

## **Problem Solving: Much More Than Just Design**

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Few concepts which fall within the scope of technology education have received as much attention as “problem solving.” *The Technology Teacher* alone contained seven articles about problem solving between 1985 and 1989 (Sellwood, 1989; Thode, 1989; Barnes, 1989; Ritz, Deal, Hadley, Jacobs, Kildruff & Skena, 1987, 1986a; Baker & Dugger, 1986; Forbes, 1985). A thorough review of each of these articles will help any technology teacher teach technology. Many additional articles discuss problem solving, although they may not focus specifically on it. This does not suggest that problem solving is a new concept; it has been listed as a goal of our profession since its inception. However, the recent interest in problem solving does raise some questions: How should problem solving be defined in the context of technology education? How important is problem solving in technology education? Does problem solving hold a different place in a technology education curriculum than it did in industrial arts?

This article will explore design and troubleshooting as subcategories of problem solving and will argue that the systematic evaluation of the impacts of technology (technology assessment) should be considered an equally important category of problem solving.

### **Problem Solving: A Definition**

Problem solving has been defined in many ways. One simple yet meaningful definition describes a problem as a need which must be met (Ritz, et al. 1986a). This need could include, among other things, the need to understand the forces of nature (science), to alter the environment (technology), or to use scientific knowledge to alter the environment (engineering).

Industrial arts, in the past, and now technology education programs have addressed problem solving. However, even the most contemporary treatment of problem solving has been primarily focused on designing new technical systems or, less often, repairing existing systems.

Unfortunately, many authors and educators consider problem solving from only the perspective of design. In fact, some use the terms “problem

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solving” and “design” interchangeably. This approach is far too limiting. Technological problem solving can be divided into three categories: design, troubleshooting, and technology assessment (impact evaluation) (see Figure 1).

Designing may be defined as proactive problem solving (Baker & Dugger, 1986). It includes not only the refinement of the original concept but also the research, experimentation, and development necessary to prepare the product for production. Innovating, creativity, and designing are closely related. A wealth of good information exists concerning design (e.g., Nelson, 1979; Hanks, Bellistrone & Edwards, 1978; and Beakley & Chilton, 1973).

Troubleshooting, or reactive problem solving (Baker & Dugger, 1986), involves the recognition that technology encompasses more than innovation. The production and utilization of technical solutions is also a valid source of course content for technology education. Finding and correcting problems during the production or utilization of technical solutions is troubleshooting.

*Figure 1. Three forms of technological problem solving.*

Technicians can be satisfied with abilities in design and/or troubleshooting. However, technologists must add the ability to critically analyze the impacts of technical solutions in order to predict possible outcomes and choose the most appropriate solution to a problem. Of course, they must also re-evaluate existing solutions. Most practitioners in the field would agree that evaluating the impacts of technology is an important part of technology education. However, finding a way to integrate impact evaluation into a program can be difficult. Encouraging students to approach the impacts of technology with a well structured, analytical process (problem solving) should result in significant learning.

### **How Important Is Problem Solving?**

Few would argue that teaching problem solving is unimportant. Whether an important component of technology education curriculum (Baker & Dugger, 1986) or the central focus of technology education curriculum (Barnes, 1989), current thinking in the field seems to strongly support the importance of problem solving. Perhaps the most persuasive of these arguments is based upon the explosive growth of technology. Because so much of what students need to

know has not yet been created, it makes little sense to teach students the most up-to-date technology if they do not exit with the ability to continue learning (Barnes, 1989). The development of problem solving ability is a key factor in creating an independent learner.

### **What Place Does Problem Solving Have In Technology Education?**

Problem solving was an important ability in industrial arts because it allowed the student to overcome certain stumbling blocks which were inevitable in producing a well crafted product. Problem solving in most aspects of industrial arts, in practice if not in theory, was a spin-off skill. Although it was rarely planned in a specific manner, some degree of problem solving ability was almost always imparted to students.

Technology education changes problem solving from simply a means to an end into the end itself. Rather than use problem solving to produce a product, the product becomes one of many ways to teach problem solving.

