DOCUMENT RESUME

ED 389 947 CE 070 517

AUTHOR Johnson, Scott D.
TITLE Learning Concepts and Developing Intellectual Skills in Technical and Vocational Education.
PUB DATE 10 Jan 96
NOTE 18p.; Paper presented at the Jerusalem International Science and Technology Education Conference (2nd, Jerusalem, Israel, January 10, 1996).
PUB TYPE Speeches/Conference Papers (150) -- Reports - Research/Technical (143)

EDRS PRICE MF01/PC01 Plus Postage.
DESCRIPTORS *Cognitive Development; Concept Formation; Creative Thinking; Critical Thinking; Epistemology; *Instructional Design; *Learning Theories; Postsecondary Education; Secondary Education; Skill Development; *Thinking Skills; *Vocational Education
IDENTIFIERS *Informal Education

ABSTRACT

Instruction should be designed to incorporate learning theories that explain how intellectual skills are developed. Through these appropriate learning theories, students learn to think conceptually, critically, and creatively when analyzing situations, developing solutions to problems, and learning from their experiences. Several critical issues confronting education also need to be examined, including problems with specialized courses designed to teach thinking skills, concerns about the failures of learning transfer, and doubts about the ability of formal education to teach what is needed in the world of work. This analysis supports the incorporation of characteristics of informal learning into formal educational settings to develop intellectual skills. Four elements of informal learning are critical for enhancing conceptual learning and developing intellectual skills: contextual learning, peer-based learning, activity-based practice, and reflective practice. They relate to the learning environment, the social aspect of learning, the learning task, and the learner. Instruction could be developed for each of these elements independently, although combining them would result in a more powerful learning environment. The educational power of informal learning environments is enhanced when knowledgeable and caring instructors incorporate modeling, coaching, and scaffolding needed by the students as well as cognitive learning principles. (Contains 62 references.) (YLB)

LEARNING CONCEPTS AND DEVELOPING INTELLECTUAL SKILLS IN TECHNICAL AND VOCATIONAL EDUCATION

Scott D. Johnson, Ph.D.
Department of Vocational and Technical Education
University of Illinois at Urbana-Champaign

Note: This paper was presented at the second Jerusalem International Science & Technology Education Conference on Technology Education for a Changing Future: Theory, Policy, and Practice to the audience of *Symposium 12* that deals with the topic of *Learning in Technical and Vocational Education* on January 10, 1996.

There is little doubt that possessing conceptual understanding and intellectual skills are important aspects of our daily lives. The ability to learn by thinking conceptually, critically, and creatively is a fundamental competency for the workplace (Secretary's Commission on Achieving Necessary Skills, 1991). The importance of learning in the workplace is due partly to the increasing complexity of work and social life. To deal with the complexity, many people have become specialists in a particular technology or process. Along with the need for specialized knowledge and skills, specialists need to interact in teams to solve problems that extend beyond the boundaries of their area of specialization. This type of interactive problem solving demands effective social and communication skills along with critical and creative problem solving abilities. The speed at which technology changes also influences the importance of learning. As technologies are developed and diffused into the workplace, new knowledge and skills are needed to install, operate, and maintain equipment and to manage the processes used to control the technologies. These changes demand that we have the ability to learn in order to gain the understanding and skill needed to adapt to the workplace changes.

Although the need for intellectual skills is of major importance, educators have had difficulty developing them. This is a major dilemma facing all educators, especially in the technical fields that provide workplace education and training. The results of the National Assessment of Educational Progress study "suggest that current forms of schooling are doing a poor job of preparing individuals for even the basics of adult life, let alone the increasingly complex demands of the workplace" (Balfanz, 1991, p. 357). We cannot continue to design instruction only around learning theories that result in telling students what to remember and what to do and then punishing or rewarding them for their performance. This common approach to instruction will get students to memorize things and perform certain tasks but it will not lead to conceptual understanding, will not help them think, nor enhance their ability to learn on their own. Part of the problem is that education has been driven by assessment practices and philosophies that emphasize the importance of knowledge gain rather than knowledge application. Efforts to increase students' factual knowledge seems to impede the development of intellectual skills (Balfanz, 1991).

We need to design instruction using learning theories that explain how intellectual skills are developed. Through these appropriate learning theories, our students will learn to think conceptually, critically, and creatively when analyzing situations, developing solutions to problems, and learning from their experiences. The purpose of this paper is to discuss formal education's difficulty in developing intellectual skills and to present recommendations that will enhance instruction and lead to educational changes in this area. The recommendations for change will be derived from thoughts about how we learn informally and from the numerous instructional innovations that have been developed recently.

Key Aspects of Intellectual Skill

Conceptual and operational definitions are needed before addressing the difficulty of developing intellectual skills. At the most basic level, intellectual skills are those mental operations that enable us to acquire new knowledge, apply that knowledge in both familiar and unique situations, and control the mental processing that is used to acquire and use knowledge. While there are many taxonomies that describe intellectual skills, Marzano, Brandt, Hughes, Jones, Presseisen, Rankin, and Suthor (1988) provide a comprehensive framework. Through a synthesis of recent research, Marzano and colleagues identified the primary dimensions of thinking; thinking skills, thinking processes, critical and creative thinking, and metacognition. It is important to note that this taxonomy of thinking skills is not based on empirical evidence. Rather, the dimensions of thinking were developed are as most taxonomies of intellectual skills, by relying on common sense and expert opinion (Balfanz, 1991). More study is needed to provide empirical evidence of the intellectual skills needed to satisfy the demands of work and daily life.

