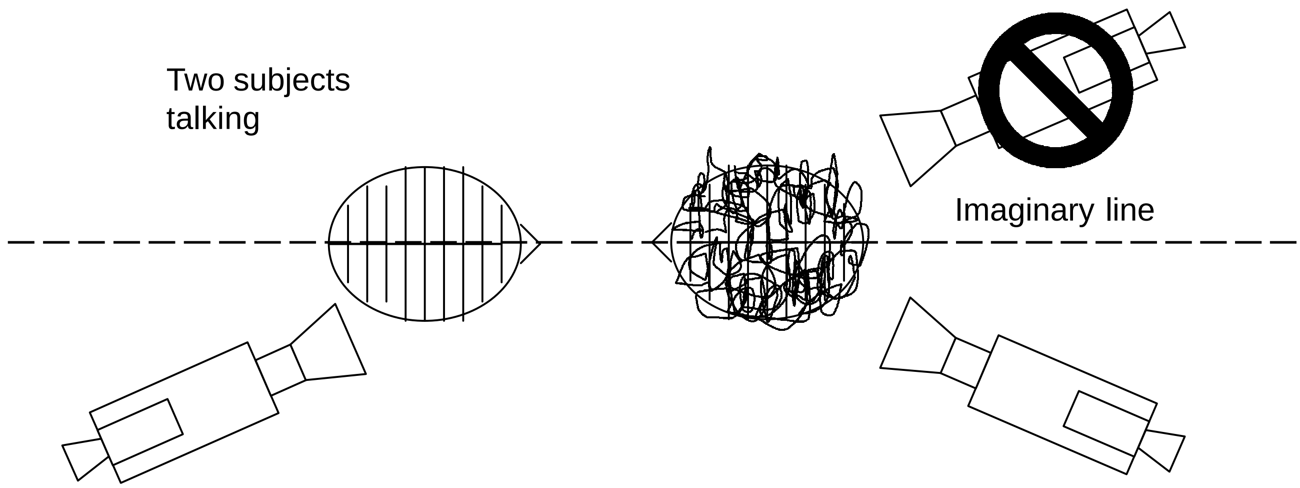


Figure 1. Cameras should not be used on different sides of the imaginary line that passes through the subjects of the scene.

It will not be difficult to have students who are not involved in planning to work on other assignments. Teachers should keep in mind that when scenes are being shot, some students might be standing around because they are needed for only part of the scene. In such a situation, students must maintain good behavior and self-control while shooting the video program. Also, if the shoot takes place in different places in the school or on location, teachers might consider asking adults to help supervise.

Safety Note:
While on the set, teachers must insist that electrical cords and other electrical equipment are not placed where people might trip or become strangled. All equipment, the set, and the props must be placed so that they do not fall on people or become top-heavy. Of course, all electrical equipment should be kept away from water and other conducting substances.

7. As a class or in groups, students should conduct an assessment of the effects of video and television technology on society. They will likely have conducted an historical study — how the integrated circuit has influenced society, for example. As a next step, they could assess video or television technology.

8. If they are completely dependent on desktop video editing, teachers may want their students to begin with a short video — a 30-second commercial, for example. The amount of video footage that can be captured is limited by the size of a computer's hard drive and to a certain extent, by the amount of RAM. If there is a stand-alone video editor, the desktop machine can be used to capture computer graphics from multimedia, sound, drawing, and other computer software. This footage can then be edited into the regular program.

   When editing, students should avoid overusing special effects, as they can be distracting for the audience — applying several different types of transition from scene to scene, for example. If the storyboard shots are well planned and the shots are successfully captured, the editing should go well. If the editing equipment is not *frame accurate*, the editor may use points of reference. These points of reference may be used when ending a clip shot from one camera angle of a scene and then begining another clip from a different angle. Such reference points might be actors opening their mouths, beginning to turn their heads, or blinking their eyes.

9. All copies of the program should be made from the editor's master video. As subsequent copies of videotapes are made, color and other image quality will be lost. This principle even applies to high quality videotape formats such as Hi-8. If the video program has been entirely digitized on the computer and if time allows, all copies can be made from that one digitized copy. Students should develop some packaging and labels for videotape copies. Depending on the equipment or the program's business partners, the program may be burned on to a CD, DVD, or similar digital format.

Assessment

Students should develop an individual portfolio containing evidence that they understand the important design concepts including the design process and communication systems. Use a rubric for portfolio evaluation.

Student self-evaluation and peer evaluation may also be appropriate for aspects of group work.

Additionally, to make the assessment more authentic, the entire group should compile a presentation representing the video development processes and products. For example, the drawings and sketches for all of the props, the script, and the storyboard should be included. The teacher and students should judge the quality of the products.

Another authentic assessment would be inviting a reviewer from a newspaper or another branch of the media to write a review of the video program and present it to the class.

Extension 1
Dividing the class into two video production companies could develop competing production designs and programs.

Extension 2
The video production activity could be made an interdisciplinary activity by dividing responsibilities across subject areas. For example, a language and composition class might be responsible for writing the script, a drama class could provide the actors, a building trades class could construct the set, and a technological studies class could take responsibility for the recording and editing work.

Extension 3
Excerpts from the video could be captured and digitized and then converted into a format that can be viewed on the World Wide Web (such as *QuickTime* movies). A website can be developed to promote the video program and the video team.

Extension 4
Depending on their interests, students may be interested in developing a program recruitment video.

Extension 5
As a training exercise, students could develop a video portfolio that includes components of their electronic work including three-dimensional and working models.

Extension 6
Depending on students' interests, the school's equipment, and the schedule, the teacher and students might consider producing a regular news broadcast for the entire school. It could be simply an audio broadcast over the intercom or a television broadcast over the closed circuit or cable television system.

Extension 7
Students could learn many video communication concepts through various forms of community-based learning discussed in Chapter 1, such as internship and job shadowing.

Addressing Benchmarks

To illustrate how students will address the various benchmarks during this activity, teachers can use the following examples.

Standard 9, Benchmark I:

Established design principles are used to evaluate existing designs, to collect data, and to guide the design process.

Standard 17, Benchmark P:

There are many ways to communicate information, such as graphic and electronic means.

Students should reflect on the various forms of communication that they used in planning, producing, and broadcasting their video program. They may submit essays with graphics, describing the video technology systems and how they work. Students should also be able to communicate the process they used in designing the video program, such as the storyboard.

Most importantly, students should reflect on the planning and design processes in their individual portfolios. They should relate their *authentic* activity to what they understand about communication in real life.

Closing Comments

If teachers have little experience in planning, shooting, and editing videotape programs, they should begin with a short program. It is important to have a tripod and to study the various types of shots and their attributes. A good video program can be made with relatively primitive equipment. The reference listed below provides a fairly good explanation of video shots and productions.

If they have very little experience with electronics and do not feel comfortable in explaining how electronic video technology works, teachers may refer to various communication technology textbooks and references. The communication text listed below provides an easy-to-understand explanation of the communication process and video technology.

For more information about teaching video communication concepts at the high school level, see Herrell & Fowler, 1998 & for more information on electronic video technology, see Sanders, 1991.

Activity 3

Reclaiming the Soil

Purpose

This activity will enable students to understand and experience engineering design and land reclamation systems and how energy is used in reclaiming the environment. Students will develop effective approaches to problem solving, and career decisions.

Standards Addressed

Depending on how the content is emphasized, the following standards may be addressed:

The Nature of Technology

Standard 3.	Students will develop an understanding of the relationships among technologies and the connections between technology and other fields of study.

Technology and Society

Standard 5.	Students will develop an understanding of the effects of technology on the environment.
Standard 6.	Students will develop an understanding of the role of society in the development and use of technology.

Design

Standard 8.	Students will develop an understanding of the attributes of design.
Standard 9.	Students will develop an understanding of engineering design.
Standard 10.	Students will develop an understanding of the role of troubleshooting, research and development, invention and innovation, and experimentation in problem solving.

Abilities for a Technological World

Standard 11.	Students will develop the abilities to apply the design process.
Standard 13.	Students will develop the abilities to assess the impact of products and systems.

The Designed World

Standard 15.	Students will develop an understanding of and be able to select and use agricultural and related biotechnologies.
Standard 16.	Students will develop an understanding of and be able to select and use energy and power technologies.

Recommended Teaching Methods

Depending on how the instruction is structured, the following methods may be useful:

Method 2: Cooperative Group Learning
If preferred, students may work in small groups to solve an environmental clean-up problem.

Methods 3 and 4: Design and Technological Problem-Solving
Given a design brief, students will design a technological solution to an environmental clean-up problem through research and development.

Method 5: Curriculum Integration
Instruction may be correlated with:
Physical science and chemistry related to the land to be reclaimed and the concepts that underlie the reclamation technology developed by students.

Method 6: Simulations, Games, Models, and Role-Play
Students will construct and demonstrate a small-scale model of their solution that will actually work or at least simulate the authentic environmental clean-up.

Method 8: Technology Assessment
Students will evaluate the quality of their clean-up system and assess the impacts that it *could* have on the environment and the economy. In the process, they should also consider the manner in which land can become polluted and how the values of society are related to pollution.

Prior Knowledge

The prior knowledge and abilities needed for this activity include:
- Word processing (reporting)
- Spreadsheet (for data analysis and representation)
- Experience in problem-solving technological problems
- Desktop publishing and multimedia development (for reports and presentations)
- Internet browser (for research and case studies)
- Computer-aided design (CAD) (to design technological solutions)
- Material processes (various) (to construct technological solutions)
- Some physical science and/or chemistry

Resources

- Plastic tank or acrylic or glass aquarium (watertight)
- Galvanized steel strips for electrodes (galvanized sheet metals)
- Sand (clean and new — not sand that has been used in a previous or unknown activity or experiment)
- Litmus paper and comparison gradient
- Source of tap water (**not** distilled water)
- Safety goggles
- Face shield
- Rubber gloves and rubber apron
- Eye wash
- Cupric sulfate (powdered, mild toxicity, common name is copper sulfate)
  (**Refer to the example material data safety sheet (MSDS) provided near the end of this activity.**)

Safety Note:
Cupric sulfate is only mildly toxic. In the powdered form, it should be kept away from ignition sources. Other metals, except galvanized steel, should also be kept away from the cupric sulfate powder. By the end of the process described in this activity, the cupric sulfate will have been chemically changed into copper and will, therefore, not present a disposal problem. See additional safety notes throughout Activity 3, and **refer to the example MSDS provided near the end of this activity and to the MSDS that comes with the cupric sulfate.**

- Insulated electrical wire
- Alligator clips
- DC power supply with variable voltage source (or a 12 V DC battery charger)
- Multi-meter or ammeter and voltmeter if meters are built into the power supply
- PVC pipe, smaller diameter with slots
- PVC tubing
- Drill and 1/8" twist drill (to drill small holes in pipe if it is not slotted)
- Sharp punch (to cut holes in PVC tubing)
- Scale to measure weight of cupric sulfate and sand
- Medicine dropper or turkey baster (to clean out sampling tubes)
- Laboratory-classroom space for several groups of students
- Sheet metal shears or tin snips
- Variety of tools and materials
- Computer with spreadsheet
- Several computers with desktop publishing and word processing software
- Several computers with CAD
- Computers with Internet access

Time

High school technological studies classes will need about two weeks to design and construct the possible solution described in this activity. The electrokinetic process to convert the cupric sulfate into copper will take approximately four weeks. Students should take a few minutes to monitor the process every other day. Another activity should be taught during the four weeks while the "reclamation" process is taking place, although some of the suggested extensions could require less time.

Description

The Design Brief

1. Students can be introduced to the environmental problem by using the design brief on the last pages of this activity. Students are asked to design a system to remove contaminants from the tailings and soil at an abandoned copper mine. (Refer to the design brief at this time.) Students will likely need some guidance regarding the approach they should take to arrive at a solution. One approach that reclamation companies take for removing certain contaminants from deep within the soil is electrokinetics. The related design brief directs students to research electrokinetics. If teachers want to avoid influencing the possible solutions that their students research and develop, they can adapt the design brief so it does not lead the students in one certain direction.

Researching the Problem

2. Teachers should help students focus on their research of the problem. It is important that students have access to the Internet because electrokinetics, as a relatively new technology, is not necessarily covered in high school textbooks. While students are researching the problem with the objective of gathering ideas for possible solutions, they should also be on the lookout for articles and references that will enrich their case study. The case study will encourage students to find and understand the resolution to similar problems. For assessing the technological solutions, teachers might use one of the techniques described in Chapter 1. A straightforward case study provides an effective approach for learning about similar problems and their solutions.

3. This activity contains significant potential for student learning. While teachers will want to provide formal instruction on safety and basic electricity, they should not have to make formal lectures related to the activity content. However, it is very important that they engage students in discussions and seminars, and help guide them when it comes to knowing what concepts are important. Teachers should monitor students to make sure that they do not misconstrue content.
   - Students need to be able to work together as groups and to use a procedure to guide them.
   - Students need to be able to organize how they will go about researching the problem, including the results of their case study.
   - Students will need time to discuss the problem and apply their creativity, in addition to scientific and technological knowledge, to their designs and solutions.
   - Students will need to control variables in an experiment and troubleshoot promising approaches to the solution's implementation.
   - Students will need to decide how to measure the effects of their solutions and record and represent the results.
   - Students will need to understand the underlying scientific, sociological, and technological concepts such as electrokinetics, electricity, soil pollution, and the cost of cleaning the environment.

   Most importantly, teachers need to work with students in such a way that they remain aware of all of the objectives above, thereby providing some structure and guidance in the middle of a relatively open-ended, ill-structured activity. Portfolios, notebooks, and seminars are important because they provide a place for students to record their insights, progress, and approaches, and to compare their understandings to those of the other students.

An Example Solution

4. Teachers will want to coordinate with science teachers for guidance in conducting the activity, in helping students understand the underlying concepts, and in procuring some of the necessary supplies.

   Electrokinetics can be modeled as an experiment in the technological studies laboratory-classroom. The various materials listed at the beginning of this activity may be used to construct the experiment. For example, when topsoil is polluted, a reclamation company may simply remove it and process or incinerate it. However, in some dump sites, such as mines, the depth of the contamination can extend hundreds of meters. Electrokinetics removes heavy metal contaminants with electricity without removing the soil.

Safety Note:
Because safety is an important consideration when working with chemicals, wearing safety goggles, face shields, rubber gloves, and rubber aprons is essential. Cupric sulfate is a mildly toxic form of metal that will act as the contaminant for students' environmental problem, and it should not come in contact with the mouth, nose, ears, eyes, or skin. Wearing contact lenses should be avoided when working with any chemical. If cupric touches the skin, it should be washed off with soap and water. The laboratory-classroom should have an eyewash station in proximity to the activity area. This mild acid should not come in contact with the body or the clothes. When acquiring cupric sulfate teachers should get a copy of the MSDS that accompanies the material.

5. A rectangular glass or acrylic tank will provide a "cross section" of the polluted land. The tank does not have to be clear — any clean, plastic container will suffice — and it should be large enough to hold about 1 Kg of sand. Powdered cupric sulfate could make a suitable contaminant to add to the sand in the tank.
6. The mildly toxic cupric sulfate will react to electrical current in a manner similar to metal pollutants, and it may be processed into copper and disposed of without harming the environment. Gather enough sand (1 Kg) to fill the tank about three-fourths full. If the sand does not fill the tank to this level, a smaller tank may be used. When adding the cupric sulfate, the sand should first be saturated with water before thoroughly mixing in 20 g of cupric sulfate powder. The sand should be saturated throughout the experiment with tap water and not distilled water. Tap water contains conductive substances that will facilitate the reclamation process. Because distilled water lacks this quality, the experiment might not work at all if it is used.

