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A Framework for Technology Education Curricula Which Emphasizes Intellectual Processes

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As the field of technology education evolves, its unique mission to provide relevant and experiential learning opportunities for students is becoming clear. Through well developed curricula, technology education programs are able to reinforce academic content, enhance higher order thinking skills, and promote active involvement with technology (Johnson, 1991). The development of curricula which addresses such goals is both difficult and complex.

A variety of curriculum perspectives exist which greatly influence the direction and results of curriculum development efforts (Eisner & Vallance, 1974; Miller & Seller, 1985; Zuga, 1989). These perspectives include academic rationalist, technical/utilitarian, intellectual processes, social reconstruction, and personal relevance. While curricula developed through each curriculum perspective vary in their contribution toward a well-rounded education, this article is based on the assumption that the development of intellectual processes should be the primary goal of education. Therefore, the purpose of this article is to establish a rationale for technology education curricula which emphasizes the development of intellectual processes and lay the foundation for an intellectual processes curriculum framework.

The Importance of Intellectual Skills in the Future

There is little doubt that the development of intellectual processes is critical in this age of advancing technology. Tremendous changes have occurred and will continue to occur in the workplace. Equipment and processes are becoming more sophisticated. This sophistication has resulted in fundamental changes in the skills needed by workers. Increased levels of skills are required to maintain the complex equipment. There has been a switch from concrete (hands-on) tasks to abstract (minds-on) tasks which require mental skills such as symbolic and abstract thinking (Grubb, 1984). Management strategies have also changed in recent years. Just-in-time manufacturing,

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participative management techniques, statistical process control, and an increased emphasis on teamwork are just a few examples of the changing nature of the workplace.

As a result of the advances in technology and the organizational changes to the industrial infrastructure, job expectations for workers have changed. Rather than simply performing repetitive tasks, workers are now expected to be skilled in many jobs. While technical skills are still needed, they are not enough. Workers need to have a broader understanding of their role in the organization, be able to work in teams, and possess higher levels of communication and computational skills. Consequently, business and industry needs a workforce that possesses a broad general education with heavy emphasis on math and science. While these changes suggest the need for a greater emphasis on academic skills, the most important job skills may be the ability to think creatively, solve problems, and make decisions. In actuality, the workforce must have the ability to learn in order to keep pace with the constantly changing world.

While technological and organizational changes are impacting the workforce, similar challenges face the general public. The impacts of technology on our society, culture, environment, and political systems need to be analyzed and evaluated by citizens. Without well developed intellectual skills and an understanding of technology, it is doubtful that the general public will be willing nor able to make critical decisions regarding technological issues.

Given the fact that the skills needed by the workforce are changing and the increased need for all citizens to have high level thinking skills, are students being provided with the opportunity to acquire those skills? The answer to that question is a disappointing NO! These skills are not being taught in the majority of the schools; students are left to discover them on their own. School curricula has traditionally been developed based on behavioral psychology foundations and traditional task analysis methods which lead to a focus on rote learning and physical and basic skill development.

Because contemporary curriculum needs to emphasize understanding rather than rote memorization and heighten higher level cognitive skills in addition to physical and basic skills, curriculum development is more complex than it has been in the past. Part of the difficulty in developing curriculum that emphasizes intellectual processes is the fact that these processes occur only in the mind and are therefore not directly observable to the curriculum developer. In addition, good thinkers and problem solvers do not know how they think and solve problems because intellectual processes become so automated that they occur instinctively (Ericsson & Simon, 1984). Because the intellectual processes are not directly observable, teachers often neglect these processes in their instruction.

Zuga (1985) acknowledges that there have been few attempts to design and operationalize an intellectual processes curriculum; partly because of the lack of a coherent framework. However, recent research in cognitive psychology has provided conceptions and techniques for identifying intellectual proc-

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esses. Findings from these studies can provide an initial framework for the development and implementation of an intellectual processes curriculum.

