Articles

Implementing Technology Education Problem-Solving Activities

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Teaching students how to solve problems is an important goal of education and industrial arts/technology education has had a long history of providing an environment for developing these skills. The congruence of technology education and problem solving is based on the fact that technologies are, in many ways, a product of problem solving. Technological problems require the application of knowledge from many different disciplines and the laboratory provides a medium to develop and test solutions.

Greenfield (1987, p. 20) suggests that students do not acquire thinking skills simply by practice in problem solving, drill, or osmosis. Problem-solving activities must be implemented with careful planning to insure intended student outcomes. Curriculum planning must involve careful consideration of the goals of problem-solving instruction, how an activity fits in relation to the goals, and the teaching style that would best facilitate goal attainment. Also, there is a difference between the product and the process when considering the value of problem-solving activities. Perkins (1986, p. 7) cautions against focusing on the products we produce and only indirectly the process by which we produce them. Specifically, how to proceed in a stepwise fashion to reach a goal. The essence of problem-solving is the application of knowledge and process that leads to a solution. Like any skill, the problem solver must acquire knowledge related to the problem, thinking skills needed to process this knowledge, and the ability to identify and apply appropriate processes to reach a solution.

Problem-Solving Processes

Problem solving is a process of resolving a known difficulty. Anderson (1980) emphasizes the processes undertaken during the act of problem solving

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by defining this behavior as goal directed sequence of operations-- an organized sequence of mental steps. Accordingly, several different problem-solving processes have been documented. Brightman (1981) discussed a process model first proposed by John Dewey in 1933. The three step process included the diagnosis phase, analysis phase, and solution phase. Other, more specific, models have been described by Polya (1971), Soloway (1988), Bransford & Stein (1984), Hatch (1988), Seymour (1987), and Devore (1987). Following are summaries of these problem-solving processes.

1. Troubleshooting/Debugging: Isolate the problem, identify possible cause, test, implement solution, test solution.
2. Scientific Process: Observation, develop hypothesis, experimentation, draw conclusion.
3. Design Process: Ideation/brainstorm, identify possible solution, prototype, finalize design.
4. Research and Development: Conceptualize the project, select research procedure, finalize research design, develop proposal, conduct research, analyze result, report result, evaluate research project.
5. Project Management: Identify project goal, identify tasks to reach the goal, develop a plan to accomplish the tasks, implement the plan, evaluate the plan.

The problem type determines the appropriate process to select and use. Therefore, the task of the problem solver is to select the best process for a given problem. To select from these processes, the problem solver must understand each process and how and when to use the appropriate one. Advanced problem solvers perceive the process of solving problems as a cycle and selected processes or subprocesses are used when needed.

Thinking Skills

The mental abilities needed to solve problems are not fully understood because of the many levels and integrations of knowledge sets that are manifested in the act of solving problems. In its simplest form, problem-solving involves the application of recalled knowledge. Woods (1987, p. 55) discusses the importance of a knowledge base pertinent to the content of the problem and further explains the value of the problem solver's ability to identify, locate, and evaluate missing information needed in the problem-solving process. These thinking skills, as they relate to technology education, may be classified as follows:

1. Prior Technological Knowledge: Knowledge and skills gained from previous study in technology education class.
2. Related Knowledge: Knowledge gained from classes other than technology education such as math and science.
3. Knowledge Seeking: Ability to identify missing information, and locate and obtain relevant information.