Safety Note:
Because working with the power supply could create a spark, students should avoid working with it near the power supply, and they should stay away from ignition sources.

The word “sand” is used in this activity description to be clear for the technological studies teacher; however, the proper reference to any particular soil that needs to be cleaned of pollution is the word “soil.” Notice that the word “soil” is used throughout the design brief at the end of this activity description.

7. Two strips of galvanized steel should be used as electrodes. These two electrodes, which will be housed in the PVC pipe, will extend from above the top of the sand to the bottom of the tank. PVC pipe should be used that is large enough in diameter (1 inch I.D.) to hold the galvanized steel with some room to spare. Two pieces of PVC pipe will hold the galvanized strips and additional lengths of tubing should be placed at intervals down the length of the tank. These additional tubes will provide places to sample the levels of cupric sulfate in the ground water. Small holes should be drilled all over the surface of the pieces of pipe, and a punch should be used to cut small holes in the tubing. (See Figure 2.)

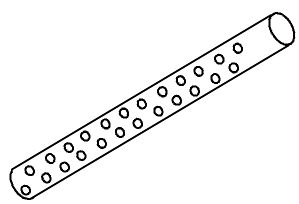


Figure 2: PVC pipe with slots/ holes drilled into the sides.

The wet, contaminated sand should be packed into the tank with a spade while standing the pipes vertically and locating them about 15 cm apart. The lengths of tubing should be placed in line with each other at regular intervals along the centerline between the pipes. The pipes and tubes should be kept relatively free of sand. (See Figure 3 below.)

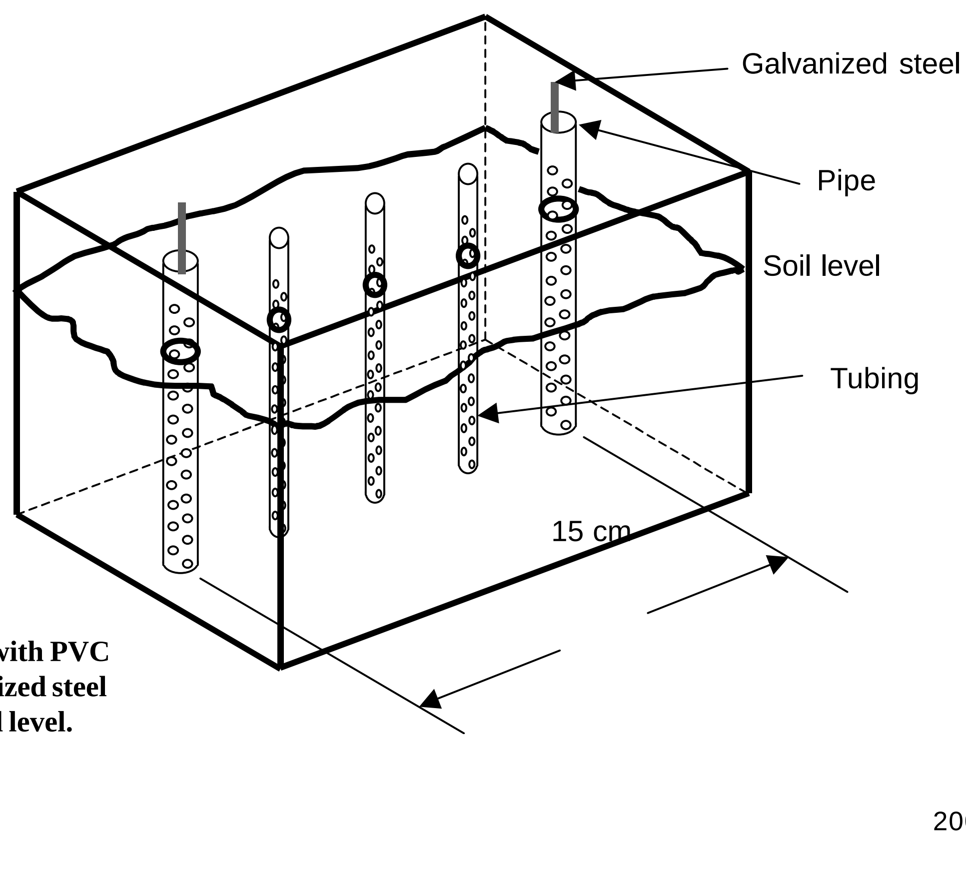


Figure 3. The tank with PVC pipe, tubing, galvanized steel electrodes, and sand level.

Filling the tank only three-fourths full will prevent spilling sand and water on tables and floors. This will help to keep the water away from the DC power supply connected to the electrodes.

Connecting and Setting the DC Power Supply

8. The DC power supply should be set on a constant voltage of 4 V DC per linear cm between the electrodes (15 cm x 4 V DC = 60 V DC). The power supply leads should be connected to the electrodes as shown in Figure 4 below. Alligator clips work well to connect the leads to the galvanized steel strips, as well as wires that are long enough to keep the power supply away from the tank of saturated, wet sand.

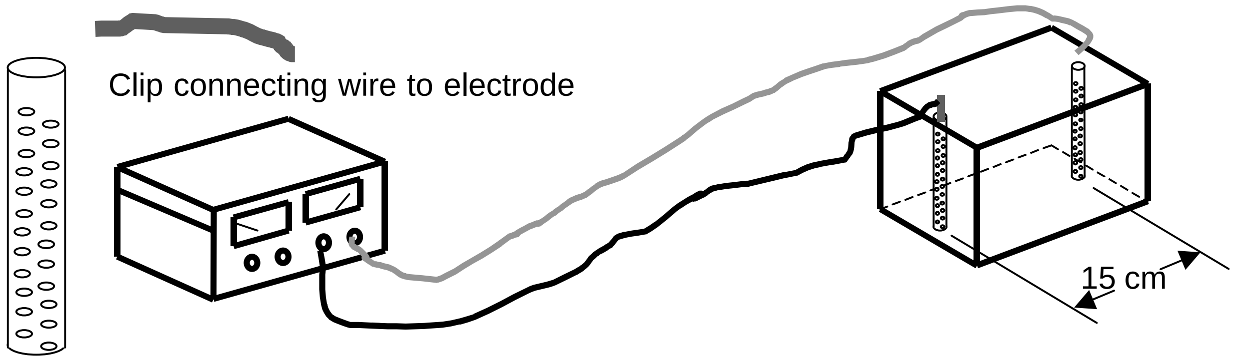


Figure 4. Connecting the DC power supply to the galvanized steel electrodes.

9. If the distance between the electrodes is 15 cm long, the voltage would be set at 60 V DC. When this reclamation system is energized, the current should read approximately 5 mA DC.

Safety Note:
Safety is an important consideration in this activity because students will work with an electrical power supply that may use up to 50 or 100 V DC and perhaps a maximum of approximately 1 A DC of electrical current. When working with electricity, the "one hand rule" should be observed — when connecting electrical wires or taking electrical measurements, only one hand should be used. When a person is electrocuted, the electrical current, which is measured in amperes, causes injury to the person's body. Even low amperage current (1 ampere or less) can cause injury. When a person uses two hands to work with electricity and accidentally makes contact with the current, it can flow through one arm, across the chest, through the heart, and down the other arm to complete the electrical circuit. In the event of accidental contact with electrical current, using one hand reduces the chance that current will flow across the heart. Because the solution may require the use of water, the power supply should be kept away from any water by using long wires to connect the power supply to the solution. The power supply should be set on no more than four volts per linear centimeter of soil. With the voltage set constant, the amperes should vary between .005 A DC (5 mA) and 1A DC.

Copper will actually form on the galvanized strip and will be quite visible against the shiny, galvanized surface. The reclamation system is configured somewhat like a cell. The positive lead from the power supply and the electrode to which it is connected form the anode and the negative side forms the cathode.

Evaluating the Solution

10. To establish a baseline reading of contamination at the site, litmus paper or pH test strips should be used to test for the presence of cupric sulfate in the soil. A reading at each tube should be taken including the tubes that house the electrodes. The amount of cupric sulfate should be fairly evenly distributed across the tubes. A reading of the electrical current provided by the power supply should also be taken. Before using the litmus paper, the old water from each tube and pipe should be extracted with a medicine dropper or basting bulb to allow the tube to refill with fresh ground water.

Cupric sulfate and electrical current readings may be taken at regular intervals — every other day, for example — and the readings should then be recorded. Because of the chemical reaction, actual copper will build up on the cathode as the process continues over the course of a month. The ground water will also be split into hydrogen and oxygen, and students will be able to observe tiny bubbles building up — oxygen around the anode and hydrogen around the cathode. At the end of the process, the reclamation system should have removed a noticeable amount of cupric sulfate from the soil, copper should be obvious on the cathode, and the current could be elevated to approximately 1 A DC. Cupric sulfate levels should drop over the course of the process, with the most reclamation starting at the anode and continuing toward the cathode over time.

In addition to recording the data that was collected, students should represent the data with tables and graphs showing relationships over time. They should be able to relate the simulated reclamation system to one that they described in their case study, and they should be able to reach conclusions and make recommendations based on their findings.

As a simulation, certain parts of the experimental setup represent real life applications. For example, the sand represents the tailings and soils at the abandoned mine. The cupric sulfate is symbolic of any heavy metal contaminant. The pipe and tubing represent the shafts that the reclamation company would drill at the site. The power supply represents the power plant at an actual site. Students should understand the chemical and physical science concepts that are employed at actual sites and in the experiment. The copper that builds up on the electrode is symbolic of the efficient recycling and extraction of pollutants while cleaning the environment. There are important energy and power technology concepts that relate to the real-life reclamation technology.

11. After the activity, the sand and the water contained in it may be simply thrown in the trashcan or a flowerbed because they are not toxic. Even though the sand and water contain only copper, the school's regulations and protocols for the disposal of wastes should be observed. Before moving the tank, students should wait for much of the water to evaporate thereby avoiding getting things wet and stained.

Assessment

Students should develop an individual portfolio containing evidence that they understand the design concepts being emphasized, including the design process and the environmental systems concepts. Use a rubric for portfolio evaluation.

Student self-evaluation and peer evaluation may also be appropriate for aspects of group work.

Additionally, to make the assessment more authentic, the entire group should compile a presentation representing all of its reclamation development processes and products. For example, the draftings for the tank and tubing should be included, as well as the data and graphs. Teachers and students should judge the quality of the products.

Another authentic assessment would be to invite the science teacher or a local environmental engineer to review the solution and provide feedback to the class and career information related to the management of the environment.

Extension 1

Experimental and control groups could be compared in this activity by using varying distances between the electrodes or by varying the surface area of the electrodes. In this case, two solutions would be constructed. The solution following the recommended distance between electrodes would be the control group, and the solution with the increased distance between the electrodes might be thought of as the experimental group. Bioremediation could also be introduced as a dual solution.

Extension 2
Instead of conducting the actual experiment, the research and development that students conduct could be applied to the construction of a mockup or non-working model of an actual reclamation site. The mockup could be a scale model of the site that shows a cross section of the soil sediments, the electrodes extending into the soil and shafts, and all of the support facilities that need to be constructed on site at ground level.

Extension 3
Another alternative is to correlate instruction with the science teacher. The science class will conduct the experiment, while the technological studies class will research, design, and build the mockup or scale model.

Addressing Benchmarks

To illustrate how students will address the various benchmarks during this activity, the following examples may be applied:

Standard 13, Benchmark K:

Synthesize data, analyze trends, and draw conclusions regarding the effect of technology on the individual, society, and the environment.

Standard 16, Benchmark L:

Energy can be grouped into major types: thermal, radiant, electrical, mechanical, chemical, and nuclear.

Students should reflect on the process by which they were able to determine that they were removing pollution from the soil. They should also reflect on the various forms of energy and reactions that are involved in the solution, as well as the work that was accomplished, and the engineering and design processes that were used in researching and developing their system. Students may submit essays with graphics that describe the reclamation technology systems and the way those systems use energy.

Most importantly, students should reflect on the planning and design processes in their individual portfolios. They should relate their *authentic* activity to what they understand about energy, power, and related technologies in real life.

Closing Comments

Agricultural engineering, related biotechnology, energy applications, and related environmental technologies are very important areas for all students to understand. Teachers should consider following up this activity with one in which students identify the agricultural, biotechnology, or environmental problems. They should be allowed the freedom to plan and implement the problem-solving process in designing and engineering solutions to their problem.

See the MSDS for cupric sulfate on the next page. A variety of public domain MSDS databases are available on the World Wide Web and on CDROM. This MSDS is taken from a public domain database maintained by Solutions Software (1999).

See the Activity 3 design brief after the MSDS.

For information about teaching energy and related environmental technologies, see Smith, 1993.

CUPRIC SULFATE
MATERIAL SAFETY DATA SHEET

NSN: 685000F034305
Manufacturer's CAGE: 4A444
Part No. Indicator: A
Part Number/Trade Name: CUPRIC SULFATE

General Information

Company's Name: Anachemia Chemicals Inc.
Company's Address: 3 Lincoln Blvd.
Rouses Point, NY 12979
Company's Country: US
Company's Emergency Phone #: 518-297-4444
Company's Information Phone #: 800-424-9300
Record No. For Safety Entry: 001
Total Safety Entries This Stk#: 001
Status: SE
Date MSDS Prepared: 23JUL91
Safety Data Review Date: 26APR94
Preparer's Company: Anachemia Chemicals Inc.
Preparer's Address: 3 Lincoln Blvd.
Rouses Point, NY 12979
Preparer's Country: US
MSDS Serial Number: BTNHD

Ingredients/Identity Information

Proprietary: No
Ingredient: Copper Sulphate, Cupric Sulfate Pentahydrate
Ingredient Sequence Number: 01
Percent: 98-102
NIOSH (RTECS) Number: GL8900000
CAS Number: 7758-99-8
ACGIH TLV: 1 MG/CUM (CU)

Physical/Chemical Characteristics

Appearance And Odor: Blue Odorless Solid Crystals
Melting Point: 302F
Specific Gravity: 2.284
Decomposition Temperature: 560C/1040F
Solubility In Water: Appreciable
pH: 3-4.5

Fire and Explosion Hazard Data

Extinguishing Media: Use media appropriate to surrounding fire conditions.
Special Fire Fighting Process: SCBA w/full facepiece operared in pressure demand/other positive pressure mode. Wear adequate protective clothing.
Unusual Fire And Expl Hazrds: Emits toxic fumes under fire conditions.

Reactivity Data

Stability: Yes
Cond To Avoid (Stability): Heat, sparks, flame
Materials To Avoid: Powdered metals/hydroxylamine/acetylene/hydrazine/nitromethane/sodium hypobromite/reducing & oxidizing agents. supp
Hazardous Decomp Products: Oxides of sulfur & copper
Hazardous Poly Occur: No

Health Hazard Data

LD50-LC50 Mixture: Oral LD50 (RAT): 300 MG/KG
Route Of Entry - Inhalation: Yes
Route Of Entry - Skin: No
Route Of Entry - Ingestion: Yes
Health Hazards, Acute And Chronic:
Eyes: Severe irritation/burns/ulceration/vision loss
Skin: Irritation/allergic dermatitis
Inhale: Respiratory inflammation/ulceration/nasal septum perforation/mucous membrane irritation
Ingest: Mouth burns/pharynx/gi tract/hemorrhagic gastritis/kidney/liver damage/CNS depression/toxic/death/jaundice/paralysis supp
Carcinogenicity - NTP: No
Carcinogenicity - IARC: No
Carcinogenicity - OSHA: No
Explanation Carcinogenicity: None
Signs/Symptoms Of Overexposure: Irritation, coughing, sore throat, shortness of breath, chills, stuffiness of head, nausea, vomiting, abdominal pain, metallic taste, diarrhea, convulsions, coma, shock, conjunctivitis, burns, symptoms of common cold
Emergency/First Aid Procedure:
Eyes: Immediately flush with water for 15 minutes.
Skin: Wash with soap and water.
Inhalation: Remove to fresh air. Give oxygen/CPR, if necessary.
Ingestion: Give large quantity of water to dilute. Induce vomiting. Never give fluids to unconscious person. Obtain medical attention in all cases.