Thinking Skills

Thinking skills are the specific mental operations that are used in combination to achieve a particular goal (Marzano et al., 1988). The following list identifies 21 core thinking skills grouped into eight broad categories. While the following list of thinking skills is not all inclusive, it does provide a conceptual scheme for organizing the specific skills that good thinkers possess (see Figure 1).

Focusing Skills
1. Defining problems
2. Setting goals

Information Gathering Skills
3. Observing
4. Formulating questions

Remembering Skills
5. Encoding
6. Recalling

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

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

Generating Skills
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).

Thinking Processes

The value of the specific thinking skills is limited unless we are able to combine them into larger thinking processes. Marzano et al. (1988) identify eight thinking processes that are used to gain knowledge and to apply it in our daily lives. The first three processes (i.e., concept formation, principle formation, comprehension) are used primarily while learning. The next four processes (i.e., problem solving, decision making, inquiry, composition) are used to apply our knowledge.

The final process, oral discourse, is used during both knowledge acquisition and knowledge application.

Critical and Creative Thinking

Critical and creative thinking are unique types of thinking processes (Marzano et al., 1988). We engage in varying degrees of creative and critical thinking while solving problems, making decisions, and conducting research. For example, when engaged in a problem solving activity, one problem solver may use a very creative approach to arrive at a solution while another may use very little creativity. Problem solvers also differ in the degree of critical thought used to reflect on the process needed to solve a problem.

Metacognition

Metacognition, or what is often called *strategic knowledge*, refers to our awareness of our own thinking processes while performing specific tasks. This is an important factor in intelligence, learning, and problem solving. Metacognition involves the planning that takes place before we begin a thinking activity, regulation of our thinking as we work through the activity, and evaluation of the appropriateness of our thinking after completing the activity. This type of thinking includes strategies such as self-monitoring, advance planning, self-checking, questioning, summarizing, predicting, generating alternatives, and evaluating.

Critical Issues Confronting Education

Before discussing instructional approaches that can enhance the development of conceptual understanding and intellectual skill, there are several critical issues confronting education that need to be addressed. These issues include problems with specialized courses designed to teach thinking skills, concerns about the failures of learning transfer, and doubts about the ability of formal education to teach what is needed in the world of work.

The Failure of Specialized "Thinking" Courses

There have been many attempts to develop courses that emphasize the development of intellectual skills. Few of these attempts have been successful (Ellis & Fouts, 1993). Specialized "thinking" courses are based on the belief that thinking can be divided into specific skills that can be taught and then combined into larger applications of thought. This is a very simplistic view.

Part of the reason these courses fail is because they ignore the importance of content knowledge as a major factor in the application of intellectual skills (Newell & Simon, 1972). Cognitive research has clearly established the link between content knowledge and intellectual processes. Chase and Simon (1973), in their classic study of chess experts, found that the superior performance of chess masters could be attributed more to their ability to recognize board layout patterns from past experience than to superior mental capabilities. In fact, Chase and Simon found that when the chess masters were confronted with random chess layouts, the experts performed like novices. Evidence of the importance of teaching intellectual processes within the context of a domain of knowledge is also provided by Chi, Feltovich, and Glaser (1981). In a study of the thought processes of experts and novices in physics, Chi and colleagues found that the two groups approached mechanics problems very differently. The better performance by the experts was attributed to their deeper conceptual understanding of physics principles. Without a conceptual understanding of the field, the novices' intellectual skills were inadequate for solving the same problems. The designers of "thinking" courses also fail to realize that in order to develop a specific thinking skill you must already possess the larger thinking processes.

Rather than view thinking as a set of discrete skills that can be learned and combined into a larger set of processes, it may be better to view the development of intellectual skills as a cyclic process of refining and honing the ability to think critically, creatively, and conceptually. This approach acknowledges the fact that learners already possess the ability to think. The fundamental issue is that thinking skills cannot be taught in isolation of content and context.

The Problem of Knowledge Transfer

A second issue confronting education relates to knowledge transfer. Once we acquire new knowledge and skills, are we able to transfer what we learned in other classes, in our daily lives, and in our work? Research suggests that all too often we cannot. Numerous examples show that students who are taught a new strategy fail to apply the strategy when it is appropriate. For example, when children are taught a skill, such as solving a problem mathematically, they often fail to recognize that their new skill can be used to solve a similar problem at a later time (Bereiter, 1984). Other studies show that students who are quite skilled with certain tasks outside of school often have difficulty solving similar problems in school (Lave, 1988; Lave, Murtaugh, & de la Rocha, 1984). Knowledge and skills do not transfer easily because students may learn *how* to perform a strategy, but they do not learn *when* it is appropriate to use. This describes the problem of *inert knowledge* (Whitehead, 1929) – knowledge that is not used in new situations and contexts even though it is relevant. In other words, the knowledge students possess is inert if they have proven that they can use it in one situation (such as in a lab or on a test) but fail to use it in an appropriate situation at a later time (such as in a restaurant, at work, or while playing). The problem of inert knowledge may be due to the failure of schools to help students develop *conditionalized knowledge* – knowledge about the conditions under which knowledge is applicable (Simon, 1980).