### **Teaching Technical Problem Solving**

Regardless of which of the three types of technical problem solving are taught, three basic concepts should be attended to. These concepts are: (a) a model for problem solving, (b) systems to subsystems approach, and (c) necessary prerequisite knowledge.

Many good problem solving models are available. Most models have between four and eight stages. The larger models provide more detail; however, a four-step model like the one that follows includes all the major steps but remains concise. Regardless of which model is chosen, it should be reviewed with students using examples to explain each step: (a) identify the problem, (b) postulate possible solutions, (c) test the best solution, and (d) determine if the problem is solved.

An understanding of a problem solving model can help students understand the process of problem solving. However, attention to content should not be neglected. Students who are taught to solve problems in a way which gives little attention to the content of the problem will have great difficulty transferring the learning to other situations (Thomas & Litowitz, 1986). In such situations, students can be taught to solve problems without becoming problem solvers.

Because technical systems are involved, an understanding of systems and subsystems is another important component of technology education (Ritz, Deal, Hadley, Jacobs, Kildruff & Skena, 1986b). A system is a group of components which work together to accomplish a common goal. Many times the component parts of a system are themselves systems, thus becoming subsystems. Two concepts are important in relationship to this definition. First, it is important to recognize that each system or subsystem has a discernible

function. Understanding how a system or subsystem operates is frequently important when solving technical problems. Second, the relationship between systems and subsystems is important. Subsystems can also affect each other. The need to understand the interdependence and function of systems and subsystems will become more apparent when discussed in the context of design, troubleshooting and technology assessment.

Problem solving is a higher level thinking skill. This type of thinking involves analysis, synthesis and evaluation. These cannot occur in the absence of appropriate supporting learning (knowledge, understanding and application). The cognitive domain taxonomy (Bloom, 1956) supports this idea (see Figure 2).

*Figure 2.* Bloom's cognitive domain taxonomy: "The Building Blocks of Learning."

Simple knowledge or even understanding of a content area will not by itself provide a sufficient basis for solving problems involving that content. However, knowledge and understanding are necessary for solving complex problems. For example, any one who has tried to understand something about which they have little or no knowledge usually ends up with little or incorrect understanding. Knowledge is foundational to understanding. Imagine trying to apply knowledge without understanding. Suppose an individual is aware of many types of building materials like plywood, drywall, nails, screws, etc. However, this person has no understanding of how these materials are used and no experience with them. Now imagine this individual attempts to build their own house; frustration would result from a missing link in the chain of things necessary to apply knowledge.

In order to explore the level of cognition necessary for problem solving, a person named Hypothetical Harry will be used. In search of a career, Harry decides to find out what skills he would need to become a building inspector. The first thing he discovers is that there are many different types of building

inspectors: electrical, plumbing, structural and others. This type of system (the whole building) to subsystem (electrical, plumbing and structural) is analogous to the type of analysis Harry will be required to do when he inspects buildings. In order to conquer the task of deciding if an entire electrical, plumbing or structural subsystem of a building is safe for occupancy, Harry will find it necessary to divide the problem into manageable pieces.

The building inspector's job sounds interesting to Harry but he decides the salary is not enough. While investigating the building trades Harry discovers that architects can have good incomes. However, this job sounds a bit more challenging. Harry begins to realize that an architect must understand all of the subsystems of a building (analysis) and he or she must recombine the component parts of these subsystems to create new solutions. In other words, an architect is expected to combine the subcomponents of electrical, plumbing, mechanical and structural systems to meet the requirements of a variety of different building projects. Harry can quickly conclude that this job would require not only the ability to divide systems into smaller systems and then to divide the systems again and again but also the ability to recombine these systems. Anyone who is good at recombining systems to create new solutions (synthesis) must first be capable of dividing the systems in the first place (analysis).

Just about the time Hypothetical Harry decides to go back to college in order to become an architect he wins the lottery. Now Harry's career aspirations shift from making money to spending and protecting his new found wealth. Harry must constantly make decisions about what to buy or which tax shelters are the best this week. The reason Harry finds this "work" so exhausting is that he is constantly evaluating which of several alternatives is the best answer to the problem at hand. To make the best evaluations Harry must be able to break the problems into digestible bits of information (analysis). He should also be able to see potential connections between varied solutions (synthesis) in order to compare them.