Precautions for Safe Handling and Use

Steps if Material Released/Spilled: Wear protective equipment. Sweep up & place in container for disposal. Avoid raising dirt. Ventilate area & wash site after material is picked up.

Waste Disposal Method: Dispose of in accordance with federal, state, and local regulations. Avoid runoff. Don't wash down the drain.

Precautions-Handling/Storing: Store in a cool, dry place, away from ignition sources. Ventilate area. Keep tightly closed. Don't add any other materials to the container.

Other Precautions: Avoid raising dust. Don't get in eyes, on skin, or clothing. Don't allow smoking or food consumption while handling.

Control Measures

Respiratory Protection: OSHA/MSHA approved chemical cartride respirator, SCBA

Ventilation: Chemical fume hood, adequate to maintain vapor/dust <TLV

Protective Gloves: Rubber

Eye Protection: Safety goggles, face shield

Other Protective Equipment: Eye bath, emergency shower, apron, rubber boots

Work Hygienic Practices: Remove/launder contaminated clothing before reuse.

Suppl. Safety & Health Data: Materials to avoid: magnesium, alkalies, zinc. The solutions of this product are very corrosive to iron & steel.

Health Hazards Continued: Hemolytic anemia

Transportation Data

Disposal Data

Label Data

Label Required: Yes
Technical Review Date: 26APR94
Label Date: 26APR94
Label Status: F
Common Name: Cupric sulfate
Chronic Hazard: Yes
Signal Word: Danger!
Acute Health Hazard-Severe: X
Contact Hazard-Severe: X
Fire Hazard-None: X
Reactivity Hazard-None: X
Special Hazard Precautions:

Eyes: Severe irritation/burns/ulceration/vision loss
Skin: Irritation/sllergic dermatitis
Inhale: Respiratory inflammation/ulceration/nasal septum perforation/mucous membrane irritation
Ingest: Mouth burns/pharynx/GI tract/hemorraghic gastritis/kidney/liver damage/CNS depression/toxic/ death/jaundice/paralysis supp.
Target organs: Eyes, skin, liver, kidney, lungs, CNS, respiratory, digestive & GI tracts, blood, possible lung irritation from silice. Long quartz.

Protect Eye: Y
Protect Skin: Y
Protect Respiratory: Y
Label Name: Anachemia Chemicals, Inc.
Label Address: 3 Lincoln Blvd.
Rouses Point, NY 12979
Label Country: US
Label Emergency Number: 518-297-4444
Year Procured: UNK

The Design Brief

Cleaning the Soil

Background
While most people probably know that industries can easily pollute the water, they might not realize that the soil can also become polluted with heavy metals. While they may be familiar with metal, they probably do not think of it as a pollutant. However, various metal substances from mercury to nuclear byproducts are toxic and can pollute the soil and ground water.

Context
Throughout the world, places are polluted from the dumping of industrial waste solids and liquids. In the U.S., the Environmental Protection Agency supervises the clean up of such waste sites with money acquired from "Super Fund" legislation. Acting as environmental engineers, students will design and simulate a plan for solving the following environmental problem.

Problem Statement
A local builder wants to construct a housing development on some abandoned land outside of town, but soil tests have revealed that the ground is contaminated. The soil has been polluted with heavy metal that soaked into the ground when tailings and other debris were discarded from the old copper mine and the processing plant that operated on the site in the 1950s. The pollution extends from ground level to 100 meters beneath the soil. Plans for building houses will, therefore, have to be delayed.

Challenge
As environmental engineers, the team's job is to free the soil of the contaminating heavy metal so that the site will be fit for a housing development, and drinking water can be piped in and sewage piped out. A case study on a similar problem should be conducted.

Requirements
The technological solution must be no larger than two cubic feet and be able to be demonstrated in the laboratory-classroom. The solution must be safe, and it must be designed, constructed, and demonstrated under the supervision of the teacher.

Objectives
Upon completing this activity, students will be able to:
- Explain the requirements of a simple electrical circuit and simple electrical components
- Understand the applications of the various forms of energy involved in electrokinetics
- Understand the properties of the chemicals, elements, and contaminants involved in the problem
- Explain electrokinetics as a means of environmental clean-up and recycling
- Explain the relationships among pollution, industry, the economy, and societal values
- Apply knowledge of electrokinetics to the solution of the environmental problem

Assessment of the Solution
The solution should address removing a metal substance from the soil. In addition to devising a way to determine the degree to which the soil has been cleaned, the team should determine the parameters that will guide their approach to engineering the solution. The extent to which the solution addresses these parameters should be one of the criteria by which performance will be graded.

Resources

Science and technology references, in addition to the World Wide Web, should be used to conduct research on electrokinetics as a part of the case study solution.

Assessment of Students

The teacher will grade students on the following:

- The degree to which the solution is guided by their research
- The extent to which the solution met the established parameters
- The extent to which they worked in a safe manner
- Portfolio representation of what was learned from the technology assessment
- Portfolio representation of all aspects of researching and developing the solution
- Effectiveness of their work as a group

The teacher will explain additional grading criteria and the percentage that each item counts toward the final grade.

Safety

Because safety will be an important consideration in this activity, students must behave very responsibly. They may be working with chemicals that will require safety goggles, a face shield, rubber gloves, and a rubber apron. They may also work with an electrical power supply that may use up to 50 or 100 volts of electricity and perhaps a maximum of one ampere of electrical current. Students may also use material processes to construct solutions. They must not use any tool or equipment unless they know how to use it safely.

Students might work with cupric sulfate, a mildly toxic form of copper that will act as the contaminant for the environmental problem. They should not get it in their mouth, nose, ears, eyes, or on their skin. They should remove contact lenses when working with chemicals and wear glasses instead. If cupric sulfate contacts the skin, it should be washed off with soap and water. Students must avoid all direct contact with cupric sulfate.

Because students may be working with an electrical power supply, they should always obey the "one hand rule" — when connecting electrical wires or taking electrical measurements, only one hand should be used. When a person is electrocuted, the electrical current, which is measured in amperes, causes injury to the person's body. Even low amperage current (1 ampere or less) can cause injury to a person. When a person uses two hands to work with electricity and accidentally makes contact with the current, it can flow through one arm, across the chest, through the heart, and down the other arm to complete the electrical circuit. In the event of accidental contact with electrical current, using one hand reduces the chance that current will flow across the heart. Your solution may require the use of water. When it is time to use a power supply with your solution, you should allow your teacher to connect the power supply to any electrical connections. The power supply can be kept away from any water by using long wires to connect the power supply to the solution. The power supply should be set on no more than 4 volts per linear centimeter of soil to be cleaned. With the voltage set constant, the amperes should vary between .005 A DC (5 mA) and 1A DC.

Activity 4

Aquaponics: Growing Plants and Animals

Purpose

This activity will help students understand and experience agricultural engineering design, hydroponics, aquaculture, and aquaponics systems. As a result, they will be able to make responsible decisions as voters and citizens, understand ways to use land responsibly, develop effective approaches to problem solving, and make career decisions.

Standards Addressed

Depending on how the content is emphasized, the following standards may be addressed:

The Nature of Technology

Standard 3. Students will develop an understanding of the relationships among technologies and the connections between technology and other fields of study.

Technology and Society

Standard 5. Students will develop an understanding of the effects of technology on the environment.

Standard 6. Students will develop an understanding of the role of society in the development and use of technology.

Design

Standard 8. Students will develop an understanding of the attributes of design.

Standard 9. Students will develop an understanding of engineering design.

Standard 10. Students will develop an understanding of the role of troubleshooting, research and development, invention and innovation, and experimentation in problem solving.

Abilities for a Technological World

Standard 11. Students will develop the abilities to apply the design process.

Standard 13. Students will develop the abilities to assess the impact of products and systems.

The Designed World

Standard 15. Students will develop an understanding of and be able to select and use agricultural and related biotechnologies.

Recommended Teaching Methods

Depending on how the instruction is structured, the following methods may be useful:

Method 2: Cooperative Group Learning

Students may work in small groups to solve an aquaponics problem.

Methods 3 and 4: Design and Technological Problem Solving

Given a design brief, students will design a technological solution to an aquaponics problem through research and development.

Method 5: Curriculum Integration
Instruction may be correlated with the **biology and chemistry** related to plant, animal, and nutrient concepts that underlie the aquaponics technology. Every teacher involved should explicitly teach students how the fields that their classes represent are related to the other classes and to technology.

Method 6: Simulations, Games, Models, and Role-Play
Students will construct and demonstrate a small scale, working model of their solution that will actually work or at least simulate the authentic aquaponics process.

Method 8: Technology Assessment
Students will evaluate the quality of their aquaponics system and assess the impacts that it *could* have on the environment and the economy. In the process, they should also consider the manner in which land and water can become polluted and how the values of society are related to food production and pollution.

Prior Knowledge

The prior knowledge and abilities needed for this activity include:
- Word processing (for reporting)
- Spreadsheet (for data analysis and representation)
- Experience in solving simpler technological problems
- Desktop publishing and multimedia development (for reports and presentations)
- Internet browser (for research and case studies)
- Computer aided design (CAD — to design the technological solutions)
- Material processes (various — to construct the technological solutions)
- Some biology and/or chemistry

Resources

- 2 (minimum) clean aquarium fish tanks (water-tight)
- Egg carton
- Potting soil and/or cotton balls
- Litmus paper and pH scale
- Plant nutrient
- Small goldfish (or small hardy species of pet fish)
- Aquarium aerator
- PVC tubing for aerator
- Fluorescent lamp
- Safety goggles
- Variety of materials used to support maturing plant root structures
- Scale and measuring spoons to measure nutrients
- Rubber gloves and rubber apron
- Work space for several groups of students
- Variety of tools and materials
- Eye wash
- Water source
- Aquarium style pump and water filter
- Computer with spreadsheet
- Several computers with desktop publishing and word processing software
- Several computers with CAD
- Computers with Internet access
- Depending on the number of student groups, 120 sq. ft. of laboratory-classroom space near fluorescent lighting or sunlight

Time

High school technological studies class will need from four to six weeks to complete this activity. However, some of the suggested extensions could require more or less time.

Description

The Design Brief

1. Students can be introduced to the aquaponics problem by using the design brief on the last pages of this activity. (Refer to it at this time.) Students will likely need some guidance regarding the primary approach to take for the solution. Fish farming in the same facility is one approach that hydroponics systems are experimenting with to reduce the amount of nutrients needed to grow plants. Like hydroponics, fish farming is a growing industry, and there are some benefits to combining both systems. If teachers want to avoid influencing the possible solutions that students will research and develop, they can adapt the design brief so that it does not lead the students in one certain direction.

Researching the Problem

2. Teachers should help students focus on their research. It is important that they have access to the Internet because hydroponics, fish farming, or aquaculture (as a growing industry), and aquaponics are relatively new technologies that are not necessarily covered adequately in high school textbooks. While students are researching the problem with the objective of gathering ideas for possible solutions, they should be on the lookout for articles and references that will enrich their case study (or their Delphi study as described in Chapter 1 and Extension 5 of this activity). The case study will encourage students to find and understand the resolution of problems similar to ones other teachers may have assigned. For assessing technological solutions, one of the techniques described in Chapter 1 could be used.

3. This activity contains a lot of potential for student learning. While teachers will want to provide formal instruction on safety, formal lectures related to most of the activity should not be necessary. However, it is very important that students be engaged in discussions and seminars, and that they are provided guidance regarding the important concepts to learn. Students need to be able to work together in groups and use a procedure to guide them.
   - Students need to be able to organize how they will go about researching the problem, including the results of their case study.
   - They will need time to discuss the problem and apply their creativity and technological knowledge to their designs and solutions.
   - They will need to control variables in an experiment and troubleshoot promising approaches to the solution's implementation.
   - Students will need to be able to decide how to measure the effects of their solutions and record and represent the results.
   - They will need to be able to understand the underlying scientific, economic, and technological concepts such as an enterprise's ability to make a profit as opposed to its ability to process pollution and maintain production levels.

   Most importantly, teachers need to work with their students in such a way that they remain aware of all of the objectives cited above and are provided structure and guidance in the middle of a relatively open-ended, ill-structured activity. A portfolio, a notebook, and seminars are important because they provide places for students to record their insights, progress, and attempted approaches, as well as to compare their understandings to those of the other students.

An Example Solution

4. Technology teachers will want to work with the school's science teachers for guidance in conducting the activity, in helping students understand the underlying concepts, and in procuring the supplies that may be needed.

   One possible way to improve or at least maintain the production of the hydroponics crops is to grow fish in the nutrient bath. To a certain extent, the waste from the fish stock will supply nutrients to the hydroponics crops, thereby reducing the amount of inorganic nutrient that has to be added to the water.

   Ideally, student groups could establish hydroponics systems over a four to six week period to establish a "baseline" reading on the amount and balance of nutrients for the hydroponics crop. However, because time is a factor in any activity, the established hydroponics production is not necessary. The problem at hand is simply whether or not adding fish to the hydroponics will allow the same amount of plant production while reducing the amount of nutrients that had traditionally been added to the system.

   Students will design a hydroponics system capable of supporting fish and maintaining all variables constant. The two systems differ in that one actually uses fish as the nutrient provider, while the other has nutrients added. If both systems are established at the same time and under the same conditions, a fair comparison can be made.

Safety Note:
Safety will be an important consideration in this activity. Working with nutrient chemicals will require safety goggles, rubber gloves, and a rubber apron. When nutrients are acquired, a copy of the material data safety sheet should be included for safety records. Students should be taught about the hazards associated with chemicals, including accidental ingestion.

Fish Production

5. A hardy species of small fish should be used for the experiment, and nothing in the experiment should harm them. The fish must be fed fish food as in an ordinary tank.

6. You will want to design the hydroponics system with the needs of the fish in mind, while satisfying the needs of the plants as well. For example, the fish will need an adequate supply of oxygen and enough room to swim freely. An aerator should be used to oxygenate the water. If the fish-based hydroponics system has a full tank of water and an aerator, the non-fish-based system should also have the same configuration.

   Although the fish-based system needs light in order to grow microscopic plants and organisms for the fish to eat, the roots of the hydroponics plants may need darkness to grow well. One possible solution to this dilemma would be a trade-off in which the top of the tank sides are covered with opaque material that will shade the plant roots, while the lower portion of the tank sides are left open to light. (See Figure 5.) Because thick blooms of algae can deplete the oxygen level in the water, students and teachers should use their judgment about cleaning the environment. However, when using the fish to supply nutrients to the plants, the water may be circulated without necessarily filtering it on a constant basis. Excessive filtering may remove nutrients from the water and deprive the hydroponics system.

   Depending on the species of fish grown in a real life facility, the fish waste may have to be physically cleaned from the system. Some facilities recycle that waste into compost that is used for starting seedlings. It is not necessary for your students to recycle the fish waste when or if it needs to be removed. Students should be able to see a difference in nutrients used in the system without recycling the waste. However, the recycling of waste should be considered a part of the students' solution if it were implemented in real life.