The Content of an Intellectual Processes Curriculum

Before laying the groundwork for an intellectual processes curriculum, conceptual and operational definitions of intellectual processes are needed. Intellectual processes are those mental operations which enable one to acquire new knowledge, apply that knowledge in both familiar and unique situations, and control the mental processing that is required for knowledge acquisition and use.

There are many paradigms which attempt to describe intellectual processes. In this article, the framework provided by Marzano, Brandt, Hughes, Jones, Presseisen, Rankin, and Suthor (1988) will be used to depict intellectual processes. Through a synthesis of recent research, Marzano et al. identified five, nondisparate dimensions of thinking; (a) thinking processes, (b) core thinking skills, (c) critical and creative thinking, (d) metacognition, and (e) the relationship of content to thinking. These five dimensions become the focus of an intellectual processes curriculum.

Thinking Processes

Thinking processes are complex mental operations which result from a combination of specific thinking skills. Marzano et al. (1988) identify eight thinking processes which are used during knowledge acquisition and use. The first three processes (i.e., concept formation, principle formation, and comprehension) are used primarily to acquire new knowledge. The next four processes (i.e., problem solving, decision making, inquiry, and composition) are used primarily during the application of knowledge. The final process, oral discourse, is used during both knowledge acquisition and knowledge application.

Core Thinking Skills

Core thinking skills are the specific mental operations that are used in combination to achieve a particular goal (Marzano et al., 1988). It is the unique combination of these core thinking skills which define the broader thinking processes identified above. Marzano et al. have generated a list of 21 core thinking skills which they have grouped into eight broad categories. The following list of thinking skills is not all inclusive, however, it does provide a way of organizing the specific skills which students must learn in order to become good thinkers (see Figure 1).

Focusing Skills
1. Defining problems
2. Setting goals

Information Gathering Skills
3. Observing
4. Formulating questions

Analyzing Skills
11. Identifying attributes and components
12. Identifying relationships and patterns
13. Identifying main ideas
14. Identifying errors

Generating Skills

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Remembering Skills
5. Encoding
6. Recalling

Organizing Skills
7. Comparing
8. Classifying
9. Ordering
10. Representing

15. Inferring
16. Predicting
17. Elaborating

Integrating Skills
18. Summarizing
19. Restructuring

Evaluating Skills
20. Establishing criteria
21. Verifying

Figure 1. Core Thinking Skills (Marzano et al., 1988, pg. 69).

Critical and Creative Thinking

While many people equate critical and creative thinking with thinking processes, Marzano et al. (1988) suggest that they are unique aspects of all thinking irrespective of the type of process used. People can engage in varying degrees of creative and critical thinking while solving problems, making decisions, and conducting research. For example, when attempting to design a more efficient alternative energy collector, one student may develop a very creative solution while another student contemplates a typical design. Problem solvers may also differ greatly in the degree of critical thought used to reflect on the process needed to solve the problem.

Metacognition

Metacognition refers to one's awareness about their own thinking processes while performing specific tasks. Often called ‘strategic thinking,’ metacognition involves the planning that takes place before engaging in a thinking activity, regulation of one's thinking during the activity, and evaluation of the appropriateness of one's thinking performance upon the completion of the activity.

Relationship of Content Knowledge to Intellectual Processes

A curriculum which focuses on the development of intellectual processes cannot be developed in isolation. Attempting to teach thinking skills without something to think about is like teaching computer-aided design principles without access to a computer; the theories and procedures can be talked about, but the necessary skills can never be fully developed.

Early attempts to create instructional programs to develop intellectual processes were unsuccessful because they focused solely on the thinking skills essential for problem solving and neglected the importance of domain knowledge (Newell & Simon, 1972). Recent cognitive research clearly establishes the link between content knowledge and intellectual processes. The classic study by Chase and Simon (1973) found that the superior performance of chess masters could be attributed more to their ability to recognize board layout pat-

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terns from past experiences than to their hypothesized superior mental capability. In fact, Chase and Simon found that when the chess masters were confronted with unconventional chess layouts, the experts performed much like novices. A recent study by Chi, Feltovich, and Glaser (1984) also provides support for the importance of teaching intellectual processes within a context of a domain of knowledge. In a study of the thought processes of experts and novices in physics, Chi et al. found that the two groups approached mechanics problems very differently. The better performance by the experts was attributed to their deeper understanding of physics principles. Without this deep understanding of the domain, the novices' intellectual processes proved to be inadequate for solving similar problems.