Higher order thinking skills involve the processing of knowledge in memory. In this respect, thinking is the process of changing knowledge. Comparing ordinary thinking and good thinking, Lipman (1988, p. 40) uses terms such as estimating, evaluating, classifying, assuming, and hypothesizing to define good thinking. Similar thinking processes have been identified by Bloom (1956); Duke (1985); Kurfman & Cassidy (1977); and Feuerstein, Rand, Hoffman, & Miller (1980). Presseisen (1985, p.45) classified thinking skills as follows:

1. Qualifications — finding unique characteristics: units of basic identity, definitions, facts, problem/task recognition.
2. Causations — establishing cause and effect, assessment: predictions, inferences, judgments, evaluations.
3. Transformation — relating known to unknown characteristics, creating meanings: analogies, metaphors, logical inductions.
4. Relationships — Detecting regular operations: parts and wholes, patterns, analysis and synthesis, sequence and order, logical deduction.
5. Classification — determining common qualities: similarities and differences, grouping and sorting, comparisons, either/or distinctions.

This list encompasses the thinking skills presented in the literature. The five categories describe ways people mentally process knowledge to change its form and function.

Teaching Methods and Styles

When implementing problem-solving activities, the level of achievement is determined by the teaching methods used to initiate and maintain students' goal directed behaviors. Maley (1978) describes 15 teaching methods appropriate for industrial arts. Nader (1984) and Costa (1984) also referenced similar methods in addition to several other commonly used teaching methods. Refer to Table 2 column 4 for a listing of these methods.

Which of these methods are best for developing students' problem-solving skills? Given the diversity of technology education content and the need to teach basic content and skills, this question is not easily answered. When students have had no experience with the subject matter, recall is the starting point. Basic knowledge and skills may best be taught with a lecture-demonstration teaching approach. To develop problem-solving skills, Sternberg & Martin (1988), and Nickerson, Perkins, & Smith (1985) recommend deemphasizing lecture. These researchers point out the value of encouraging interaction between student and teacher and maintaining a balance between structure and unstructured learning environments.

The teaching style defines the interaction of student and teacher. The steps involved in developing problem-solving skills move the student from teacher dependence to independence. Sternberg & Martin (1988, p. 569) describe a four step process beginning with direct instruction followed by intragroup problem solving, intergroup problem-solving, and individual problem solving. The process begins by fostering teacher-to-student interaction then encouraging student-to-student interaction. When students internalize the problem-solving skills, individual problem-solving skills can be developed.

Problem-solving activities implemented in technology education are characterized by the problem-solving processes and thinking skills that are taught. The teaching method and teaching style determine the environment in which learning occurs. The interactions of these variables define the level of student development on the continuum of problem-solving performance.

Problem solving, whether direct or indirect, has long been a part of technology education because of the nature of technological content. To continue to develop and improve technology education problem-solving activities, it is worthwhile to establish a baseline that quantifies the best in current practices. The purpose of this study was to identify and describe problem-solving processes, thinking skills, teaching methods, and teaching styles typically used by technology education teachers that were recognized for their teaching excellence.

Methodology

Subjects

The sample consisted of 44 technology education teachers from the population of teachers recognized for their teaching excellence. Two groups of teachers were identified to participate in this study. One group consisted of the International Technology Education Association's 1989 Teacher of the Year award winners and members of the other group were nominated by state directors for technology/vocational education. State directors were asked to nominate teachers from their state who were noted for providing instruction of high quality and developing and/or implementing innovative learning experiences related to problem solving. Since the intent of this study was to describe the best in current practices, teachers of each group were asked to participate if they had successfully implemented innovative problem-solving activities.

Twenty-two of the 44 ITEA Teachers of the Year award winners participated in the study. Twenty-two teachers nominated by state supervisors participated. Twenty teachers taught high school students, 15 taught middle school students and 5 taught students at both the middle and high school level. Four teachers did not respond to the question regarding grade level.