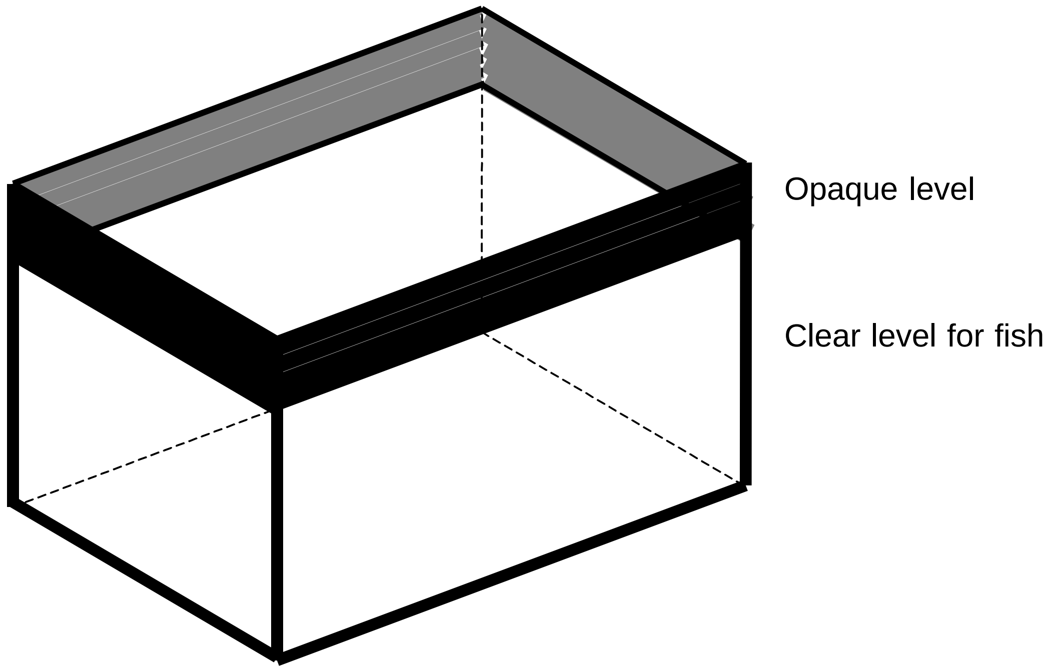


Figure 5. The tank with opaque and clear levels

The Hydroponics System

7. One of the design objectives is to develop a hydroponics system that supplies mature crops at all times. The plants could be grown on top of the fish tank. Placing seedlings on a mesh supported by polystyrene foam frames provides a very simple solution to supporting the plants' root structures while being able to rotate them through the system in order of maturity. (See Figure 6.)

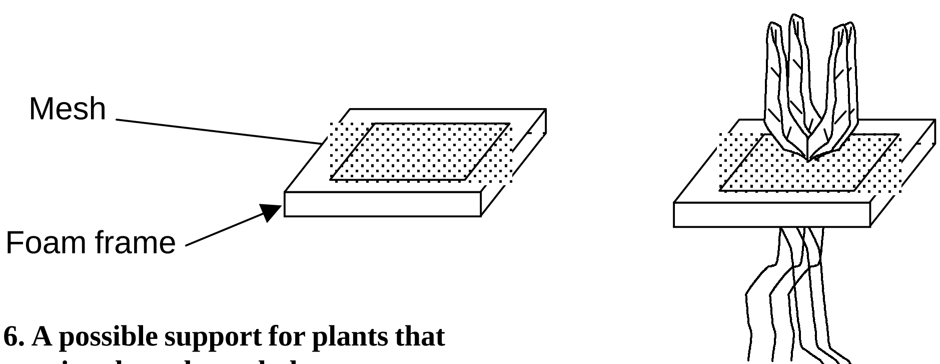


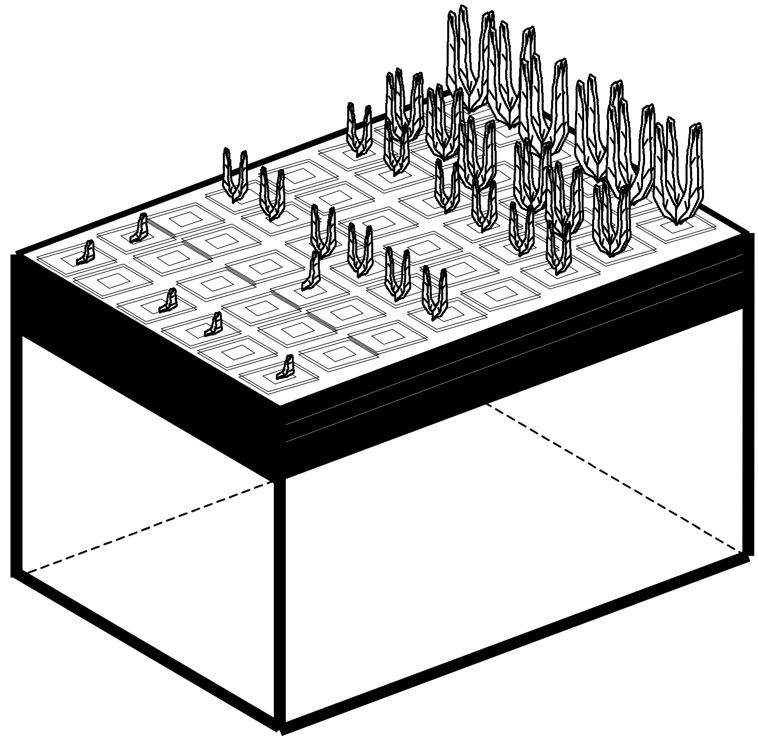
Figure 6. A possible support for plants that makes rotating them through the system easy

These frames will allow the roots to contact the water, the plant to stay afloat, and the plants to be rotated through the system and arranged according to which plants will be harvested first. (See Figure 7.) There is an abundance of hydroponics designs that students will research. One important control involves using the same design for both the fish-based and non-fish-based systems.

8. Radish, a relatively quick growing plant, will be useful for this experiment. To load the system shown in Figure 7, seedlings should be rooted in an egg carton (enough for one row of crops). About two days later, the next row of crops should be rooted, and so on. This method should be applied to both hydroponics systems.

The biology and chemistry teachers may act as consultants to help students achieve the right balance of nutrients for the purely hydroponics system, and they can also help to monitor the water conditions in both systems.

Figure 7. Crops rotate through the system from immature to mature crops.



Evaluating the Solution

9. Students must keep careful records of how they treat each system. Crop yield is one of the key measures for comparing the systems. The crop should not actually mature in a small simulated experiment like this one. The yield could be determined by the number of leaves on each plant and the height and/or the quality of each. If students are interested in measuring the yield of fish in terms of weight, they might be convinced not to because the fish are not technically part of the problem. Plus, weighing the fish could injure them. However, if the yield of fish were an interest, the number of new fish born could be recorded.

Assessment

Students should develop an individual portfolio containing evidence that they understand the design concepts being emphasized, including the design process and the aquaponics systems concepts. Use a rubric for portfolio evaluation.

Student self-evaluation and peer evaluation may also be appropriate for aspects of group work.

Additionally, to make the assessment more authentic, the entire group should also compile a presentation representing all of its hydroponics development processes and products. For example, the drawings and sketches for the tank and root support systems, in addition to the data and the graphs, should be included. The teacher and students should judge the quality of the products.

Another authentic assessment would involve inviting the science teacher or a local biologist, agricultural engineer, or hydroponics grower to review the solution and provide feedback and career information related to hydroponics, aquaculture, and aquaponics.

Extension 1

An additional “control” group could be compared in this activity by introducing a third fish tank. This tank would contain fish without plants, and it would represent fish farming, while avoiding the use of a significant number of plants.

Extension 2
Instead of conducting the actual experiment, the research and development that students perform could be applied to the construction of a mockup or non-working model of an actual aquaponics facility. The mockup could be a scale model of the site that shows a cross section of the buildings, treatment ponds, fish ponds, composting area, and the like.

Extension 3
Another alternative is to correlate instruction with the science teacher. The science class will conduct the experiment, and the technological studies class will research, design, and build the mockup or scale model.

Extension 4
The experiment could be left in place and maintained for the entire semester while more reliable data is collected and observed.

Extension 5
The task of researching and determining the best ways to produce hydroponics crops could be the central focus of the technological studies activity. Student groups might concentrate their efforts in running a Delphi study, which would take about three to six weeks to complete. The teachers would want to conduct the study while the class also worked on other activities. When conclusions about the best approaches to production are reached, students could then design, construct, and maintain a scale version of the system.

Addressing Benchmarks

To illustrate how students will address the various benchmarks during this activity, the following examples can be used:

Standard 15, Benchmark N:

> *The engineering design and management of agricultural systems requires knowledge of artificial ecosystems and the effects of technological development on flora and fauna.*

Students should reflect on the various forms of environmental harm and good their system causes, in addition to the benefits of aquaponics and the engineering and design processes used in researching and developing their system. Students may submit essays with graphics that describe the aquaponics technology systems that they used and how they work.

Most importantly, students should reflect on the planning and design processes in their individual portfolios. They should relate their authentic activity to what they understand about pollution and agriculture in real life.

Closing Comments

Important areas for all students to understand include agricultural engineering, related biotechnology, and related environmental technologies. Teachers should consider following this activity with one in which students identify the agricultural, biotechnology, or environmental problem. They should be allowed the freedom to plan and implement the problem-solving process that they will use to in designing and engineering solutions.
See the Activity 4 design brief on the next page.

For more information about teaching agricultural engineering, related biotechnology, and related environmental technologies at the high school level, see LaPorte and Sanders, (1996).

The Design Brief

Aquaponics: Growing Plants and Animals

Background
Agriculture is very important because it provides food for human beings. During the twentieth century, agriculture became more mechanized and automated, which resulted in fewer people working the land and increased productivity. While agriculture became more automated, cities and suburbs began to grow at an almost uncontrollable rate.

Context
Land has become a precious resource, in terms of the way it is used for both urban and agricultural purposes. Therefore, new ways must be developed to produce food while protecting the quality of the land and water, in addition to meeting the growing demand for food. Hydroponics and fish farming are two new ways that have become increasingly popular as alternative methods to traditional agriculture. Hydroponics is the production of crops without using soil —"soil-less" agriculture. Aquaculture, often used to describe fish farming, is an intensive way to produce fish and tends to save money and reduce over-fishing in the ocean. When hydroponics and aquaculture are combined, the system is often referred to as "aquaponics."

Problem Statement
A new hydroponics company recently conducted a profit/loss analysis and determined that it is losing money. The company found that it was spending more money on water treatment and crop nutrient (fertilizer) than it could afford. This new company also determined that its current practice of growing hydroponics crops in single batches (all plants mature at the same time) creates delays in filling orders and shipping crops to customers. To make things worse, the company also learned that a competing hydroponics company was selling similar crops to the same customers.

Challenge
Acting as agricultural engineers, students should design an aquaponics system that will reduce the amount of wastewater treatment that the hydroponics company must perform in order to recycle the water that they use. The system should also help to reduce the amount of plant nutrient that the company adds to the water. In addition, the system must have mature crops available in order to fill orders at all times. Finally, the system has to help the company diversify the products being offered to its customers.

Requirements
The technological solution must be no larger than can be managed in the laboratory-classroom, and it must be demonstrated in that space. If the solution requires chemical plant nutrients, students should use it only with the supervision of their teacher. If animals are used as part of the aquaponics system, every effort must be made to provide for their health and safety.

Objectives
Upon completing this activity, students will be able to:
- Explain the requirements of a simple aquaponics system
- Explain interrelationships of among plants, animals, and their environment
- Explain the relationships among pollution, industry, the economy, and societal values
- Apply their knowledge of science and technology to the solution of the aquaponics problem

Assessment of the Solution

The solution should reduce the amount of nutrient added to the water for hydroponics while still maintaining the level of plant production. The solution should also introduce a new product that may be cultivated and sold along with the established crop. Students should devise a way to determine the degree to which the water has been improved for plant production by the addition of the new food product. Furthermore, the solution should always provide mature food ready for harvest. The team should determine parameters that will guide the approach to engineering the solution.

Resources

Science and technology references, in addition to the World Wide Web, should be used to conduct research on hydroponics, aquaculture, and aquaponics.

Assessment of Students

Teachers will grade students on the following:

- The degree to which the solution is guided by their research
- The extent to which the solution met the established parameters
- The extent to which they worked in a safe manner
- Portfolio representation of what was learned from the technology assessment
- Portfolio representation of all aspects of researching and developing their solutions
- The effectiveness of their work as a group

The teacher will explain additional grading criteria and the percentage that each item counts toward the final grade.

Safety

Because safety will be an important consideration in this activity, students must act very responsibly. They may work with chemicals that require safety goggles, rubber gloves, and a rubber apron. If chemicals accidentally contact the skin, the area should be washed immediately with soap and water. All chemicals should be kept away from the skin, eyes, mouth, ears, and nose.

When students are working with an electrical water pump and aerator, they must be sure that the area is dry when connecting them to the electrical power.

Activity 5

Assisted Living

Purpose

This activity will help students understand and experience architectural design, engineering design, construction systems, and medical technologies. As a result, students will be able to begin to understand the various practices and procedures in these areas of design, and they will, therefore, be able to make responsible decisions as consumers. Students should develop consideration for people with special needs and diverse backgrounds. They should focus on community service while developing effective approaches to group problem solving.

Standards Addressed

Depending on how the content is emphasized, the following standards may be addressed:

Technology and Society

Standard 4.	Students will develop an understanding of the cultural, social, economic, and political effects of technology.

Design

Standard 8.	Students will develop an understanding of the attributes of design.
Standard 9.	Students will develop an understanding of engineering design.
Standard 10.	Students will develop an understanding of the role of troubleshooting, research and development, invention and innovation, and experimentation in problem solving.

Abilities for a Technological World

Standard 11.	Students will develop the abilities to apply the design process.
Standard 13.	Students will develop the abilities to assess the impact of products and systems.

The Designed World

Standard 14.	Students will develop an understanding of and be able to select and use medical technologies.
Standard 20.	Students will develop an understanding of and be able to select and use construction technologies.

Recommended Teaching Methods

Depending on how the instruction is structured, the following methods may be useful:

Method 2: Cooperative Group Learning
Students will work in small groups, with each representing a department in an architectural firm. Each group will have specific responsibilities in order to develop, design, and produce an assisted living facility.

Methods 3 and 4: Design and Technological Problem Solving
Students will design the site layout and structures for people who need assisted living. Students will specify, invent, or innovate medical products that will accommodate the needs of the residents, in addition to planning the facility as a community and developing architectural plans and models. They may develop model prototypes or mockups of necessary medical devices and facilities.

Method 5: Curriculum Integration
Instruction may be correlated with social studies relating to the demographic data of an “aging population;” art relating to renderings and “artists conceptions” of the solutions; and biology relating to the medical needs of senior citizens and other people who could benefit from special living accommodations. Every teacher involved should explicitly teach students how the fields represented by their classes are related to the other classes and to technology.

Method 6: Simulations, Games, Models, and Role-Play
Not only will students develop detailed architectural models, they may also develop working models to test the ergonomic factors related to fixtures and medical devices needed in the assisted living residences.

Method 7: Modular Instruction
This activity serves as a culminating experience for students who have been building prerequisite skills in modular laboratory-classrooms. Some students will have developed abilities at various modules related to the “prior knowledge” items listed below. They can apply those abilities and knowledge to this design activity.