The Structure of an Intellectual Processes Curriculum

Given the importance of intellectual processes in this world of constant change, what kind of curriculum design can ensure that the processes are developed in students? The following discussion provides an initial framework for curricula which emphasize the development of intellectual processes.

Goals of an Intellectual Processes Curriculum

Curricula which emphasize intellectual processes seek to develop the capacity for general and complex thinking skills. While not exhaustive, the following list identifies several key goals for a technology education curriculum which is designed to emphasize intellectual processes:

1. Students should acquire a repertoire of cognitive and metacognitive skills and strategies that can be used when engaged in technological activity such as problem solving, decision making, and inquiry.
2. Through explicit emphasis on intellectual processes, students should gain an awareness of the nature of thinking and their mental capability to control attitudes, dispositions, and development.
3. Through the numerous experiential activities found in technology education curricula, students should be able to use thinking skills and strategies with increasing independence and responsibility.
4. Because technology itself is interdisciplinary, students should attain high levels of knowledge in a variety of subject areas including technology, mathematics, science, social studies, and composition.
5. Because learning occurs best when related to experience and transfers to situations similar to the conditions of learning, students should be provided with activities that closely represent real world situations and contexts.

An Instructional Model for an Intellectual Processes Curriculum

A variety of existing instructional models are appropriate for an intellectual processes curriculum. Possibly the most promising model of instruction for enhancing student intellectual processes is called cognitive apprenticeship (Collins, Brown, & Newman, 1989). Cognitive apprenticeship uses many of the instructional strategies of traditional apprenticeship but emphasizes cogni-

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tive skills rather than physical skills. Traditional apprenticeship contains three primary components; (a) modeling, (b) coaching, and (c) fading. In traditional apprenticeship programs, the master craftsman models expert behavior by demonstrating to the apprentice how to do a task while explaining what is being done and why it is done that way. By observing the master perform, the apprentice learns the correct actions and procedures and then attempts to copy them on a similar task. The master then coaches the apprentice through the task by providing hints and corrective feedback if needed. As the apprentice becomes more skilled, the master gives the apprentice more and more control over the task by 'fading' into the background. Another important aspect of apprenticeship includes the emphasis on 'real world' activities which are appropriately sequenced by the master to fit the apprentice's current level of ability.

Cognitive apprenticeship uses the same modeling, coaching, fading paradigm to enhance students' cognitive abilities. During the modeling phase of cognitive apprenticeship, the instructor shows students how to complete a task or solve a problem while verbalizing the activity. However, in contrast to typical school instruction, the activity is modeled within the context of real world situations. For example, if a lesson deals with the concept of recycling, an activity for students should be designed around a real problem such as the development of a community recycling program. As an introduction to this lesson, the instructor should work through a similar problem with the class to model the thinking processes to be used. By modeling the desired intellectual processes, students will discover that there are many ways to solve problems, that experts make mistakes, and that seemingly simple problems are very complex in the real world.

Following the modeling of the desired processes, instructors need to become coaches. This involves observing students while they carry out a task, analyzing their performance, and providing hints and assistance if needed. Finally, as the students' cognitive skills become more accomplished they will be able to perform with less and less instructor intervention. This fading aspect of cognitive apprenticeship results in the gradual transfer of responsibility for learning from teacher to student.

In addition to the three primary components, the cognitive apprenticeship model includes several other defining characteristics. These characteristics include increasing complexity and diversity in lesson sequences and providing a learning environment which promotes intrinsic motivation, cooperation, and competition (Collins et al., 1989). For example, the student space simulation activity at McCullough High School in The Woodlands, Texas began as an activity in one class and quickly expanded into a project which involved virtually every program in the school. This project also generated considerable interest and cooperation among students and teachers due to its real world relevance (McHaney & Bernhardt, 1989).