Harry is not the only person who must have the ability to evaluate. As consumers and citizens every individual should possess these capabilities.

Problem solving may require analysis, synthesis, evaluation, or a combination of these. The building blocks which support these various levels of learning may be supplied by the teacher, sought out by the student, or teacher and student may share the responsibility for discovering these prerequisite skills.

The more abstract forms of learning, problem solving included, cannot occur without the foundation of concrete learning. Despite well intentioned claims to the contrary, how much of what is actually accomplished in education progresses beyond the concrete levels of knowledge, understanding and application? Education which involves abstract learning is rare and it is certainly more difficult to produce and evaluate than a system which focuses on the retaining of facts. However, analysis, synthesis and evaluation level thinking skills are essential to the development of a competitive work force. Figure 3

illustrates the relationship between this type of abstract learning and problem solving.

*Figure 3. Levels of learning.*

### **Teaching Design**

A key in teaching design is the essential element creativity plays in this type of problem solving (Thomas & Litowitz, 1986). Every technology teacher should examine their teaching style to determine its effect on students' ability to generate alternative solutions to a problem. Does the laboratory experience students have encourage diversity or demand conformity? The product oriented, skill development strategies typical of the industrial arts philosophy rarely celebrate diverse solutions (Clark, 1989). The need to efficiently transfer skills is one which bleeds over into technology education because a knowledge base is a prerequisite to developing problem solving ability. However, efficiency should not be allowed to overshadow effectiveness; they should be balanced. When teaching design, a strategy must be developed which not only tolerates but rewards alternative solutions. This type of problem solving should involve a divergent as opposed to a convergent thinking process (Hatch, 1988). Students who are encouraged to take control of their own learning will be much more likely to develop a broad rather than narrowly focused approach to problem solving. The idea that students can help teach themselves (Villalon, 1982) is appropriate for teaching design.

The temptation is present to simply teach divergent thinking the way one might teach multiplication tables. The problem with this approach lies in the critical role creativity plays in the type of divergent thinking which is required to come up with truly unique solutions to problems. Can one teach creativity?

Can an educational system so steeped in convergent thought encourage or even tolerate divergent thinking?

A discovery method of learning can be utilized in the teaching of design. When students are faced with the need to know certain information, they will seek out that information. This requires them to work their way down Bloom's Taxonomy of Learning, perhaps even jumping around a bit filling in the gaps as they find need. For example, suppose a student wants to assess the impact of a coal gasification. First, the student must satisfy him or herself that they understand what coal gasification is (knowledge and comprehension). Second, the student should begin to ask questions like: how is coal converted to a gas, why is this process desirable, what type of pollution can be eliminated by coal gasification, and will new problems be created? In this second step the student breaks the problem down into manageable chunks (analysis). Finally, the student brings the answers to all the smaller questions together in order to answer the question: considering both the positive and negative aspects of coal gasification, what should be done with this technology (synthesis and evaluation). This method casts the teacher as guide and facilitator. The student becomes an investigator (Sellwood, 1989). The following illustrates a design brief in which the student uses this investigative approach. When using this approach, care must be exercised to insure that each student obtains the prerequisite knowledge. As has been mentioned, proper attention to context is necessary if students are to transfer the problem solving process to new situations.

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#### Design Brief Introduction to Control

A paper shear can cut fingers as easily as it cuts paper. Design a control system which will reduce accidents by forcing the operator to press two buttons at once to start the shear. Follow the steps below in finding your solution.

1. Identify and document what you will use as the components of your control circuit (i.e., signals, decisions, actions).
2. Identify and document what type of logic you will use in the decision section of your control circuit.
3. Draw a wiring diagram for your solution and discuss it with the instructor.
4. Wire the circuit you have designed; have the instructor check the circuit before testing it.
5. Evaluate your solution; return to a previous step if necessary.

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The design brief becomes a launching point for the student. It is intended to define the assignment without being too limiting.