Method 8: Technology Assessment
Students will assess trends in population change and try to relate their results to the technological needs of the population.

Prior Knowledge

The prior knowledge and abilities needed for this activity include:
- Word processing
- Spreadsheet
- Experience in solving simpler technological problems
- Desktop publishing and multimedia development
- Computer-aided design (CAD)
- Basic design and representation
- Architectural drafting
- Various material processes

Resources

- Several computers with CAD
- Laboratory-classroom space for several groups of students
- Plywood
- Architect’s scales
- Several sheets of matte board
- Utility knives or matte board cutter
- Wide metal straight edge (several, for cutting matte board)
- Safety glasses and other lab safety equipment typical in technological studies labs
- Variety of tools, materials, and supplies
- Computer with spreadsheet software
- Several computers with desktop publishing, graphics, and word processing software

Time

High school technological studies class will need from four to six weeks to complete this activity as described. However, some of the suggested extensions will require less time.

Description

Establishing Design Groups
Students will form an architectural design firm. After identifying many of the tasks that must be completed in order to design the assisted living "community," students should form cooperative groups that will work on various aspects of the research, planning, and design of the project.

- Research — Conduct a population assessment to identify trends in the changing characteristics of the population.
- Site planning — Determine the requirements of traffic flow, land use, power, water and sewage, landscaping, and the overall layout of the community. Develop a large, scale model of the entire assisted living community.
- Community buildings — Be responsible for the design of facilities that are needed by the entire community such as a hospital or medical facility, a dining and shopping facility, maintenance and support, recreation, etc.
- High level assisted living facility — Design the building(s) where residents live to have access to a higher level of assistance when necessary.
- Residential buildings — Design single-family residences (and certain interior fixtures) with necessary accommodations for assisted living.

These departments represent the cooperative groups of students that will carry out the various responsibilities of the firm. The teacher might decide to group students according to their expertise. For example, in a modular laboratory-classroom, some students may have performed well at CAD, others at modeling, and yet others at desktop publishing and word processing.

Researching the Project

1. Although one group could be responsible for the population study, all students could participate. This group should also conduct research regarding the cultural interests and backgrounds of the subjects in their assessment. While the population study is under way, students in other groups should be conducting research related to the design and building codes, in addition to the conventions of architectural drafting and methods for architectural modeling.

2. In most locations in the U.S., Canada, and parts of Europe, the demographics reflect growth in the number of people over age 50, a trend that reveals that people are living longer. When they begin to assess the technological needs of the residents of an assisted living community, students should also begin to reach conclusions similar to the following:
   - Traditional retirement communities do not adequately provide for the needs of people who require assistance at various levels.
   - Traditional convalescence and nursing facilities have not adequately addressed the spiritual and cultural needs of patients.
   - The assisted living community should provide for residents from a variety of cultural backgrounds.
   - The community should provide for the various spiritual needs of residents.
   - The community should provide medical facilities related to the needs of senior citizens and people with special medical needs.
   - Housing should provide for the special accommodations needed by residents.
   - Housing accommodations should be designed for flexibility and safety.
   - Depending on the locality, the community should be able to grow over time.

   These conclusions should be included with the design criteria that will guide the planning and design of the community.

Design Work

3. Site or plot plans should be developed with the growth of the community in mind. Some computer simulations may help in developing this concept — SimCity®, for example. The main road that enters the community should be designed to accommodate the volume of traffic that would be expected in 10 to 20 years. The initial building arrangements and their locations on the whole property should be planned in relationship to the estimated growth of the community. For example, the community buildings that serve all of the residents should be centrally located with the neighborhoods growing from this hub. Buildings that will be needed in the future can be zoned now. This group of students should make decisions regarding how to run utility systems to the community (and through the community) without destroying aesthetics. Based on the cartography of the land, they should also design landscaping, streets and sidewalks, and transportation facilities. As residents need more assistance, they may move to buildings that are closer to the community's center and medical facilities.

4. Community buildings must be designed to meet a more stringent set of building codes than do private residential structures. Students will want to design buildings that provide for a specific number of community requirements, and they can choose one particular building to design in detail. They will need to specify durable construction materials and design facilities for people with physical disabilities, in addition to designing entrances, hallways, and seating for people with mobility challenges. They need to provide accommodations and systems for people who are hearing impaired or have similar problems.

   The community facilities should accommodate the cultural backgrounds and interests of the residents, and the buildings should be easily maintained and provide for expansion as the population grows.

5. High-level assisted living facilities should be developed to provide housing for residents who need more assistance and a higher level of care than residents who are able to live in single family dwellings. Students should be sure to address the shortcomings of traditional nursing facilities in their designs. Medical technology should be available in the corridors, at nursing stations, and in the rooms of the residents. The design should facilitate improved nursing care and attention to the cultural and spiritual needs of the residents.

6. Housing designs, and even the arrangement of houses in a neighborhood, should take into account conclusions that have been reached based on the population study. Private residences have not been traditionally designed to accommodate the needs of senior citizens and people with disabilities.
   Physical access is only one special design consideration. Others include:
   - Remote communication with healthcare providers
   - Remote monitoring of residents if desired
   - Security from intruders
   - Fire detection and prevention
   - Placement and use of emergency medical equipment
   - Access to the entire residence for people with a variety of physical disabilities
   - Ergonomics of furnishings, fixtures, and in-home medical equipment
   - Exercise and self-administered therapies and health maintenance
   - Residents' community involvement, recreation, and cultural and spiritual needs

Rendering, Modeling, Prototyping

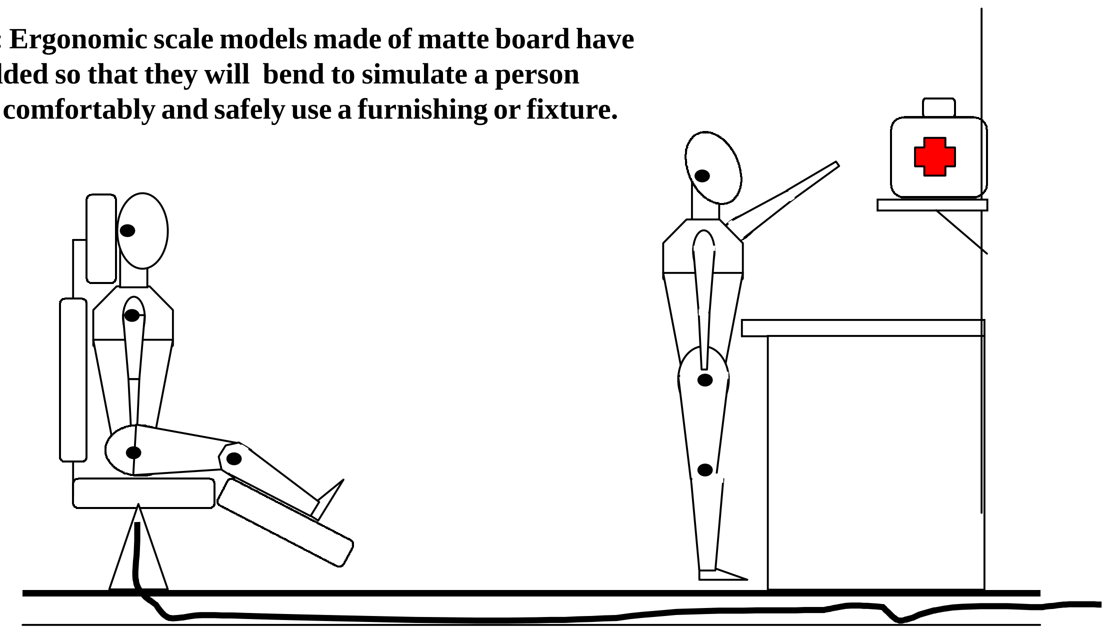
7. Students in all design groups should be actively sketching and rendering ideas to communicate effectively with their teams. Once ideas seem to be developed to the point that they meet the teams' design criteria, as well as meeting building codes and other considerations, ideas should then be drafted on the computer. Teams should continue to test designs and check for problems throughout the design process.

8. Students should begin making architectural models and testing the ergonomics of furnishings, fixtures, and medical devices as soon as working drawings, including elevations, are completed. Some work may begin prior to the completion of draftings. Scale models must be designed to be small enough to be placed on display and to

look proportional. An architect's scale is essential for this requirement. A second requirement for good architectural models is that the tools used to cut the modeling materials must be very sharp. Matte board is a relatively easy material to use for architectural modeling because it is easy to glue and fairly stable in humid conditions. Also, the color of the matte board may be chosen based on the color of the structure's exterior. By using a sharp utility knife and a wide straight edge or a matte cutting mechanism, matte board can provide a crisp look.

The ergonomics of furnishings, location and installation of various medical equipment, as well as other fixtures, can be tested by making scale models of senior citizens. Matte board would be an ideal medium for this work. (See Figure 8 below.) The student has made a model of a chair that will report a person's vital signs to a remote location. The model person can tell the student whether or not the chair design is safe, comfortable, and effective.

Figure 8: Ergonomic scale models made of matte board have pivots added so that they will bend to simulate a person trying to comfortably and safely use a furnishing or fixture.



> **Safety Note:**
> Teachers should instruct students on how to safely use hand tools such as utility knives, keeping in mind that the width of the metal straightedge used to guide the blade is important. The wider the strip of metal, the further away hands are from the cutting area. If possible, it is safer to use a matte cutter with guide bars to move the blade and with stops and clamps to hold the matte board.

9. Finally, for the purpose of presentation, renderings should be developed that show the "artist's conception" of the structures, fixtures, and devices that students have designed.

Assessment

Students should develop an individual portfolio containing evidence that they understand the design concepts being emphasized, including the design process, as well as the construction and medical systems concepts about which they have developed insights. Use a rubric for portfolio evaluation.

Student self-evaluation and peer evaluation may also be appropriate for aspects of group work.

Additionally, to make the assessment more authentic, the entire company should compile a presentation representing all of its development processes and products. For example, the working drawings for all of the assisted living designs, renderings, site model, structural models, and model devices should be included. Research statistics and summary reports should be included, and the teacher and students should judge the quality of the products.

Extension 1
Competing designs and prototypes could be developed. In fact, teachers might divide their classes into two design firms and have them compete.

Extension 2
The class could focus on only one aspect of the assisted living community and fully develop it.

Extension 3
As community service projects, the class could raise money and then design and construct a ramp at the home of someone with mobility problems. They could design and construct a storage shed and then later donate it to a construction site for Habitat for Humanity or another similar service organization. Teachers must observe the school system's policies on what students are allowed to do off campus.

Extension 4
Students could learn many architectural and community-planning concepts through various forms of community-based learning discussed in Chapter 1— such as internship and job shadowing, for example.

Addressing Benchmarks

To illustrate how students will address the various benchmarks during this activity, teachers can use the following examples:

> For more information about teaching construction systems and architectural design concepts at the high school level, see Pollete and Landers, 1995; Wagner and Smith, 1996; and Kicklighter, 1995.

Standard 20, Benchmark L:

The design of structures includes a number of requirements.

Standard 14, Benchmark K:

Telemedicine reflects the convergence of technological advances in a number of fields, including medicine, telecommunications, virtual presence, computer informatics, artificial intelligence, robotics, materials science, and perceptual psychology.

Students should reflect on the relationships between their research and their designs for structures and medical technologies.

Most importantly, students should reflect on construction systems, architectural design processes, and medical technologies in their individual portfolios. They should relate their authentic activity to what they understand about these fields in real life.

Closing Comments

If teachers have little experience in teaching construction and architectural design, they might ask for help from local carpenters, contractors, architects, and structural engineers. These professionals could also be involved in teaching and critiquing the students' work.

Activity 6

Forecasting the Future of Transportation Systems

Purpose

This activity will help students understand techniques of technology assessment, and the complexities and problems related to transportation systems.

Standards Addressed

Depending on how the content is emphasized, the following standards may be addressed:

Technology and Society

Standard 4. Students will develop an understanding of the cultural, social, economic, and political effects of technology.

Standard 5. Students will develop an understanding of the effects of technology on the environment.

Standard 6. Students will develop an understanding of the role of society in the development and use of technology.

Standard 7. Students will develop an understanding of the influence of technology on history.

Abilities for a Technological World

Standard 13. Students will develop the abilities to assess the impact of products and systems.

The Designed World

Standard 18. Students will develop an understanding of and be able to select and use transportation technologies.

Recommended Teaching Methods

Depending on how the instruction is structured, the following methods may be useful:

Method 2: Cooperative Group Learning

Students will work in cooperative groups that will act like “think tanks” to assess and forecast various aspects of transportation systems.

Method 5: Curriculum Integration

Instruction may be correlated with social studies relating to the social, political, and economic influences on the development of transportation technologies and demographics; and biology, chemistry, and physical science relating to the effects of transportation on the environment and the influence of environmental circumstances on the development of transportation. Every teacher involved should explicitly teach students how the fields represented by their classes are related to the other classes and to technology.

Method 8: Technology Assessment

Student “think tanks” will assess trends in the development of transportation technologies.

Prior Knowledge

The prior knowledge and abilities needed for this activity include:
- History of technology — prior introduction
- Basic understandings of the economic system
- Basic understandings of the environment and how it functions

Resources

- Laboratory-classroom space for several groups of students
- Several computers with desktop publishing, graphics, and word processing software
- Several computers with Internet access and browsers
- Research materials

Time

It will take the high school technological studies class from one to three weeks to complete this activity as described; however, some of the suggested extensions may better suit other time requirements.

Description

Establishing Assessment Groups

1. A large concept map will help students understand the breadth and complexity of the world's transportation systems. Once students have a sense of the components of the world of transportation, the teacher will be able to assign various aspects of the transportation technology assessment to cooperative groups. Depending on their prior knowledge of transportation systems and with the teacher's guidance, students could develop a concept map similar to the one shown in Figure 9. As the activity progresses, various student groups will select "student experts" who will represent the group in a Delphi study that will make a forecast about future trends in transportation technology.

   Based on the concept map in Figure 9, groups could be assigned their research by modes. For example, there could be "think tanks" for water transportation, land transportation, air transportation, and transportation research. Alternately, the class could focus on one mode of transportation, and group research could be assigned by vehicular sub-systems such as the propulsion group, the guidance group, the vehicle control group, and so on.