Instrumentation

A survey instrument was designed to identify problem-solving activities that teachers had successfully implemented and variables associated with the implementation process. The survey consisted of two parts. In the first part, participants were asked to list and briefly describe one or more innovative problem-solving activities that they found to be positive student learning experiences. The second part of the survey contained 33 items. These items, included the variables that affect implementation of problem-solving activities as identified in the review of literature. A verbal frequency scale was used to measure the frequency of use of the five problem-solving processes described by Polya (1971), Soloway (1988), Bransford & Stein (1984), Hatch (1988), Seymour (1987), and Devore (1987); the eight thinking skills described by Woods (1987, p. 55) and Presseisen (1985, p.45); and the 17 teaching methods described by Maley (1978), Nader (1984) and Costa (1984). Four questions were used to measure the continuum of teacher-to-student interaction as described by Sternberg & Martin (1988), and Nickerson, Perkins, & Smith (1985). Participants recorded their responses to the second part of the survey on a CompuTest form using the following verbal frequency scale: A = always, B = usually, C = occasionally, D = seldom and E = never. For data analysis, these response categories were coded on a one (i.e always) to five (i.e never) point ordinal scale.

Results

The participants identified and briefly described 109 activities, an average of 2.5 activities per participant. Sixty-nine of these activities were different in title and description. The activities listed were used in a variety of grade levels ranging from 8th grade to post secondary. The subject area also varied. Teachers of CAD, construction, drafting, electronic communication, engineering, exploring technology, general technology education, graphics communication, industrial technology, introduction to industry, introduction to technology, manufacturing, power and energy, product design, transportation, and woodworking reported the activities.

Survey items were categorized according to problem-solving processes, thinking skills, teaching methods, and teaching styles. These items were used to determine typical techniques used by the teachers surveyed when they implemented problem-solving activities.

A cluster analysis, the Ward's Method, was used to classify the set of variables into homogeneous groups based on similarity of response. With this analysis, the mean verbal frequency scores of each item were grouped to minimize the overall sum of squared within-cluster distances. Therefore, the clusters represent questionnaire items that shared similar frequency of use when teachers implemented problem-solving activities. To understand the similarity of the items in each cluster and the differences between the five clusters, Table 1 shows the characteristic response that items in each cluster share. For clarity the clusters were labeled according to mean rank of cluster characteristics, therefore cluster one represents items most frequently used and cluster five represents items least frequently used.

Table 1
Cluster Characteristics

Cluster	Mean	MDN	SD
1	2.30	2.0	.966

2	2.68	3.0	1.11
3	3.07	3.0	1.20
4	3.18	3.0	1.12
5	3.96	4.0	1.08

The five clusters are summarized in Table 2. Cluster one contained eight items. One problem-solving process, the design process, was a member of this cluster. The thinking skills in this cluster included application of related knowledge gained from classes other than technology education and prior technological knowledge gained from technology education class. The teaching style clustered in this group was described as the teacher shared goals and objectives with the student and decisions

Table 2
Cluster Groupings of Survey Items

Cluster	PS Process	Thinking Skills	Teaching Methods	Teaching Style
1	Design Process	Related Knowledge Prior Technological Knowledge	Discussion Demonstration Experimentation Lecture	Goals are shared by teacher. Decisions reached through agreement.
2			Individual Instruction Media	Goals are set by teacher. Teacher facilitates goal attainment.
3	Troubleshooting Scientific Project Management Research & Develop		Discovery Simulation Readings Game-Structured Competition	Teacher directs all learning experi- ences.
4		Classification Causations Qualifications	Competency-based	

	Relationships Knowledge Seeking		
5		Seminar Scenario Contract Case Study Panel Discussion Role Play	Student develops goals and means to reach them.

were reached through agreement. The characteristics of this cluster, listed in Table 1, indicate that these methods were the most frequently used by technology teachers with a mean of 2.30. Sixty-one percent of the teachers

surveyed used the items listed in this cluster usually or always and 98.3% used them at least sometimes.

Cluster two was characterized by mean of 2.68. Four items were always or usually used by 43.9% of the teachers. Individualized instruction and media were teaching methods grouped in this cluster. The teaching style, like the teaching method, was teacher directed with goals and objectives set by the teacher and the teacher guided goal attainment. These methods and this style are conducive to attainment of basic level knowledge that is a prerequisite to successful problem solving.