Instructional Principles for Developing Intellectual Processes

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Five broad, general principles emanate from the cognitive research literature which emphasize the development of intellectual processes (Thomas, Johnson, Cooke, DiCola, Jehng, & Kvistad, 1988). Those principles include making thinking and learning easier, building on what students already know, facilitating information processing, facilitating 'deep thinking,' and making thinking processes explicit. The following list identifies the instructional principles which are used to enhance intellectual processes. See Thomas et al. (1988) for more detailed descriptions of these principles.

Principle 1: Help Students Organize Their Knowledge. Research shows that experts are able to process large amounts of information when solving problems while novices often get 'mentally bogged down' when confronted with lots of information. Instruction to improve intellectual processes must reduce the overload on student's working memory in order to enhance their ability to learn and solve problems. One way to reduce the 'load' on working memory is through the use of an external memory. Use of an external memory enables problem solvers to keep track of where they are in the process of solving a problem, thereby easing the load on working memory (Larkin, 1988). External memories can be as simple as a bill of materials for a project or as complicated as a diagram of an electronic device or complex social system. Concept mapping is another form of external memory that helps students organize new information (Novak, Gowin, & Johansen, 1983).

Principle 2: Build on What Students Already Know. Learning theories state that the ability to gain and use new knowledge is greatly affected by the knowledge students bring to a learning situation. Students use their existing knowledge to interpret and understand what is presented each day. If a student does not come to class with the appropriate prerequisite knowledge, the student will have difficulty understanding and remembering the new content. In essence, prerequisite knowledge serves as an 'anchor' to hold new information in memory. Without an appropriate anchor in the student's memory, the new information will simply 'float away.' As a result, in order for learning to take place, teachers must be sure that students have the prerequisite knowledge needed to learn. Two instructional techniques which address this principle are advanced organizers and analogies.

Principle 3: Facilitate Information Processing. Cognitive science research has consistently indicated that the way something is learned influences later use of that knowledge. New knowledge is 'indexed' in the mind when it is learned so that it can be easily found and retrieved when needed (Phye & Andre, 1986; Reiser, 1986). Indexing of information in memory is analogous to using a card catalogue to 'index' books in a library. With such an indexing system, specific books can be identified and located easily. Consequently, instruction must ensure that new information is indexed in ways that make it accessible at a later time. Strategies which facilitate information processing

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include supporting instruction through written, verbal, and graphic materials, providing outlines and organizing schemas for new content, and using real world scenarios for examples and activities which match student interests and experiences.

Principle 4: Facilitate 'Deep Thinking.' Any instructional method that causes students to consciously work harder at learning will help them achieve the instructional outcomes. Thinking hard increases the clarity of new information and aids understanding and recall. One of the best ways to get students to think is to have them elaborate on the material. In general, elaboration means that students think about the meaning of the material, identify relationships to other information, connect new information to what is already familiar, and generate expectations, predictions, and questions about the material. Techniques such as cooperative learning, peer tutoring, and paired problem solving can be used to get students to think.

Principle 5: Make Thinking Processes Explicit. There appears to be a growing consensus among researchers and teachers that it is beneficial to explicitly and directly teach students both the concept of metacognition and the use of metacognitive processes. When using direct instruction, teachers should explicitly teach strategies and skills by explaining not only what the strategy is, but also how, when, where, and why the strategy should be employed. Problem solving, decision making, planning, evaluating, and reflecting are all skills that can be reinforced in technology education classrooms. The direct teaching of these skills will improve student's overall performance by teaching them how to learn better rather than teaching them to perform isolated skills. In essence, the approach can be described by the old adage 'Give people fish and they are fed for a day, but teach them to fish and they are fed for a lifetime.'