Background Research

2. Once group topics are assigned, students need access to a variety of references including technical publications such as *Scientific American*, *Popular Mechanics*, and *Nature*. They need access to references that will help them understand the history of transportation technology, as well as access to the Internet for up-to-the-minute developments in transportation policy, statistics (e.g.: U.S. Department of Transportation), and technical innovations. Among other guidelines, students will want to be on the lookout for information in the following categories:
   - Historical trends of the technology
   - Political influences on the technology
   - Economic influences of the technology
   - Social influences of the technology
   - Environmental consequences of the technology
   - Technological innovations on the technology

Creating "Experts"

3. As each "think tank" begins to yield information from its research, each group should discuss its finding among the members. An effective way to focus discussions is to ask each researcher to present interesting findings in

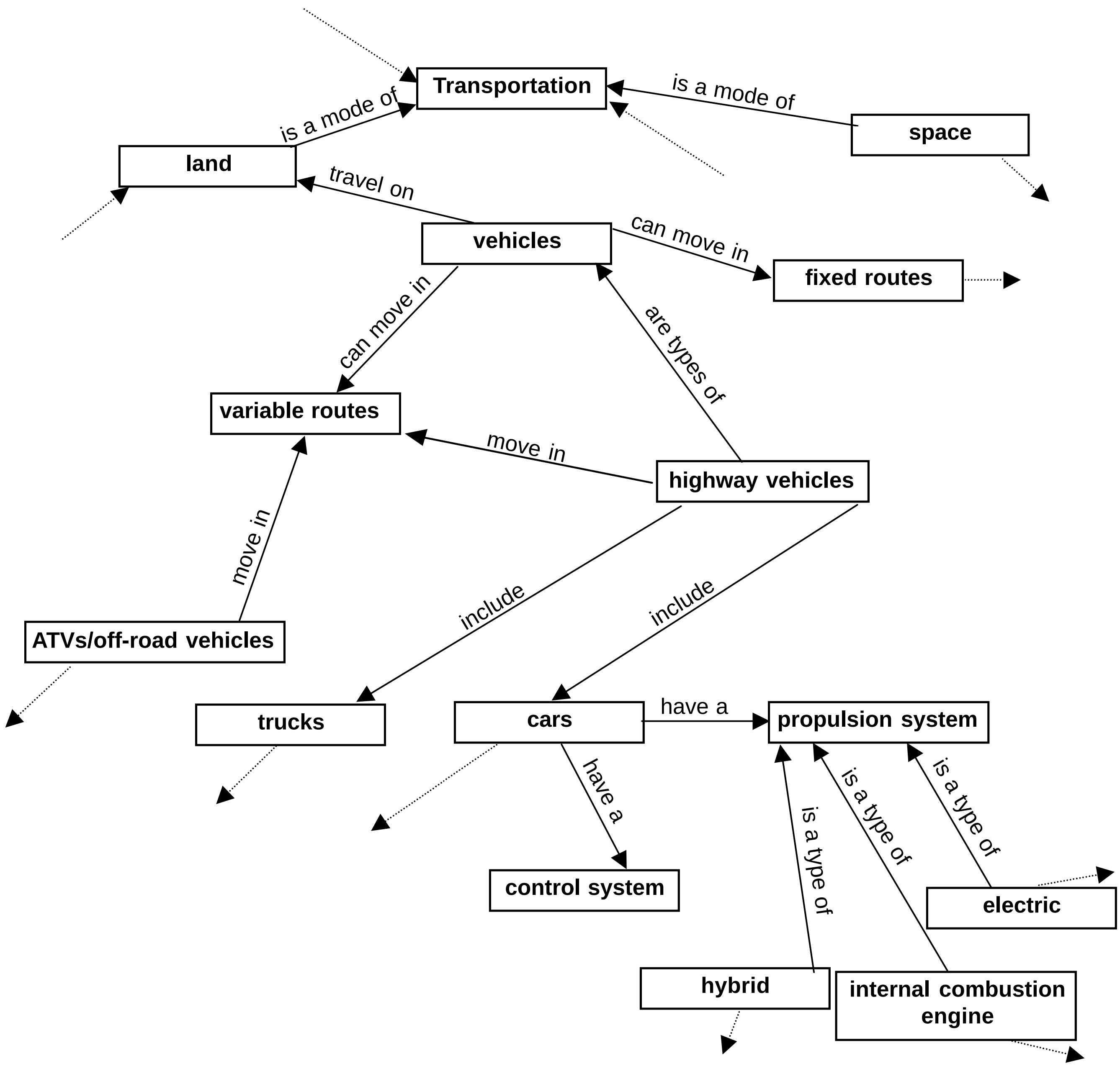


Figure 9. The diagram above represents one fourth of a possible concept map that a student may develop in order to document his or her understanding of the world of transportation. The diagram should include phrasing to show the student's train of thought leading to and between the boxes.

terms of the positive and negative developments and influences related to each of the categories listed above. The universal systems model may provide a framework to guide small group discussions in answering questions about the technological aspects of the topic: What are any important inputs, processes, outputs and feedback methods used? What were some of the expected, unexpected, desirable, and undesirable outputs of the systems?

Students should begin listing things that they found in common across their research efforts. Trends should begin to appear based on the technology's past and present status.

Forecasting

4. Within each "think tank" group, students could develop a relevancy tree, a feasibility matrix and/or a flow diagram in order to forecast what could and should happen to transportation technology in the future. The groups should list their conclusions and organize their research and forecasts into their portfolios.

Delphi Studies

5. Each group should briefly explain the focus of their efforts to the other groups. At this point, each group will develop a survey of questions to poll other "think tank" experts about the future of transportation. They will conduct their Delphi studies as described in Chapter 1.

6. Building on the example in Figure 9, some of the many conclusions that students may develop about propulsion technology should include:
   - The interstate highway system was developed from a so-called concern for the rapid deployment of troops throughout the U.S. during the early part of the Cold War.
   - Automobile fossil fuel emissions greatly improved in the 1970s and 1980s.
   - Automobile fuel economy began to improve in the late 1970s as a reaction to the Arab Oil Embargo.
   - Innovations have allowed automakers to develop engines that are lighter, more powerful, and relatively economical — for example, ceramics and lightweight, durable alloys and complex mechanical innovations, such as overhead quadruple intake and exhaust systems.
   - Current evidence tends to support the plausibility of the greenhouse theory of global warming.
   - Air pollution from highway vehicles appears to significantly contribute to greenhouse emissions.
   - Because of the limitations of storage batteries, current electric car technology is inadequate to support the needs of suburban commuters and cargo transfer.
   - Solar electric films will allow future solar electric cars to have attractive shapes.
   - Changing climates will hasten the development of alternative power plants and fuels for highway vehicles.
   - Hybrid propulsion systems will combine solar-electric, electric, and fossil fuel technologies.
   - "Smart highway" control systems will ease congestion, reduce fatalities, and provide more fuel economy, in addition to other advantages.

Presentation of Findings, Conclusions, and Recommendations for Future Development

7. After the rounds of the Delphi studies are concluded, each "think tank" should present some of its background research and the results of their Delphi studies to the whole class. They should develop graphics to support presentations that highlight their findings, conclusions, and recommendations.

Assessment

Students should develop individual portfolios that contain evidence they understand the background transportation concepts learned through research, as well as the forecasting techniques they used. A record and sample of the development and analysis of their Delphi studies should also be included. A rubric should be designed to evaluate the portfolio that could be similar to the one on the next page. Student self-evaluation and peer evaluation are also appropriate for aspects of cooperative group work.

Extension 1

"Think tank" groups could compete on the same forecasts to determine whether they reach the same or similar conclusions.

Extension 2

Each group could develop three-dimensional models to help communicate what they have learned.

Extension 3

Students could develop posters that show the relationships of transportation systems to other fields.

A Sample Rubric

Criteria / Scale	1 Beginning to Attain Standard	2 Nearly Attained Standard	3 Achieved Standard	4 Exceeded Standard
Portfolio is aesthetically appealing.	Portfolio unit has few unintended mistakes in the way it is decorated and appears.	Portfolio unit has extra graphic and text elements that accent contents and provide an interesting look.	Portfolio unit has extra graphic and text elements that accent contents, provide an interesting look, and establish a format that carries over from one unit to the next.	Portfolio has format elements that improve the look and interest of the portfolio, are drawn well, maintain the overall format, and are mistake-free.
Portfolio is effectively organized.	Portfolio unit has broad categories that help the student to group research processes.	Portfolio unit has subheadings that further organize the research process.	Portfolio unit is organized in a way appropriate for the content being studied and has an appropriate amount of narrative explanation.	Portfolio is organized by a research process sequence, has appropriate narrative explanation, and is appropriate transportation forecasting.
Portfolio includes a concept map, a taxonomy, or sketches that communicate an overall understanding of transportation.	Portfolio provides some understanding of the structure of transportation.	Concept map or overall understanding is evident.	Portfolio includes concept map and some narrative explanation of the transportation structure being studied.	Concept map and narrative represent a complete understanding of the structure of transportation.
Portfolio includes preliminary research conducted by the think tank group.	Some research is evident.	Research from several categories is evident.	Research from historical, political, economic, social, environmental, technological categories are evident.	Portfolio has research from all categories and that research is complete.
Portfolio includes relevancy tree, feasibility matrix, flow diagram or other appropriate techniques.	Forecasting techniques are evident.	Forecasting technique is evident and is complete.	Forecasting technique is evident through a graphic component and accompanied by some narrative explanation.	Forecasting technique is evident through a graphic component and accompanied by some narrative explanation and is complete.
Portfolio includes Delphi study development and results.	Delphi study research is evident.	Delphi study results are organized.	Delphi study procedure and results are evident and logically organized.	Delphi study procedure and results are complete, logically organized, and are followed by conclusions and recommendations.

Addressing Benchmarks

To illustrate how students will address the various benchmarks during this activity, teachers can use the following examples:

Standard 13, Benchmark L:

Use assessment techniques, such as trend analysis and experimentation to make decisions about the future development of technology.

Standard 18, Benchmark M:

> *The design of intelligent and non-intelligent transportation systems depends on many processes and innovative techniques.*

Students should reflect on the relationships among their research findings and those concepts specified in *Standards for Technological Literacy*, including those for both transportation and technology assessment.

Most importantly, students should reflect on transportation systems and technology assessment in their individual portfolios.

Closing Comments

This same approach could be used to teach many of the content standards. After students complete this activity, teachers might consider giving extra credit to students who bring in and present current events and news articles that support and contradict the conclusions and recommendations that they made while performing the original activity. Finally, this activity can be thought of as a starting point in the study of transportation systems and their relationship to society.

> For more information about teaching transportation systems concepts at the high school level, see Johnson and Farrar-Hunter, 1993.

Chapter 3

Resources for Teaching Technology: High School

Strategies for Standards-Based Instruction

Chapter 3

Resources for Teaching Technology: High School

Section A

A Quick Reference of Standards for Technological Literacy

The Nature of Technology

Standard 1.	Students will develop an understanding of the characteristics and scope of technology.
Standard 2.	Students will develop an understanding of the core concepts of technology.
Standard 3.	Students will develop an understanding of the relationships among technologies and the connections between technology and other fields of study.

Technology and Society

Standard 4.	Students will develop an understanding of the cultural, social, economic, and political effects of technology.
Standard 5.	Students will develop an understanding of the effects of technology on the environment.
Standard 6.	Students will develop an understanding of the role of society in the development and use of technology.
Standard 7.	Students will develop an understanding of the influence of technology on history.

Design

Standard 8.	Students will develop an understanding of the attributes of design.
Standard 9.	Students will develop an understanding of engineering design.
Standard 10.	Students will develop an understanding of the role of troubleshooting, research and development, invention and innovation, and experimentation in problem solving.

Abilities for a Technological World

Standard 11.	Students will develop the abilities to apply the design process.
Standard 12.	Students will develop the abilities to use and maintain technological products and systems.
Standard 13.	Students will develop the abilities to assess the impact of products and systems.

The Designed World

Standard 14.	Students will develop an understanding of and be able to select and use medical technologies.
Standard 15.	Students will develop an understanding of and be able to select and use agricultural and related biotechnologies.
Standard 16.	Students will develop an understanding of and be able to select and use energy and power technologies.
Standard 17.	Students will develop an understanding of and be able to select and use information and communication technologies.
Standard 18.	Students will develop an understanding of and be able to select and use transportation technologies.
Standard 19.	Students will develop an understanding of and be able to select and use manufacturing technologies.
Standard 20.	Students will develop an understanding of and be able to select and use construction technologies.

Section B

Selected Websites Directly Related to Chapter 2 Activities

Aquaculture, Aquaponics, Hydroponics

Nelson / Pade Multimedia (1999). *Aquaponics.com* [online]. Available: http://www.aquaponics.com/

U.S. Department of Commerce, Minority Business Development Agency (1999). *MBDA Virtual centers: Technical information* [online]. Available: http://www.mbda.gov/Virtual_Centers/Aquaculture/technicalInfo.html

Assisted Living

Johnson, M., Duncan, R., Gabriel, A & Carter, M. (1999). *Home modifications and products for safety and ease of use* [online]. Available: http://www.design.ncsu.edu:8120/cud/built_env/housing/article_hmod.htm

Lighthouse International (1999). *Aging and vision news: A publication for practitioners, researchers and educators* [online]. Available: http://www.lighthouse.org/text_only/t_aging&vision_accom.htm

Manufacturing

Society of Manufacturing Engineers (2000). *Manufacturing is cool: Educational resources* [online]. Available: http://www.manufacturingiscool.com/cgi-bin/mfgcoolhtml.pl?/curricula.htm&

Soil Reclamation

Argonne National Laboratory, U.S. Department of Energy (2000). *Energy and environment research highlights: Argonne sets standard for expedited site characterization* [online]. Available: http://www.anl.gov/OPA/Frontiers97/EE8.html

Argonne National Laboratory, U.S. Department of Energy (2000). *Energy systems (ES) division* [online]. Available: http://www.es.anl.gov/htmls/remediation.html

Lindgren, E., Sandia National Laboratories (2000) *Demonstration of electrokinetic remediation of chromium from unsaturated soil* [online]. Available: http://www.pnl.gov/WEBTECH/mwlid/electkin.html

Technology Assessment

World Future Society (1998). *Welcome to the World Future Society* [online]. Available: http://www.wfs.org/

Videography

Videography Magazine (2000). *Videography online: For video production professionals* [online]. Available: http://www.vidy.com/

Section C

General Technology-Related Websites

Teachers should update this listing of websites on a regular basis. Website addresses (URLs) change frequently.

Brain, M. (1999). *How stuff works* [online]. Available: http://www.howstuffworks.com/index.htm
Description: Collection of animated explanations of how various technological processes work.

Center for Mathematics, Science, and Technology (2000). *Integrated mathematics, science, and technology project (IMaST)* [online]. Available: http://www.ilstu.edu/depts/cemast/
Description: Provides general descriptions of IMaST and the modules developed as a result of the curriculum development project.

Council on Technology Teacher Education (CTTE) (2000). *Council on technology teacher education* [on line]. Available: http://teched.edtl.vt.edu/CTTE/
Description: Provides a guide to professional and research activities in technology teacher education.

International Technology Education Association (ITEA) (2000). *Technology for All Americans Project* [online]. Available: http://www.iteawww.org/TAA/TAA.html
Description: Links with ITEA-CATTS material descriptions.

ITEA (2000). *International technology education association* [online]. Available: http://www.iteawww.org/
Description: Links Publications/Curriculum Materials and Technology Education Resources. Order curriculum materials from the former. Browse K-12 sites from the latter.

ITEA (2000). *TTTe: An electronic extension of the technology teacher* [online]. Available: http://www.iteawww.org/F3.html
Description: Collection of selected articles on technology education and technological studies.

ITEA and Council on Technology Teacher Education (2000). *Journal of technology education* [online]. Available: http://scholar.lib.vt.edu/ejournals/JTE/
Description: Journal for research in technology education.

National Aeronautics and Space Administration (NASA). (2000). *Education program* [online]. Available: http://education.nasa.gov/
Description: Links with a variety of educational programs, resources, and activities.

National Association of Industrial and Technical Teacher Educators (NAITTE) (2000). *National association of industrial and technical teacher educators* [on- line]. Available: http://www.coe.uga.edu/naitte/
Description: A guide to the professional activities of NAITTE.

NAITTE (2000). *Journal of industrial teacher education* [online]. Available: http://borg.lib.vt.edu/ejournals/JITE/jite.html
Description: Research journal on technological-related education.

National Science Foundation (2000). *Teacher resources* [online]. Available: http://www.ehr.nsf.gov/ehr/teachlinks/html/teachlinks.htm
Description: Collection of a variety of science teaching resources.

North Carolina Department of Public Instruction (NCDPI) (2000). *North Carolina info web for technology education* [online]. Available: http://www.dpi.state.nc.us/workforce_development/technology/index.html
Description: Provides an overview and guide to technology education in North Carolina. Includes links to technology education curriculum guides.