A second reason why knowledge and skills do not transfer easily is because of differences between the learning situation and the situation where the transfer is to occur. These differences have been described as "near transfer" or "far transfer" (Clark & Voogel, 1985; Perkins & Salomon, 1988; Royer, 1986; Salomon, 1988). Near transfer occurs when students apply their knowledge and skills in situations and contexts that are similar to those in which the learning occurred. Because this type of transfer happens because of the similarity between the learning context and the context in which the skill is applied, instruction should provide learning environments that are similar to the situations in which the knowledge and skills will be used. In contrast, far transfer occurs when a skill is performed in a context that is very different from the context in which the skill was learned. Far transfer involves the development of generalizable skills that are acquired and used in different contexts (Clark & Voogel, 1985). Far transfer occurs less often and is more difficult than near transfer because you must deliberately analyze the situation in order to recall the rules or concepts needed to apply your knowledge and skill in that particular situation (Salomon, 1988).

Perkins and Salomon (1988) contend that even if students are taught knowledge and skills that are transferable, they are not taught to recognize when transfer is appropriate. By using the terms "low road" and "high road" transfer, Perkins and Salomon contend that transfer depends on the depth of learning. Learning to drive a car is a good example of a skill that transfers easily to new situations because of both near transfer and low road transfer. When learning to drive, the skills of starting and stopping a car and driving through town are practiced over and over until they become automatic. People usually have little difficulty trying to drive a car that is different from the one they originally learned to drive. The reason this "low road" transfer occurs is because the surface features of the two cars are so similar and the context in which driving occurs has not changed (near transfer) and because they have practiced the skill until it is nearly automatic (low road transfer). In contrast, "high road" transfer requires conscious attempts to recognize similar features across situations that are very different. High road transfer occurs when a military cadet realizes that the rules of "surround and capture" in chess can be applied in tactical planning. In this case, the surface features and overall context between chess and warfare are very different and, in most cases, transfer would be unlikely to occur (far transfer). However, if the learner was taught to look beyond the surface features and recognize the abstract rules that apply in a situation (high road transfer), transfer may occur. High road transfer depends on "deliberate mindful abstraction of skill or knowledge from one context or application to another" (Perkins & Salomon, 1988, p. 25).

Knowledge and skills also fail to transfer to new situations because what is learned in school is not necessarily what is needed in later life. For example, Lesgold and colleagues (1988) found that expert radiologists use different intellectual skills to analyze x-rays than those taught in medical school. In another study, Scribner (1984) found that dairy workers who assemble delivery orders and take inventory do not use the strategies and formulas they learned through formal mathematics instruction, rather, they use their knowledge of the physical environment and constraints to invent strategies that are physically and mentally more efficient. Similar studies of reading show that workers employ reading strategies that are different and more effective than those learned in school (Diehl & Mikulecky, 1980; Mikulecky, 1982). Along these same lines, Scribner and Cole (1981) found that the cognitive skills used by literate people who had no formal schooling were very different from the cognitive skills of those who became literate through formal schooling. It has even been suggested that many of the strategies used by laborers are similar to the procedures used by children prior to instruction and by unschooled adults who have learned through experience (Balfanz, 1991). Ultimately, the learning transfer problem occurs because formal education emphasizes the mechanical aspects of knowledge (e.g., rote learning of facts, calculation formulas, rules, and procedures) rather than the activity of thinking.

The issue of enhancing learning transfer through technical education is an important one. Near transfer has been an important priority of technical education. Students in many technical programs have been trained for occupations that involve specific job tasks and specialized types of equipment. Technical programs have attempted to procure and maintain "state of the art" equipment that very closely resembles equipment used in the workplace. However, with the rapid changes that are occurring in the workplace, technical programs cannot keep up with those changes. As a result, technical educators should begin giving more thought to the teaching of far transfer in their curriculum. Technical education curriculum developers must ask themselves what the educational priority should be regarding the transfer of knowledge and skills. If near transfer is desired, specific teaching strategies related to the development of automaticity will be needed. If far transfer is desired, metacognitive control of knowledge and skills must be taught.

The Impact of Schooling on Real World Thinking

We have recently become more aware of the differences between how we learn in school and how we learn outside of school (Resnick, 1987). In her discussion of these differences, Resnick contends that school is a special place of learning that is too often unrelated to daily life and work. In other words, schools teach students how to think in order to succeed in school, but those same skills are rarely useful outside of the school. Resnick uses four contrasts to make this point.

- In schools we emphasize individual thinking while shared cognition is most important in daily life and work.
- In schools we emphasize independent thinking that is done without the external support of books, notes, calculators, and other tools. In daily life and work we rely on books, manuals, job aids, computers, and other cognitive and physical tools to facilitate our thinking.
- In schools we emphasize the manipulation of symbols and rule following in artificial contexts while thinking in daily life and work occurs in a rich contextual environment that

includes objects, events, people, and many other variables that may facilitate the thinking process.