## Teaching Troubleshooting

Troubleshooting involves a systematic approach to locating and correcting problems in existing systems. A much more structured approach can be applied to teaching troubleshooting than can be applied to teaching design. Usually the knowledge and understanding necessary can be identified by the teacher and delivered in a structured fashion. This process begins when the teacher helps the students identify the subsystems involved in the system under study. Next, the function and operation of all subsystems must be completely explored. Finally, a troubleshooting system can be taught. Troubleshooting combines three factors: (a) interrelationship of systems and subsystems, (b) subsystem function and operation (what and how), and (c) a search strategy.

Each subsystem has a function which the student must know. This answers the question: What does the system do? Students must also understand the operation of each subsystem, or how each subsystem performs its function. Without an understanding of what each subsystem function is, it becomes very difficult to determine if the subsystem is functional. Equally problematic is an attempt to isolate a malfunction within a subsystem with no knowledge of how the subsystem performs its function.

Most subsystems are affected by the other subsystems within the same overall system. An understanding of the interrelationships of each subsystem to be troubleshot is essential to success. An inefficient search strategy cannot only waste time but may cause the true source of a problem to be overlooked. A binary search strategy is the most efficient search method. If each successive step in the search divides the remaining alternatives in half, a problem can be isolated very quickly. Good diagnostic charts are organized in this fashion. In fact, students who are accomplished in the three factors in problem solving will be able to write their own diagnostic charts (see Figure 4).

Assuming that a communications class contains a unit on telecommunication, a part of that unit might include telecomputing. The networks computers use to communicate would probably be an important consideration within this sub-unit. One good way to teach students about computer networks would be to ask them to create a troubleshooting scheme for isolating problems with such a network. The teacher might provide written resources to help students identify the systems: (a) purpose, (b) inputs, (c) outputs, (d) component subsystems, and (e) interaction with outside systems. In this way, students can be allowed to “research” the information needed to solve this problem. Such an assignment follows:

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### Creating a Diagnostic Tree

A diagnostic tree is a device that guides the troubleshooter through a series of steps which efficiently and correctly identify a malfunction. Creating a diagnostic tree requires not only a thorough understanding of the system in-

volved but also an understanding of how to efficiently search for a problem. Complete the following steps in creating your own diagnostic tree. Carefully document your work. Every diagnostic tree should contain three basic components: preliminary checks, system output test, and problem isolation. Proceed as follows:

1. Identify the purpose of the system. Identify the input and output points of the system.
2. Determine how other systems might effect the system under consideration.
3. Identify all subsystems (components which contribute to the function of the system under consideration).
4. Determine how each subsystem performs its function.
5. Devise and conduct a test which will determine if supporting systems are functioning. (This is your first set of tests.)
6. Devise and conduct a test which will determine if the entire system is functional. (This is your output test and will be a second test.)
7. If the system is not functional, devise and conduct a test which will split the system in half (or as nearly in half as possible).
8. Repeat step seven until the malfunction is isolated. Correct the problem.
9. Retest the output of the system.

*Note:* Devising the test for a system or subsystem requires an understanding of what the function of the system is; you are determining if this function is being achieved. An understanding of how the function is achieved is also important because a test will usually grow out of this knowledge.

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### **Teaching Technology Assessment**

Although the evaluation of impacts of technical systems is an important philosophical consideration in technology education, it is often difficult to find the time or a method to address this point. Not only should time be made in the curriculum for work with impact evaluation, but also students should be guided during their experience by a systematic method of inquiry which stresses the development of critical thinking skills. Students should practice evaluation frequently enough to begin to synthesize these experiences into a coherent technological value system.