NCDPI (2000). *Teachers connect* [online].Available: http://www.teachers-connect.net/
Description: Collection of a wide variety of general teaching resources.

Omicron Tau Theta (1999). *Journal of vocational-technical education* [online]. Available: http://scholar.lib.vt.edu/ejournals/JVTE/
Description: Research journal on technological-related and vocational education.

Technology Student Association (2000). *Technology student association* [online]. Available: http://www.tsawww.org/
Description: A guide to teaching resources and activities related to the Technology Student Association

Wheeling Jesuit University/NASA Classroom of the Future (COTF) (1998). *NASA's classroom of the future™* [online]. Available: http://cotf.edu/
Description: Collection of the Classroom of the Future's own programs and activities and links with a variety of educational programs, resources, and activities.

COTFs *Bioblast* [online]. Available: http://www.cotf.edu/BioBLAST/main.html
Description: Collection of biotechnology-related activities.

COTFs *Exploring the environment* [online]. Available: http://www.cotf.edu/ete/main.html
Description: Collection of environmental-related activities.

COTFs *Astronomy village* [online]. Available: http://www.cotf.edu/AV/main.html
Description: Collection of astronomy activities.

Section D

References and Readings: General Methods and Approaches to Instruction

Standards

International Technology Education Association (1996). *Technology for All Americans: A rationale and structure for the study of technology*. Reston, VA: Author. 703-860-2100, 1914 Association Drive, Suite 201, Reston, VA 20191, ISBN: 1-887101-01-02.

International Technology Education Association (2000). *Standards for technological literacy: Content for the study of technology*. Reston, VA: Author. 703-860-2100, 1914 Association Drive, Suite 201, Reston, VA 20191, ISBN: 1-887101-02-0.

Curriculum Guides and Implementation Strategies

American Association for the Advancement of Science (1993). *Benchmarks for science literacy*. New York: Oxford University Press. 200 Madison Avenue, New York, NY 10016, ISBN: 0-19-508986-3.

Commission on Standards for School Mathematics (1989). *Curriculum and evaluation standards for school mathematics*. Reston, VA: National Council of Teachers of Mathematics.

Commission on Standards for School Mathematics (2000). *Curriculum and evaluation standards for school mathematics* [online]. Reston, VA: National Council of Teachers of Mathematics. Available: http://www.nctm.org/standards/

Florida Technology Student Association (1995). *TSA new chapter program kit: A guide for implementing TSA activities in technology education curriculum.* Fort Lauderdale, FL: author. 954-476-2030, P.O. Box 550103, Fort Lauderdale, FL 33355-0103.

International Technology Education Association (1999). *A guide to develop standards-based curriculum for K-12 technology education*. Reston, VA: Author. 703-860-2100, 1914 Association Drive, Suite 201, Reston, VA 20191.

International Technology Education Association (2000). *Exploring technology: A technology education standards-based middle school model course guide.* Reston, VA: Author. 703-860-2100, 1914 Association Drive, Suite 201, Reston, VA 20191.

International Technology Education Association (2000). *Teaching Technology: Middle School.* Reston, VA: Author. 703-860-2100, 1914 Association Drive, Suite 201, Reston, VA 20191.

National Research Council (1996). *National science education standards*. Washington: National Academy Press. 800-624-6242, 2101 Constitution Avenue, NW, Box 285, Washington, DC 20055, ISBN: 0-309-05326-9.

National Research Council (1995). *National science education standards* [online]. Washington: National Academy Press. Available: http://bob.nap.edu/html/nses/

Technology Student Association (1998). 1998-2000 *Curricular resources guide, high school program*. Reston, VA: Author. 703-860-9000, 1914 Association Drive, Reston, VA 20191-1540.

Umphrey, J. (Ed.), (1999). *The high school magazine*, 7(4), [entire issue on implementing standards in general].

Teaching Methods and Approaches to Teaching Technology

Borich, G. (2000) *Effective teaching methods*. Upper Saddle River, NJ: Prentice Hall. Person Education, Upper Saddle River, NJ 07458. ISBN: 0-13-936130-8.

Daly, J. (1999). *Bridge building module* [Computer software]. Salisbury, NC: author.

Dennison, R. (1999). *Web searching: A group project*. The Technology Teacher, 58(8), 5-9. 703-860-2100, 1914 Association Drive, Suite 201, Reston, VA 20191.

Edmison, G. (1992). *Approaches: Teaching strategies for technology education*. Reston, VA: International Technology Education Association. 703-860-2100, 1914 Association Drive, Suite 201, Reston, VA 20191.

Gow, G. (2000). *Understanding and teacher creativity*. Tech Directions, 59(6), 32-35. 734-975-2800, Prakken Publications, 3970 Varsity Drive, P.O. Box 8623, Ann Arbor, MI 48107-8623.

Idaho Division of Vocational Education (1996). *Technology education resource binder*. Boise, ID: author.

Johnson, I. H. (1988). Games and simulations. In W. H. Kemp and A. E. Schwaller (Eds.), *Instructional strategies for technology education: 37th yearbook of the Council on Technology Teacher Education* (pp. 183-200). Lake Forest, IL: Glencoe. 800-521-0600, University Microfilms International, 300 N. Zeeb Rd., Dept. PR, Ann Arbor, MI 48106, ISBN: 0-02-677114-4.

Johnson, S. (1994). Research on problem solving instruction: What works, what doesn't. *The Technology Teacher*, 53(8), 27-29, 36. 703-860-2100, 1914 Association Drive, Suite 201, Reston, VA 20191.

Johnson, S. (1995). Transfer of learning. *The Technology Teacher*, 54(7), 33-35. 703-860-2100, 1914 Association Drive, Suite 201, Reston, VA 20191.

LaPorte, J. E., & Sanders, M. E. (1995). Integrating technology, science, and mathematics education. In G. E. Martin (Ed.), *Foundations of technology education: 44th yearbook of the Council on Technology Teacher Education* (pp. 179-220). Lake Forest, IL: Glencoe. 800-521-0600, University Microfilms International, 300 N. Zeeb Rd., Dept. PR, Ann Arbor, MI 48106, ISBN: 0-02-677114-4 Return to Curriculum Integration.

Loveland, T. (1999). Adapting modular curriculum in the classroom. *The Technology Teacher*, 58(8), 10-15. 703-860-2100, 1914 Association Drive, Suite 201, Reston, VA 20191.

Michigan Department of Education (1998). *Technology education curriculum guide*. Lansing, MI: author.

Nickolai-Mays & Goetsch (1986). Cooperative learning in the middle school. *Middle School Journal*, November, 28-29.

Thode, B. (1989). Applying higher level thinking skills. *The Technology Teacher*, 49(2), 6-13. 703-860-2100, 1914 Association Drive, Suite 201, Reston, VA 20191.

Student Assessment

Cooke, J., Drennan, J., & Drennan, P. (1997). Peer evaluation as a real-life learning tool. *The Technology Teacher*, 57(2), 23-27. 703-860-2100, 1914 Association Drive, Suite 201, Reston, VA 20191.

Custer, R. (1996). Rubrics: An authentic assessment tool for technology education. *The Technology Teacher*, 55(4), 27-37. 703-860-2100, 1914 Association Drive, Suite 201, Reston, VA 20191.

Shackelford, R. (1996). Student portfolios: A process/product learning and assessment strategy. *The Technology Teacher*, 55(8), 31-36. 703-860-2100, 1914 Association Drive, Suite 201, Reston, VA 20191.

Special Populations, Equity, and Diversity

Householder, D. L. (1998). Mentors for women in technology education. In B. L. Rider (Ed.), *Diversity in technology education: 47th yearbook of the Council on Technology Teacher Education* (pp. 123-138). Lake Forest, IL: Glencoe. 800-521-0600, University Microfilms International, 300 N. Zeeb Rd., Dept. PR, Ann Arbor, MI 48106, ISBN: 0-02-831274-0.

Logwood, M., & Hadley, F. (1996). Assistive technology in the classroom. *The Technology Teacher*, 56(2), 16-19. 703-860-2100, 1914 Association Drive, Suite 201, Reston, VA 20191.

MacKinnon, G. (1999). Teaching the history of technology: A cooperative learning activity [racial equity and diversity]. *The Technology Teacher*, 59(2), 7-11. 703-860-2100, 1914 Association Drive, Suite 201, Reston, VA 20191.

Tracey, K. C. (1998). Reading, writing, and technology. In B. L. Rider (Ed.), *Diversity in technology education: 47th yearbook of the Council on Technology Teacher Education* (pp. 97-122). Lake Forest, IL: Glencoe. 800-521-0600, University Microfilms International, 300 N. Zeeb Rd., Dept. PR, Ann Arbor, MI 48106, ISBN: 0-02-831274-0.

Volk, K., & Holsey, L. (1997). TAP: A gender equity program in high technology. *The Technology Teacher*, 56(4), 10-13. 703-860-2100, 1914 Association Drive, Suite 201, Reston, VA 20191.

Community-Based Learning and Partnerships

Devier, D. (1999). Corporate partnerships: Winning relationships. *Tech Directions*, 59(5), 20-22. 734-975-2800, Prakken Publications, 3970 Varsity Drive, P.O. Box 8623, Ann Arbor, MI 48107-8623.

Gager, D. (1995). Staking the claim: Industry's interest in education. *Ties Magazine*, March, 38-42. 609-771-3333, 103 Armstrong Hall, P.O. Box 7718, Ewing, NJ 08628-0718.

Janaes, M., Schaeffer, S., & Folkestad, J. (1999). Toy for tots: Manufacturing for a purpose. *Tech Directions*, 59(4), 36-39. 734-975-2800, Prakken Publications, 3970 Varsity Drive, P.O. Box 8623, Ann Arbor, MI 48107-8623.

Karwatka, D. (1997). How British teachers use their technical museums. *The Technology Teacher*, 56(4), 34-37. 703-860-2100, 1914 Association Drive, Suite 201, Reston, VA 20191.

Leonard, M., & Lyles, B. (1999). Challenging young minds: A concept that works in Maryland [museum-based education]. *Ties Magazine*, October, 10-13. 609-771-3333, 103 Armstrong Hall, P.O. Box 7718, Ewing, NJ 08628-0718.

Curriculum Integration

Brusic, S. (1991). *Determining effects on fifth grade students' achievement and curiosity when a technology education activity is integrated with a unit in science*. (Doctoral dissertation, Virginia Polytechnic Institute and State University, 1991).

Dugger, Jr., W. E. (1994). The relationship between technology, science, engineering, and mathematics. *The Technology Teacher*, 54(3), 5-8, 20-23. 703-860-2100, 1914 Association Drive, Suite 201, Reston, VA 20191.

IMAST *Teacher resource binders for wellness, waste management, food production, and energy transformations*. New York: Glencoe McGraw-Hill. 800-334-7344, P.O. Box 543, Blacklick, OH 43004-0543, To order IMAST modules and resource binders.

Jacobs, H. H. (1991). Introduction. In R. Fogarty (Ed.), *The mindful school: How to integrate the curriculum* (pp. xi-xv). Palintine, IL: Skylight.

LaPorte, J. E., & Sanders, M. E. (1993). Integrating technology, science, and mathematics in the middle school. *The Technology Teacher*, 52(6), 17-21. 703-860-2100, 1914 Association Drive, Suite 201, Reston, VA 20191.

LaPorte, J. E., & Sanders, M. E. (1996). *The Technology, Science, Mathematics Connection Activities*. New York: Glencoe McGraw-Hill. 800-334-7344, P.O. Box 543, Blacklick, OH 43004-0543.

SRS Associates (1998). *Making Connections Curriculum Integration Project: A Partnership between Daimler Chrysler and the Michigan Department of Education website. http://www.connections.msu.edu*. Ann Arbor, MI: Michigan State University.

Vars, G. F. (1987). *Interdisciplinary teaching in the middle grades*. Columbus, OH: National Middle School Association.

Section E

References and Readings: Technological Methods

Design, Problem Solving, and Engineering

Denton, H., & Williams, P. J. (1996). Efficient and effective design. *The Technology Teacher*, 55(6), 15-20. 703-860-2100, 1914 Association Drive, Suite 201, Reston, VA 20191.

Frye, (1997). *Engineering problem solving for mathematics, science, and technology education*. Hanover, NH: Trustees of Dartmouth College.

Henak, R. M. (1988). Cooperative group interaction techniques. In W. H. Kemp and A. E. Schwaller (Eds.), *Instructional strategies for technology education: 37th yearbook of the Council on Technology Teacher Education* (pp. 143-165). Lake Forest, IL: Glencoe. 800-521-0600, University Microfilms International, 300 N. Zeeb Rd., Dept. PR, Ann Arbor, MI 48106, ISBN: 0-02-677114-4.

Hendricks, J. (1997). Engineering technology. *The Technology Teacher*, 56(4), 14-15, 31-32. 703-860-2100, 1914 Association Drive, Suite 201, Reston, VA 20191.

Hutchinson, J., & Karsnitz, J. (1997). *Design and problem solving in technology*. New York: Glencoe McGraw-Hill. 800-334-7344, P.O. Box 543, Blacklick, OH 43004-0543.

Hutchinson, P. (1999). Children designing and engineering. *Ties Magazine*, May, 4-7. 609-771-3333, 103 Armstrong Hall, P.O. Box 7718, Ewing, NJ 08628-0718.

Hutchinson, P., Davis, D., Clarke, P., & Jewett, P. (1989). The design portfolio: Problem-solving illustrated. *Ties Magazine*, November-December, 17-27. 609-771-3333, 103 Armstrong Hall, P.O. Box 7718, Ewing, NJ 08628-0718.

Hutchinson, P. (1986). *Problem solving in the British craft, design and technology programs*. Unpublished doctoral dissertation, New York University, New York.

James, W. (1990). Development of creative problem-solving skills. *The Technology Teacher*, 49(5), 29-30. 703-860-2100, 1914 Association Drive, Suite 201, Reston, VA 20191.

Komacek, S.(1995). Transportation technology education [see section on "Technological Problem Solving"]. In G. E. Martin (Ed.), *Foundations of technology education: 44th yearbook of the Council on Technology Teacher Education* (pp. 179-220). Lake Forest, IL: Glencoe. 800-521-0600, University Microfilms International, 300 N. Zeeb Rd., Dept. PR, Ann Arbor, MI 48106, ISBN: 0-02-677149-7.

Maley, D. (1987). *Research and experimentation in technology education*. Reston, VA: International Technology Education Association. 703-860-2100, 1914 Association Drive, Suite 201, Reston, VA 20191.

Singer, L., & Ritz, J. (1995). Industrial design: Enhancing our technological world. *The Technology Teacher*, 55(3), 19-26. 703-860-2100, 1914 Association Drive, Suite 201, Reston, VA 20191.

Todd, R., Todd, K., & McCrory, D. (1996). *Portfolio & activities resource: Introduction to design and technology*. New York: Thomson Learning Tools.

Technology Assessment and Environment-Related

Adams, S., & Merz, J. (1989). Teaching "technology and change." *The Technology Teacher*, 49(2), 27-31. 703-860-2100, 1914 Association Drive, Suite 201, Reston, VA 20191.

Brokow, R. (1995). Smoke gets in your eyes [appropriate technology]. *Ties Magazine*, May, 24-28. 609-771-3333, 103 Armstrong Hall, P.O. Box 7718, Ewing, NJ 08628-0718.

Gilberti, A. (1992). *Integrating technology, people, and the environment*. Reston, VA: International Technology Education Association. 703-860-2100, 1914 Association Drive, Suite 201, Reston, VA 20191.