- In schools we emphasize general, widely usable skills and theoretical principles that are believed to transfer to situations outside of schooling even though evidence suggests otherwise. In daily life and work, we use our practical knowledge to invent strategies and develop competencies that are useful in specific situations.

Resnick's set of contrasts between learning that occurs in school and outside of school is a useful starting point for understanding why education has difficulty developing intellectual skills. Yet, her contrasts oversimplify the differences between learning in schools and learning in daily life and work. While Resnick's description of schools seems accurate, we can also apply those same characteristics to formal training programs in business and industry (Sorohan, 1993). Also, not all learning that occurs in schools is as formal as Resnick implies. In formal educational institutions (i.e., public schools, technical institutes, private sector training centers) considerable learning takes place as students interact between classes, collaborate in study groups, and socialize during breaks and after class activities. Rather than try to dichotomize in school and outside of school learning, it may be better to contrast those settings in terms of their degree of formality, that is, in terms of the differences between formal learning and informal learning. The "in school" problems described by Resnick are characteristic of formal educational settings while the "outside of school" characteristics occur through informal learning, whether that learning occurs in school or elsewhere.

Characteristics of formal learning. Formal learning is usually classroom based and is highly structured. Part of the problem of formal education is that schools have been designed around the model of the factory. Students are viewed as raw materials that move through various processes until the desired product is achieved. The organization and traditions of schooling evolved from the industrial goal of efficiency. Learning goals, instructional practices, and management strategies are designed to enhance efficiency. The "factory-model" of schooling can be seen in the connection between common views of work and what actually goes on in schools through terms like homework, schoolwork, and seatwork (Marshall, 1988). Even the methods of reinforcement in schools, such as grades, are metaphors that suggest that students are "paid" for their performance (Marshall, 1988).

Building on Resnick's four characteristics of typical school learning, the following list identifies many of the features that are characteristic of formal learning.

- Formal learning emphasizes individual work and assessment. Working together is viewed as cheating.
- The content taught in formal settings is designed for the near average student. This means that most students are given the same tasks to complete, irrespective of their ability levels and prior experience.
- Formal learning is highly structured and inflexible. The curriculum, learning objectives, and specific competencies are determined prior to instruction.
- Formal learning is teacher directed, authority driven, and builds on a "transmission" philosophy of education where knowledge is transferred from the mind of the teacher into the mind of the learner.
- Formal learning places major emphasis on thought and minor emphasis on action.
- Formal learning places major emphasis on theory and minor emphasis on application of that theory.
- Formal learning occurs in settings that lack the rich context of real life.

Characteristics of informal learning. Not all learning takes place in schools; considerable learning takes place outside the control and confines of formal education (Brookfield, 1984; Caffarella & O'Donnell, 1987). It has been said that as much as 90 percent of workplace learning is informal (Sorohan, 1993). However, the myth that learning comes only from formal training programs is well-entrenched in the minds of many (Marsick & Watkins, 1991). We need to broaden our thinking about the nature of learning and realize that most of what we know is learned through informal experiences; primarily through work and play. When children build a fort for a make-believe game or imitate a friend, they are engaged in informal learning. When employees discuss a problem with a new manufacturing process during a break in production or watch a technician adjust and repair equipment in their work station, they are engaged in informal learning. Informal learning is a very powerful way to learn. Through informal learning we can gain new knowledge, develop or refine skills, and improve the way we think.

What makes informal learning so powerful? We learn so much from work and play activities because they occur in settings that are ideal for learning: settings that involve other people, real problems, and authentic tools and resources. When we learn informally, we gain understanding through experience by trying out actions and then reinterpreting or reframing the experience in light of the consequences of our actions (Schon, 1983). But merely experiencing is not enough, we must have the right *type* of experience. For example, the technician who has five years experience solving difficult problems has a greater opportunity to develop troubleshooting skills than the technician who has thirty years experience replacing parts (Johnson, 1991). If the right opportunities are provided, these experiences can lead to substantial *practical knowledge*: knowing how, knowing what, and knowing why (Jarvis, 1992). The following list describes some of the primary characteristics of informal learning that lead to practical knowledge.

- Informal learning can occur at any time and place. Wherever it occurs, the natural environment provides a meaningful context in which to apply developing skills.
- Informal learning usually involves interaction with others and develops skills in cooperation, collaboration, observation, sharing, and negotiation.
- Informal learning is task or project oriented and therefore learning occurs on a "need to know" basis. By virtue of being activity-based, informal learning is motivational because it is self initiated and often involves imagination, games, and competition.
- While informal learning can be guided or facilitated by authority figures (e.g., supervisors or parents), external control is usually absent.

Using the Characteristics of Informal Learning to Develop Intellectual Skills

Based on the above discussion of formal and informal learning, one might conclude that we should do away with formal instruction and develop an infrastructure that supports informal learning. This, however, is not the case. Rather, a better conclusion is that we should incorporate what we know about informal learning into formal educational settings. This is exactly what numerous educators have proposed. Many innovative instructional models and strategies have been developed recently that build on various characteristics of informal learning. These new instructional approaches include cognitive apprenticeship (Collins, Brown & Newman, 1989), situated learning (Lave & Wenger, 1990), reciprocal teaching (Palincsar & Brown, 1984), anchored instruction (Bransford, Sherwood, Hasselbring, Kinzer & Williams, 1990), communities of learners (Brown & Campione, 1990), cooperative learning (Johnson & Johnson, 1991; Slavin, 1990), and work-based learning (Michigan Occupational Information Coordinating Committee, 1992). While the intent of this paper is not to examine each of these approaches, we can gain insights from them to guide the reform of formal instruction.