Wise producers and consumers of technology must be capable of the type of critical thinking necessary to see beyond shallow, short-term considerations and select the most appropriate technologies. Well thought out arguments are built in much the same way technical systems are designed. Discrete pieces of information or arguments are combined in a logical fashion which leads to a well supported conclusion. This is similar to the relationship between systems and subsystems. In fact, one way to explain analytical thinking is to consider it the ability to identify and/or create both the discrete pieces of information

and the logical links between this information. Once the logical links between discrete pieces of information can

*Figure 4.* Partial computer network system diagnostic tree.

be identified, correct conclusions can be made. Critical thinking skills involve the analysis of the logic behind an argument. Eventually students should progress beyond analyzing others' arguments to producing their own. An example of such an assignment follows:

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Technological Impacts of Transportation Systems

Directions: You may sign up for a topic below. Prepare a one page summary to be submitted the day of your presentation. The presentation should include a brief (5 minutes) discussion of your topic and conclude with a short class discussion. The emphasis of this assignment is on your ability to draw logical conclusions. Collecting technical information will help you draw conclusions; however, it is not the ultimate purpose here. Once you have collected the information, use it to come to a logical conclusion. You will be evaluated on how clearly the facts and your arguments support your conclusion. Present both sides of the issue, then take a stand and justify it. The discussion following your presentation should involve the controversial nature of your topic. Have two or three questions prepared to start the discussion. Include this sheet when you turn in your summary.

Evaluation: Your presentation will be evaluated on the following three criteria:

|                                  | Possible  | Actual |
|----------------------------------|-----------|--------|
| A. Organization and Presentation | 5 points  |        |
| B. Content and Persuasiveness    | 10 points |        |
| C. Written Report                | 5 points  | _____  |
| Total                            | 20 points |        |

Topics:

- America's bridges die of neglect.
- Transportation systems and the greenhouse effect.
- Alternative fuels and the internal combustion engine: A step forward or sideways?
- The role of the automobile in the transportation systems of the future.
- Trucking vs. rail transportation.
- The impact of the trucking industry on rail and water transportation.
- The automobile and mass transit—the bus.
- America's roadways: An investment which limits options for future transportation systems.
- The automobile, a deadly weapon.
- Drunk driving: More should be done/we are doing too much now.
- The automobile, a form of recreation: Auto racing.
- A love affair with old cars: Antique cars—are they safe?
- Automotive air pollution: Still a problem?
- Asbestos and the transportation industry.
- The impact of the automobile on our national economy.
- Marine transportation and pollution; oil spills.
- The automobile and stress.
- Seat belts and school buses.
- Only insured drivers may legally drive.
- State inspections: Necessity/annoyance.
- Other topics by approval of instructor.

## Summary

As the field of industrial arts evolves into technology education, problem solving should take on an increasingly important role in the curriculum. Students cannot be considered “technologically literate” until they understand that technology involves making changes to our environment to solve problems or meet human needs. Equally important is that students appreciate that the solution to one problem often creates other problems and/or other benefits.

Design has long been an important part of industrial arts. However, design must be integrated in all aspects of technology education. Students will be much more likely to appreciate the important role technology plays in their lives if they have been provided with the opportunity to become designers and solve technological problems.

Unfortunately, problem solving and design are sometimes thought to be synonymous. When designs are produced, some troubleshooting will generally occur, unless the prototype works perfectly the first time. This approach, if it is the only experience with troubleshooting, neglects the fact that most people's experience with technology involves trying to solve problems created by technologies which they did not design themselves. Students should also be given the experience of locating and correcting problems in existing technological systems.

Many of the problems involved with technology go well beyond conceptualizing, creating and maintaining technological systems. They involve the fact that technological solutions almost always create some impacts which are undesirable and sometimes unforeseen. It is not enough to simply recognize that these problems exist, or even to discuss them in detail. A systematic method of identifying and dealing with these impacts must be developed. The increasingly powerful technologies of the future will almost undoubtedly create extremely dangerous impacts on society unless these technologies are carefully controlled. The way for this control to occur in a democratic society is to prepare the majority of the electorate to make wise choices about technology. This requires that today's students demand consideration of the impacts of technology when they become adults.

In order to prepare the type of technologically literate citizenry necessary to control technology, three things must occur. First, people must view technology as the way in which we change our environment to meet our needs. Second, it must be understood that when technological solutions are implemented new problems are created. Finally, identifying these impacts, both before and after a solution is identified, and balancing these impacts against the original goals of the technology must become a way of life.

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