McLaughlin, C. (1994). Developing environmental literacy. *The Technology Teacher*, 54(3), 30-34. 703-860-2100, 1914 Association Drive, Suite 201, Reston, VA 20191.

Naisbitt, J. (1982). *Megatrends*. New York: Warner Books.

Naisbitt, J., & Aburdene, P. (1990). *Megatrends 2000*. New York: Avon Books.

Sisk, D., & Whaley, C. E. (1987). *The futures primer for classroom teachers*. New York: Trillium.

Solutions Software (1999). *MSDS database on CDROM* [Computer software]. Enterprise, FL: author.

Tidewater Technology Associates (1989). Resources in Technology. Water: A magic resource. *The Technology Teacher,* 49(2), 15-22. 703-860-2100, 1914 Association Drive, Suite 201, Reston, VA 20191.

Tidewater Technology Associates (1991). Resources in Technology. Population issues. *The Technology Teacher*, 51(2), 15-22. 703-860-2100, 1914 Association Drive, Suite 201, Reston, VA 20191.

Virginia Department of Education (1992). *Design and technology: Teacher's guide for high school technology education [*also useful as curriculum integration reference]. Richmond, VA: author.

Whaley, C. E. (1987). *Future studies: Personal and global possibilities*. New York: Trillium.

Whaley, C. E., & Whaley, H. F. (1986). *Future images: Future studies for grades 4 to 12*. New York: Trillium.

Wiens, A. E. (1997). Looking ahead: How will technology affect the future. *The Technology Teacher*, 57(3), 21-23. 703-860-2100, 1914 Association Drive, Suite 201, Reston, VA 20191.

Section F

References and Readings: Technological Systems

Agricultural and Related Biotechnology

Gilberti, A. F. (no date). *Integrating technology, people, and the environment*. Reston, VA: International Technology Education Association. 703-860-2100, 1914 Association Drive, Suite 201, Reston, VA 20191.

Hanes, F. (1999). New England aquaculture educators network: AQUA. *Ties Magazine*, March/April, 26-27. 609-771-3333, 103 Armstrong Hall, P.O. Box 7718, Ewing, NJ 08628-0718.

LaPorte, J. E., & Sanders, M. E. (1996). *The Technology, Science, Mathematics Connection Activities* [see the "Plant Plant" section for an example hydroponics activity]. New York: Glencoe McGraw-Hill. 800-334-7344, P.O. Box 543, Blacklick, OH 43004-0543.

Wright, P. (2000). *Curriculum brief: Biotechnology*. Reston, VA: International Technology Education Association. 703-860-2100, 1914 Association Drive, Suite 201, Reston, VA 20191.

Communication

Herrell, A, & Fowler, J. (1998). *Camcorder in the classroom: Using the video camera to enliven curriculum*. Upper Saddle River, NJ: Prentice Hall. Person Education, Upper Saddle River, NJ 07458.

Maughan, G., & Prince Ball, K. (1999). Synergistic curriculum for the high performance workplace [teamwork and interoffice network communication]. *The Technology Teacher*, 58(7), 28-32. 703-860-2100, 1914 Association Drive, Suite 201, Reston, VA 20191.

North Carolina Department of Public Instruction, (1997). *Scientific and technical visualization I and II*. Raleigh, NC: author.

Sanders, M. E. (1991). *Communication technology*. New York: Glencoe McGraw-Hill. 800-334-7344, P.O. Box 543, Blacklick, OH 43004-0543,

Supko, M. (1991). The making of who I am: A step-by-step approach to basic video production. *Ties Magazine*, November/December, 44-49. 609-771-3333, 103 Armstrong Hall, P.O. Box 7718, Ewing, NJ 08628-0718.

Construction

Foster, P., Kendrick, M., & Kirkwood, J. (1994). Habitat for Humanity. *Ties Magazine*, September/October, 32-39. 609-771-3333, 103 Armstrong Hall, P.O. Box 7718, Ewing, NJ 08628-0718.

Kicklighter, C. (1995). *Architecture: Residential drawing and design*. Tinley Park, IL: Goodheart-Willcox. 800-365-3907, 18604 West Creek Dr., Tinley Park, IL 60477, ISBN: 1-56637-590-8.

Polette, D., & Landers, J. (1995). *Construction systems*. Tinley Park, IL: Goodheart-Willcox. 800-365-3907, 18604 West Creek Dr., Tinley Park, IL 60477, ISBN: 1-56637-041-8.

Wagner, W., & Smith, H. (1996). *Modern carpentry*. Tinley Park, IL: Goodheart-Willcox. 800-365-3907, 18604 West Creek Dr., Tinley Park, IL 60477, ISBN: 1-56637-569-X.

Energy

Smith, H. (1993). *Energy sources, applications, alternatives*. Tinley Park, IL: Goodheart-Willcox. 800-365-3907, 18604 West Creek Dr., Tinley Park, IL 60477, ISBN: 0-87006-956-X.

Manufacturing

Michigan Department of Education (no date). *Manufacturing careers, design, engineering, & industrial technology: Integrated technology curriculum, teacher guide*. Mason, MI: Ingham Intermediate School District. 517-244-1338.

Michigan Department of Education (no date). *Manufacturing careers, design, engineering, & industrial technology: Integrated technology curriculum, student guide*. Mason, MI: Ingham Intermediate School District. 517-244-1338.

Shackelford, R. (1993). Thermoforming plastics. *Ties Magazine*, March-April, 40-43. 609-771-3333, 103 Armstrong Hall, P.O. Box 7718, Ewing, NJ 08628-0718.

Wright, J. R. (1999). Teaming: The key to world class manufacturing. *The Technology Teacher*, 58(5), 27-31. 703-860-2100, 1914 Association Drive, Suite 201, Reston, VA 20191.

Wright, R. T. (1990). *Manufacturing systems*. Tinley Park, IL: Goodheart-Willcox. 800-365-3907, 18604 West Creek Dr., Tinley Park, IL 60477, ISBN: 1-56637-584-3.

Medical and Related

Raines, A. (1999). Education for success [medical technology]. *Ties Magazine*, November-December, 14-17. 609-771-3333, 103 Armstrong Hall, P.O. Box 7718, Ewing, NJ 08628-0718.

Transportation

Hadley, F. (1994). Resources in technology: Electric vehicle development. *The Technology Teacher*, 54(3), 15-24. 703-860-2100, 1914 Association Drive, Suite 201, Reston, VA 20191.

Johnson, S. R., & Farrar-Hunter, P. (1993). *Exploring transportation*. Tinley Park, IL: Goodheart-Willcox. 800-365-3907, 18604 West Creek Dr., Tinley Park, IL 60477, ISBN: 1-56637-675-0.

Jones, B. (1994). Building a solar powered vehicle. *The Technology Teacher*, 54(3), 25-29. 703-860-2100, 1914 Association Drive, Suite 201, Reston, VA 20191.

Missouri Alternative and Renewable Energy Technology Center (1998). *Solar BikeRayce*. http://www.sunrayce.com/BikeRayce, [solar bicycle competition and teaching materials].

Northeast Sustainable Energy Association (1999). http://www.nesea.org, [information on solar and alternative energy; NESEA is the sponsor of the American Tour de Sol, a solar vehicle competition].

Sepabfour, B. (1999). The great American moon buggy race. *Ties Magazine*, October, 4-6, 8-9. 609-771-3333, 103 Armstrong Hall, P.O. Box 7718, Ewing, NJ 08628-0718.

Section G

Glossary

Additional terms may be found in *Standards for Technological Literacy: Content for the Study of Technology.*

Bioremediation: Using living organisms to change or correct a condition.

Alternative assessment: An exercise, such as an activity, portfolio, experiment, or performance that seeks to measure a student's skills or knowledge. The exercise chosen is typically different than traditional written testing.

Aquaculture: The production of fishes and other aquatic animals in a controlled environment.

Aquaponics: A term often used to name the combining of hydroponics processes and aquacultural processes into the same system.

CAD (computer aided design): The use of a computer to assist in the process of designing a part, circuit, building, etc.

CNC (computer numerical control): Typically, the control of machining processes with a computer by interfacing the computer with the machine. Milling machines and lathes are frequently automated and controlled with this process.

Constraint: A limit to the design process. Constraints may be such things as appearance, funding, space, materials, and human capabilities.

Cooperative learning: Teaching approach in which students learn in small groups. Typically, students work together in order to perform a common task or meet a common objective. Teachers and students may organize student groups according to individual student talents and abilities in a manner that provides each group member with the opportunity to contribute to the group's success.

Curriculum: The subject matter that teachers and students cover in their studies. It describes and specifies the methods, structure, organization, balance, and presentation of the content.

Curriculum development: The process of planned development of curriculum pedagogy, instruction, and presentation modes.

Curriculum integration: A process of curriculum development and instruction in which the content of one or more disciplines or school subjects is taught in relationship to, or in the context of, other disciplines or school subjects. There are many variations to curriculum integration approaches, such as the total school approach, curriculum correlation, true integration or core integration, etc. Curriculum integration is theorized to improve student achievement and appears to improve student motivation by making content more relevant than it is during traditional, subject-centered instruction. The term "cross curricular" is used to describe similar approaches.

Design: An iterative decision-making process that produces plans by which resources are converted into products or systems that meet human needs and wants or solve problems.

Design brief: A written plan that identifies a problem to be solved, its criteria, and its constraints. The design brief is used to encourage thinking of all aspects of a problem before attempting a solution.

Design process: A systematic problem-solving strategy with criteria and constraints, used to develop many possible solutions to solve a problem or satisfy human needs and wants and to narrow the possible solutions to one final choice.

Discovery: The process of identifying new knowledge, insights, and realizations in the context of active modes of inquiry. An example of a discovery approach is when students apply the scientific method to discover something (learn something new) about the world.

Drawing: A work produced by representing an object or outlining a figure, plan, or sketch by means of lines. A drawing is used to communicate ideas and provide direction for the production of a design.

Electrokinetics: A process by which some property of a material or substance is changed by applying an electrical current across it. This technique is sometimes applied to the removal of polluting substances or to the neutralization of their hazardous properties.

Enabling objective: A specification of a student's performance and level of performance in relation to a criterion. Enabling objectives often describe a prerequisite performance that is necessary to master before achieving a terminal objective. Such objectives also may specify the conditions under which the student will perform.

Engineering: The profession of or work performed by an engineer. Engineering involves the knowledge of the mathematical and natural sciences (biological and physical) gained by study, experience, and practice that are applied with judgment and creativity to develop ways to utilize the materials and forces of nature for the benefit of mankind.

Engineering design: The systematic and creative application of scientific and mathematical principles to practical ends such as the design, manufacture, and operation of efficient and economical structures, machines, processes, and systems.

Ergonomics: The study of workplace equipment design or how to arrange and design devices, machines, or workspace so that people interact with things safely and most efficiently. Also called human factors analysis or human factors engineering.

Forecast: A statement about future trends, usually as a probability, made by examining and analyzing available information. A forecast is also a prediction about how something will develop, usually as a result of study and analysis of available pertinent data.

Hydroponics: A technique of growing plants without soil. Plants are grown in water or sometimes an inert medium (e.g., vermiculite) containing dissolved nutrients.

Indirect instruction: Techniques and strategies teachers and students may use beyond traditional lecture and demonstration for the purpose of helping students perform at higher levels of achievement.

Iterative: Describes a procedure or process that repeatedly executes a series of operations until some condition is satisfied. An iterative procedure may be implemented by a loop in a routine.

Just-in-time: Often used to describe several manufacturing or management processes such as the control of inventory and the scheduling and expediting of production in order to minimize the resources that an enterprise must commit until production is actually ready to be expedited. In the case of inventory, the idea is to receive and pay for the needed supplies and materials "just in time" for the production run.

Laboratory-classroom: The formal environment in school where the study of technology takes place. At the elementary school, this environment will likely be a regular classroom. At the middle school and high school levels, a separate laboratory with areas for hands-on activities, as well as group instruction, should constitute the environment.

Literacy: Basic knowledge and abilities required to function adequately in one's immediate environment.

Medical technology: Of or relating to the study of medicine through the use of and advances of technology, such as medical instruments and apparatus and imaging systems in medicine. Related terms: biomedical engineering and medical innovations.

Model: A visual, mathematical, or three-dimensional representation in detail of an object or design, often smaller than the original. A model is often used to test ideas, make changes to a design, and to learn more about what would happen to a similar, real object.

Modular instruction (also programmed instruction): A delivery system for instruction in which a student (or small group of students) learns from self-contained units. Each module is organized into frames or sections of content, prescribes behaviors and activities, provides for assessment of the student, and has the tools, equipment, and supplies necessary to perform prescribed tasks. Typically, when students have completed one module, then they move to the next module in a prearranged sequence. The student may receive assistance from an instructor but does not necessarily receive traditional lecture or demonstration.

Performance assessment: An activity used to measure a student's ability to conduct a process, typically used as an alternative to written testing.

Portfolio: A systematic and organized collection of a student's work that includes results of research, representations of successful and less successful ideas, notes on procedures, and data collected.

Problem solving: The process of understanding a problem, devising a plan, carrying out the plan, and evaluating the plan in order to solve a problem or meet a need or want.

Process: Human activities used to create, invent, design, transform, produce, control, maintain, and use products or systems.

Product lifecycle: Stages a product goes through from concept and use to eventual withdrawal from the marketplace. Product lifecycle stages include research and development, introduction, market development, exploitation, maturation, saturation, and finally decline.

Propulsion system: A system that provides the energy source, conversion, and transmission of power to move a vehicle, object, or substance.

Prototype: A full-scale, working model used to test a design concept by making actual observations and necessary adjustments.

Requirements: The parameters placed on the development of a product or system. The requirements include the safety needs, the physical laws that will limit the development of an idea, the available resources, the cultural norms, and the use of criteria and constraints.

Research and development (R&D): The practical application of scientific and engineering knowledge for discovering new knowledge about products, processes, and services, and then applying that knowledge to create new and improved products, processes, and services that fill market needs.

Resource: The things needed to get a job done. In a technological system, the basic technological resources are: energy, capital, information, machines and tools, materials, people, and time.

Sketch: A rough drawing representing the main features of an object or scene and often made as a preliminary study.

Solution: A method or process for solving a problem.

Structure: Something that has been constructed or built of many parts and held or put together in a particular way. In the construction industry and in the study of construction, the term structure is often used as a reference to a product that has been constructed.

Technology: The innovation, change, or modification of the natural environment to satisfy perceived human needs and wants.

Technology content standard: A written statement that specifies the knowledge (what students should know) or process (what students should be able to do) students should possess in order to be technologically literate.

Technology education: A study of technology, which provides an opportunity for students to learn about the processes and knowledge related to technology that are needed to solve problems and extend human capabilities.

Technological studies: See technology education.

Terminal objective: A culminating specification of a student's performance and level of performance in relationship to a criterion.

Telemedicine: The investigation, monitoring, and management of patients and the education of patients and staff using systems, which allow ready access to expert advice and patient information, no matter where the patient or the relevant information is located. The three main dimensions of telemedicine include health service, telecommunication, and medical computer technology.

Thematic unit: Set of lesson presentations that organize classroom instruction around certain texts, activities, and learning episodes related to a topic(s). A thematic unit might integrate several content areas.

Trend analysis: A comparative study of the component parts of a product or system and the tendency of a product or system to develop in a general direction over time.

Troubleshoot: To locate and find the cause of problems related to technological products or systems.

Webbing: A planning process to determine areas of content that overlap or are common among disciplines or school subjects.

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