Building on what we know about informal learning, it appears that four elements are critical for enhancing conceptual learning and developing intellectual skills: (a) contextual learning, (b) peer-based learning, (c) activity-based practice, and (d) reflective practice. These four elements relate to the learning environment, the social aspect of learning, the learning task, and the learner. Instruction could be developed for each of these elements independently, although combining these elements will result in a more powerful learning environment.

Contextual Learning

A rich learning environment filled with authentic problems and real situations is critical for developing intellectual skills. Expertise is created through interaction with the environment, not in isolation from it (Berryman & Bailey, 1992). Brown, Collins, and Duguid (1989) view contextual learning as a form of enculturation. As we interact with others in a contextually rich learning environment, we "pick up relevant jargon, imitate behavior, and gradually start to act in accordance with" the norms of the cultural setting (Brown et al., 1989, p. 34). Through this "authentic" activity, we have the chance to observe the behaviors of others, practice the skills we see, use the tools and materials of the day, and give and receive advice. Learning within a rich context also helps address the transfer problem by learning in an environment that reflects the way knowledge will be used in real life (Collins et al., 1989). Various approaches to instruction that build on contextual learning have been developed recently including situated learning, anchored instruction, and cognitive apprenticeship.

The power of context on intellectual skills was observed in a study of troubleshooting expertise. Flesher (1993) conducted an in-depth protocol analysis of electronic troubleshooters from three different contexts: design, production, and repair. Flesher provided technicians from each of these contextual settings with a faulty electrical system and analyzed their troubleshooting performance from a cognitive perspective. His results showed that context influenced the troubleshooters' initial frame of reference, which impacted their ability to locate faults. Similar evidence of the influence of context on performance has been noticed in Johnson's study of generator troubleshooters (Johnson, 1987) and Martin and Beach's study of CNC machining (1992). Martin and Beach, for example, noticed differences in the thinking patterns of technical personnel as a result of prior experience and the type of training they received. They also noticed that when they were confronted with a technical problem, engineers thought about economic concerns, machinists thought about contingencies, and setup people thought about practical matters.

If education is to facilitate learning that is useful outside the classroom, it must take place in contexts that resemble the situations in which the knowledge and skills will be used (to facilitate near transfer) and provide extensive opportunities for practice (to facilitate low road transfer). Once students develop a relatively firm grasp of the rules and principles that underlie concepts and are taught how to apply them in other situations, they will be more likely to spontaneously use (i.e., transfer) their knowledge in new situations.

Peer-Based Learning

"We learn from the company we keep" (Smith, 1992, p. 432). All cognitive activity is socially defined, interpreted, and supported (Rogoff & Lave, 1984). By interacting with others, tutoring them, and being tutored by them, we have the opportunity to learn from them, share our knowledge, and engage in competition, cooperation, collaboration, conversation, and negotiation of meaning. Essentially, through the social activity of learning, we have the opportunity to develop a *community of learners* (Brown, 1994).

Peer-based learning involves working together to achieve a learning goal and this team approach makes training programs more realistic. Therefore, what is learned cooperatively may be more transferable to the real world because of the similarity between the training situation and the actual work situation (Holubec, Johnson, & Johnson, 1993). The teacher's role is to participate as a peer, monitor the activity, and facilitate and moderate as needed. Getting the right answer is not as important as getting the learners to work together to develop a solution. Even if an incorrect solution is reached, how and why it was reached must be understood so the error will be less likely to occur again. Example of instructional approaches that are grounded in peer-based learning include reciprocal teaching (Palincsar & Brown, 1984), cooperative learning (Johnson & Johnson, 1991; Slavin, 1990), peer tutoring and cross-age tutoring (Gaustad, 1993), and paired problem solving (Lochhead & Whimbey, 1987).

One of the reasons students learn so well when working with others is because of the amount of verbalization that takes place. Peer-based learning fosters extensive verbal elaboration that aids cognitive restructuring of information (Slavin, 1990). In fact, it is the verbal interaction among group participants that contributes the most toward learning (Holubec et al., 1993; Jones & Carter, 1995). Jones and Carter (1995), for example, found that low ability students spoke significantly more words when paired with high ability students than with low ability students. This was also true for high ability students who were paired with lower ability students. In addition, the high ability students showed more helping behavior when paired with lower ability peers.

Working with others leads to verbal interactions that help in several ways. First, by verbalizing their thoughts, learners become more aware of thinking activities and actually begin to listen to their thinking (Lochhead, 1985). Second, the interaction helps students learn how to modify someone else's thinking and how to defend their own ideas (Krulik & Rudnick, 1980). Third, group interaction supports reflective activity as learners self-monitor and self-correct by observing and modifying their own cognitive behavior. Finally, the verbalization process contributes to more precise thinking and stimulates conceptual development (Lochhead, 1985).