Cluster three contained items typically used often by the teachers surveyed. The mean response for items in this cluster was 3.07 with 34.8% of the teachers using them always or usually. Four of the five problem-solving processes were part of this cluster. They included troubleshooting/debugging, scientific process, research and development and project management. Teaching methods included in this cluster were discovery, simulation, and reading. The teaching style that was close to the mean of this cluster was one where the teacher directed all learning experience. Six of the eight thinking skills were grouped in cluster four. Competency based instruction was also grouped in this cluster. The characteristics of cluster four were similar to cluster three with 33.8% of the teachers using the members of this cluster usually or always.

The items with the lowest frequency, typically seldom used, were grouped in cluster five. This cluster was characterized by a mean of 3.96 with 9.7% of the teachers surveyed indicating that they used the teaching methods and style usually or always. Seminar, scenario, contract, case study, panel discussion and role play were members of this cluster. Also, the teaching style that was defined as students develop goals and objectives and the means to reach them was seldom used by the teachers surveyed.

Discussion

Problem-solving activities develop important skills. They teach students how to think and provide them with opportunities to experience knowledge seeking, selection, application, and evaluation. Implementing problem-solving activities means more than just giving students assignments. The outcomes of activities are dependent on the problem-solving processes and thinking skills that are taught and applied. The environment that fosters problem solving is created by the teaching methods and styles that define the teacher-to-student and student-to-student interaction.

This study identified elements of problem-solving activities that were frequently used by a sample of technology education teachers recognized for their teaching excellence. The inferential qualities of the data are limited due to the sample size, but the cluster analysis does establish norms for describing the characteristics of technology education problem-solving activities. The typical activities required students to apply knowledge gained in technology education class as well as other classes. The design process was used to structure a procedure for reaching a solution. Lecture, discussion, demonstration, and experimentation were methods most frequently used to implement activities. Teachers typically shared the goals of the activity with students and decisions were reached through agreement.

The results represent a hierarchal paradigm that emphasizes the design process and application of knowledge learned in school. Four of the five problem-solving processes and six of the eight thinking skills were typically used occasionally. Increasing the application of those elements less frequently used could be the focus for improving technology education problem-solving activities. Relating to thinking skills, Feuerstein, Miller, Hoffman, Rand, Mintzker & Jensen (1981) have shown that the development of thinking skills increases problem-solving performance. Narrol, Silverman & Waksman (1982) have shown that remedial students in vocational education programs benefit from thinking skill instruction.

The teaching methods used by teachers represent techniques that are associated with teaching low as well as high level cognitive skills. As discussed by Nickerson, Perkins, & Smith (1985, p. 327), the use of several teaching methods is common when implementing problem-solving activities. Often students need to gain basic knowledge to apply to the solution especially in a new area of study. The sequence of instruction then leads students to methods such as experimentation, game structured competition, and discovery that give them a more active role in knowledge seeking. The teaching methods listed in cluster five were seldom used by the teachers surveyed. These methods are associated with developing cognitive skills associated with effective problem solving. Likewise, the teaching style used least frequently (cluster five) is associated with high-level performance. Methods such as case study, contract and scenario could be used to focus activities on current technological problems.

This study showed that technology education is providing students with experiences, as defined by the literature cited, that develop valuable problem-solving skills. To improve technology education problem-solving activities, the intent of instruction and scope of problem-solving skill developed are the issues. If the intent of instruction is to focus on certain elements and treat others as subsets then a hierarchal paradigm should be the focus for further development. If the elements are to be treated with equal value then a paradigm representing a balance in scope should be pursued. With this paradigm, students should be taught to identify the problem type and select the appropriate process.

As problem-solving activities continue to evolve, educators must insure that appropriate processes and thinking skills are taught and teaching methods and styles allow students to grow. Curriculum developers should consider the variables identified and described in this study to analyze the paradigm that characterizes the learning potential of problem-solving activities within the scope and sequence of technology education instruction.

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