The Role of the Teacher

For an intellectual processes curriculum to be effective, the instructor must view teaching as a cooperative learning venture between student and instructor. The instructor's role is not to transmit information to the student, rather, the instructor should serve as a facilitator for learning. This involves creating and managing meaningful learning experiences and stimulating student thinking through questions and probes. Above all else, the instructor must be knowledgeable about and pay close attention to student reasoning and thinking processes.

An excellent example of the role of the teacher in an intellectual processes curriculum has been developed for teaching mathematical problem solving (Schoenfeld, 1983). In this approach, Schoenfeld teaches a set of problem solving strategies for solving mathematical problems to his students. His teaching involves showing students how he, as a mathematician, solves problems. However, unlike most teachers, he does not work the problems out in

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advance in order to show the students a smooth and successful solution. He even encourages his students to bring problems to class for him to solve. By being confronted with unfamiliar problems, Schoenfeld is forced to solve them as a mathematician would; by using a variety of strategies and by making errors. Through this technique, the students have the opportunity to see that there are many ways to solve mathematics problems and that even expert mathematicians make mistakes.

Schoenfeld does not stop his problem solving activity when an answer has been found because mathematicians in the ‘real world’ continue looking for alternative solutions, easier methods to solve the problem, and then attempt to generalize the solution to other problems.

Because technology education content is often taught through a problem solving method, Schoenfeld's instructional approach can be easily adapted to the technology education classroom. Technology teachers need to act like technologists in their classrooms. They need to solve unfamiliar technological problems for students and not be afraid to make errors or have difficulties finding solutions. By serving as a role model, technology teachers can show students how to collect and use information to solve technological problems and help them realize that not all problems have straight forward and simple solutions.

Evaluation of an Intellectual Processes Curriculum

Evaluating student attainment of the desired intellectual processes is the weakest component of this curricular approach. Evaluation for this type of curriculum must focus on the acquisition of complex intellectual skills. However, because students' intellectual processes are not directly observable, it is difficult to determine when students have reached the desired level of performance. Current approaches to evaluation through written examinations are not adequate for testing the attainment of intellectual processes. Instructors are left with evaluation methods which rely on their intuitive skills to subjectively assess student intellectual abilities. Clearly, considerable research in this area is needed.

Constraints to an Intellectual Processes Curriculum

While there are many reasons for developing an intellectual processes curriculum there are also several obstacles which must be faced by curriculum designers (Miller & Seller, 1985). First, the intellectual processes curriculum can be criticized for its narrowness. An intellectual processes curriculum focuses primarily on left-brain oriented logical thinking and problem solving while ignoring the more intuitive, right-brain thinking. However, a well planned curriculum which incorporates learning experiences with ill-structured, design-oriented problems may help avoid this constraint.

A second constraint faced by an intellectual processes curriculum involves a perception that many of the learning experiences can be characterized as ‘playing school, scientist, or engineer.’ To counteract this potential con-

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straint, students need to see the relevance of the activities and be allowed to act on the issues so problem solving is integrated at a deeper, more holistic level.

Third, intellectual processes curricula can be criticized for its apparent neglect of content knowledge. On the surface an intellectual processes curriculum can appear to focus solely on thinking. However, as indicated earlier, an intellectual processes curriculum cannot be effective unless it includes a substantial amount of emphasis on content knowledge. As a result, this constraint can be resolved by developing high quality curricula.

Summary

Building on the assumption that the most important skill for the future is the ability to think, an initial framework for an intellectual processes curriculum theory has been described. While it is acknowledged that the curricular framework is incomplete, it is hoped that a critical examination and elaboration of the framework will be undertaken by technology educators. Many of the exemplary programs described in recent issues of *The Technology Teacher* (McHaney & Bernhardt, 1988; Thode, 1989a; Thode, 1989b) and *TIES* magazine (Craig, 1990; Neuman, 1991; Todd & Hutchinson, 1991) contain aspects of the proposed intellectual processes curriculum and should serve as a testing ground for further refinements of this initial framework.

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