Other studies have shown that verbalization leads to more effective problem solving (Andre, 1986; Biemiller, 1993; Glass, 1991). Glass (1991), for example, in a study of technical problem solving, found that students who verbalized their thoughts while problem solving tended to form more accurate problem representations, could transfer their knowledge to other problem situations, were more aware of their thinking, and appeared to be more task-oriented and focused on the problem. It is thought that verbalization induces greater elaboration and cognitive structuring of the presented material. The effect is even greater if the learner expects to teach the material to others.

Activity-Based Practice

As one examines educational practice, there seems to be an assumed separation between knowing and doing in education (Brown et al., 1989). Knowing is valued over doing. Mental activity is valued over physical activity. This separation, however, has been challenged in recent years. The activities through which learning occurs are inseparable from cognition. "People who use tools . . . build an increasingly rich implicit understanding of the world in which they use the tools and of the tools themselves. The understanding, both of the world and of the tool, continually changes as a result of their interaction. Learning and acting are interestingly indistinct, learning being a continuous, life-long process resulting from acting in situations" (Brown et al., 1989, p. 33). In order for peer-based learning to be successful, some form of activity must become the focus of the community of learners. This activity should be oriented toward the design or construction of a project or product and involve the integration of knowledge and skills.

Activity-based practice can be provided in many forms. Discovery learning, thematic instruction, and project-based learning are common techniques for engaging students in motivational activities that involve considerable amounts of creativity, decision making, and problem solving. Arthur Anderson & Company uses six instructional approaches to engage their trainees in active learning: (1) structured-on-the-job training, (b) apprenticeships, (3) goal-based scenarios, (4) action learning, (5) problem-based, and (6) project-based (Montgomery, 1994). Each of these instructional approaches emphasizes the importance of learning from experience: experience that is highly goal driven and activity-based. Since these activities usually take a considerable amount of time to complete, they provide for sustained thinking about specific problems over long periods of time.

Learning through activity-based practice is closely connected with learning as a social activity. Experiential learning provides extensive opportunities for apprenticeship-type activity. For example, action learning is the term used in executive training to describe activity-based practice and involves giving teams of learners (i.e., peer-based learning) real business problems to solve. "Action learning is representative of emerging models of workplace learning, which recognize that knowledge isn't something we pour from one vessel (a teacher) into another (a student). Instead, ... our natural drive to learn thrives when we can direct our own learning, share knowledge, and emulate experts–and make mistakes" (Sorohan, 1993, p. 48).

Through the years, apprenticeship has been a common activity-based form of learning technical skills. Traditional apprenticeship typically involves an expert who models the desired performance for novices, coaches them through a task, and gives them more autonomy as their skills develop. In a traditional craft guild, for example, the master models how to do a task while explaining what is being done and the reason behind it. 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 as needed. As the apprentice becomes more skilled, the master gives the apprentice more control over the task by "fading" into the background.

While traditional apprenticeship emphasizes physical ability, Collins, Brown, and Newman (1989) advocate using cognitive apprenticeship as a model for developing intellectual skills. Modeling of correct performance, coaching students through difficult tasks, providing scaffolds as needed, and providing less assistance as their competency increases are major components of this model. Cognitive apprenticeship also includes the selection and sequencing of learning experiences based on an individual's performance.

Learning Through Reflective Practice

"There is a big difference between having experiences and learning from them" (Marsick & Watkins, 1991, p. 11). Even if instruction occurs in rich contexts and involves interacting with peers while working on various activities, quality learning will not take place unless there is reflective introspection. People who do not *reflect* on their experience fail to learn from their experience (Jarvis, 1992).

Everyday practice is influenced by the reflective conversations we have about a situation (Schon, 1983). Strategic knowledge, or what is often called metacognition, is an important part of reflective practice and an important factor in intelligence, learning, and problem solving. According to Brown (1978), "the ability to monitor one's own understanding . . . is an essential pre-requisite for all problem solving ability" (p. 83). Bransford (1979) extended this idea a step further when he stated that "the ability to plan and evaluate our own learning strategies seems to be a hallmark of intelligent activity" (p. 244).

While most educators agree that learners should be aware of their own thinking, the merits of teaching metacognition directly versus indirectly have been debated. There appears to be a growing consensus that it is beneficial to explicitly and directly teach learners both the concept of metacognition and the use of metacognitive processes (Brown, 1978; Collins et al., 1989; Jackson, 1986). When using the direct approach, teachers should explicitly teach strategies and skills.

Teachers should explain not only what the strategy is, but also how, when, where, and why the strategy should be employed. Once students become aware of metacognitive processes, they should be able to apply their metacognitive skills through reflection while working on various learning activi'ies.

Reflective practice is compatible with the movement toward "continuous learning for continuous improvement" in the workplace (Marsick & Watkins, 1991). As we become more comfortable reflecting on our own thinking, we will also be more aware of the limitations in our knowledge, skills, and thinking abilities. Once we are aware of these deficiencies, we can work to reduce them.

Informal Learning is not Enough

Incorporating these four elements of informal learning into formal instruction will not, by themselves, lead to enhanced conceptual learning and intellectual skill development. The educational power of informal learning environments is enhanced when knowledgeable and caring instructors combine the appropriate learning environment with the modeling, coaching, and scaffolding needed by the students. Instructors need to also incorporate cognitive learning principles into the elements of informal learning. Cognitive research has led to the development of six broad, general instructional principles that enhance conceptual learning and thinking (Johnson & Thomas, 1994). These five principles include helping students organize their knowledge, building on what students already know, facilitating information processing, facilitating "deep thinking," and making thinking processes explicit. Johnson and Thomas (1994) have also identified many instructional strategies that can be used in formal instruction to address the cognitive principles of learning (see Figure 2). Combining direct instruction using strategies that are designed around the six cognitive principles of learning within an environment provided by the four elements of informal learning will result in robust opportunities for students to gain conceptual understanding and develop their intellectual skills.

Implications for Vocational and Technical Education

When we compare the elements of instruction discussed in this paper with instructional practice in vocational and technical education, we notice considerable congruence. Throughout its existence, possibly beginning with ancient forms of apprenticeship, technical education has been activity-based, rich in context, and to a lesser extent, peer-based and encouraging of reflective practice. This should not be surprising because the content of technical education is driven by the needs of the workplace and the instructors maintain a close connection with the "real world." The curriculum is very skill-oriented, project-based, and taught in rich contextual settings that often have a high degree of correspondence to the workplace. These characteristics have not gone unnoticed, as researchers have begun to turn to vocational and technical education to learn more about "non-traditional techniques and methods" (Stasz, McArthur, Lewis & Ramsey, 1990, p. 2) including "micro-apprenticeships," one-to-one tutoring, and authentic project-centered problems.

Is instructional practice in vocational and technical education determined through an understanding of contemporary learning theory and research or is it based primarily on common sense and tradition? Even though many of the desired instructional characteristics discussed in this paper are evident in vocational and technical education, the reasons for their existence is not clear. The field has been criticized for placing too much emphasis on developing basic technical skills and competencies rather than the higher level cognitive skills. It seems as though the field is using cognitive-oriented instructional practices to achieve motor skill development and the learning of work procedures, goals that can be addressed through behavioral learning theories. This has resulted in instruction that is delivered through lectures and demonstrations, emphasizes memorizing information, teaches large skill sets as small discrete tasks, and encourages practice of

Instructional Principles and Strategies for Enhancing Cognitive Learning

Principle 1 Reduce Load on Limited Working Memory

- Teach how to create external memories
- Provide external memories such as notes, outlines, and concept maps
- Strategically focus attention through graphical cues such as boldface type, underlining, bright colors, loud sounds, and novelty
- Help learners organize their memory into chunks through concept mapping, contrast sets, mnemonic devices, and pattern recognition

Principle 2 Activate Existing Knowledge Structures

- Ask thought provoking and probing questions.
- Use text or visual cues to help learners access appropriate knowledge.
- Use advance organizers.
- Use analogies and metaphors.
- Explicitly remind learners of what they already know

Principle 3 Support Encoding and Representation of New Knowledge

- Establish a purpose for what is to be learned.
- Highlight distinctive features of new information.
- Contrast similarities and differences in new information.
- Encourage use of multiple representation forms (e.g., verbal, iconic, symbolic).
- Teach mnemonic memory enhancement strategies.

Principle 4 Facilitate "Deep Thinking"

- Encourage learners to reflect on their actions and beliefs.
- Plan activities that facilitate learner interaction (e.g., pair problem solving or cooperative learning strategies).
- Involve learners in teaching roles (e.g., peer tutoring or reciprocal teaching).
- Encourage learners to generate questions, explanations, and summaries.
- Design laboratory or computer-based simulations that require extensive cognitive processing.
- Challenge learners' understanding through dialectic dialogue.

Principle 5 Enhance Cognitive Control Processes

- Adapt metacognitive instruction to the learners' ability levels.
- Teach metacognitive strategies directly through techniques such as reciprocal teaching
- Use precise language that clearly identifies the processes to be used.
- Encourage learners to "think aloud" while problem solving to make cognitive processes explicit

Principle 6 Support the Use and Transfer of Knowledge and Skills

- Plan activities around real situations and contexts.
- Design activities of increasing complexity and diversity.
- Model appropriate skills and behaviors
- Provide hints, reminders, and explanations to help learners accomplish tasks they could not otherwise complete.
- Provide less external support as skill and autonomy increase
- Provide practice opportunities to develop automaticity

Figure 2. Instructional Principles and Strategies for Enhancing Cognitive Learning (Johnson & Thomas, 1994, p. 41).

BEST COPY AVAILABLE

technical skills until they can be performed accurately. Because the courses are taught in laboratories or "shops" and students are actively using tools and equipment to complete projects, one might hope that the development of intellectual skills would be an integral focus in the courses. While those skills are enhanced through technical instruction, it occurs because of the richness of the learning environment and not because those skills are explicitly emphasized in the course. In essence, the intellectual skills that are developed through technical education are a byproduct of the learning environment and not a result of an explicit and conscious effort by the curriculum designers and instructors.

If intellectual skill development is to become a larger focus of the technical curriculum, a better understanding of social-constructionist theories of learning are needed. This does not imply that the behavioral theories of learning be tossed aside in favor of the more contemporary social-constructionist theories. Instructional designers and technical instructors need to match their desired learning goals and instructional methods to the appropriate learning theories.

Royer (1986) provides a taxonomy of educational goals that helps clarify which learning theories are appropriate for the different types of learning that occur in technical education. Those learning goals include memorization of important information, development of motor skills, understanding concepts and relationships, and enhancement of intellectual skills such as problem solving and decision making. Designing instruction around the behavioral learning theories is appropriate when the learning goal is to help students remember important information or to develop their skill in using and operating tools and equipment. These types of goals are prevalent in technical education and the behavioral approaches have served the field well. However, because of the changing nature of the workplace and society, there is an increased need to emphasize learning goals that involve the development of understanding and the improvement of intellectual skills. These types of goals require that instruction be designed around the social-constructivst learning theories. This will result in the design of stimulating learning environments in which flexible, highly active, group and project-oriented methods are used. The four elements of informal learning and the instructional principles and strategies shown in Figure 2 provide a starting point for selecting appropriate instructional methods that enhance understanding and the development of intellectual skills.

References

Andre, T. (1986). Problem solving and education. In G. D. Phye & T. Andre (Eds.), *Cognitive classroom learning: Understanding, thinking, and problem solving*, (pp. 169-204). New York: Academic Press.

Balfanz, R. (1991). Local knowledge, academic skills, and individual productivity: An alternative view. *Educational Policy, 5*(4), 343-370.

Bereiter, C. (1984). How to keep thinking skills from going the way of all frills. *Educational Leadership, 42*(1), 75-77.

Berryman, S., & Bailey, T. (1992). *The double helix of education and the economy*. New York: Columbia University, Teacher College, The Institute on Education and the Economy.

Biemiller, A. (1993). Lake Wobegon revisited: On diversity and education. *Educational Researcher, 22*(9), 7-12.

Bransford, J. D. (Ed.). (1979). *Human cognition: Learning, understanding and remembering*. Belmont, CA: Wadsworth.

Bransford, J. D., Sherwood, R. S., Hasselbring, T. S., Kinzer, C. K., & Williams, S. M. (1990). Anchored instruction: Why we need it and how technology can help. In D. Nix & R. Spiro (Eds.), *Advances in computer-video technology*, . Hillsdale, NJ: Erlbaum.

Brookfield, S. D. (1984). Self-directed adult learning: A critical paradigm. *Adult Education Quarterly, 35*, 59-71.

Brown, A. L. (1978). Knowing when, where, and how to remember: A problem of metacognition. In R. Glaser (Ed.). *Advances in instructional psychology*, (Vol. 1, pp. 77-165). Hillsdale, NJ: Erlbaum.
Brown, A. L. (1994). The advancement of learning. *Educational Researcher, 23*(8), 4-12.
Brown, A. L., & Campione, J. C. (1990). Communities of learning and thinking, or A context by any other name. In D. Kuhn (Ed.). *Contributions to Human Development, 21*, 108-125.
Brown, J. S., Collins, A., & Duguid, P. (1989). Situated cognition and the culture of learning. *Educational Researcher, 18*(1), 32-42.
Caffarella, R. S., & O'Donnell, J. M. (1987). Self-directed adult learning: A critical paradigm revisited. *Adult Education Quarterly, 37*, 199-211.
Chase, W. G., & Simon, H. A. (1973). The mind's eye in chess. In W. G. Chase (Ed.). *Visual information processing*, (pp. 215-281). New York: Academic.
Chi, M. T. H., Feltovich, P. J., & Glaser, R. (1981). Categorization and representation of physics problems by experts and novices. *Cognitive Science, 5*, 121-152.
Clark, R. E., & Voogel, A. (1985). Transfer of training principles for instructional design *Educational Communication and Technology Journal, 33*(2), 113-123.
Collins, A., Brown, J. S., & Newman, S. E. (1989). Cognitive apprenticeship: Teaching the craft of reading, writing, and mathematics. In L. B. Resnick (Ed.), *Knowing, learning, and instruction: Essays in honor of Robert Glaser*, (pp. 453-494). Hillsdale, NJ: Erlbaum.
Diehl, W. A., & Mikulecky, L. (1980). The nature of reading at work. *Journal of Reading, 24*(3), 221-227.
Ellis, A. K., & Fouts, J. T. (1993). *Research on educational innovations*. Princeton, NJ: Eye on Education.
Flesher, J. W. (1993). *An exploration of technical troubleshooting expertise in design, manufacturing, and repair contexts*. Unpublished doctoral dissertation, University of Illinois at Urbana-Champaign, Urbana, IL.
Gaustad, J. (1993). *Peer and cross-age tutoring* (ERIC Digest EDO-EA-93-1). Eugene, OR: ERIC Clearinghouse on Educational Management.
Glass, A. R. (1991). *The effects of thinking aloud pair problem solving on technology education students' thinking processes, procedures, and problem solutions*. Unpublished doctoral dissertation, University of Minnesota, St. Paul, Minnesota.
Goodlad, J. I. (1984). *A place called school*. New York: McGraw-Hill.
Holubec, E., Johnson, D. W., & Johnson, R. T. (1993). Impact of cooperative learning on naval air traffic controller training. *The Journal of Social Psychology, 133*(3), 337-346.
Jackson, R. M. (1986). Thumbs up for direct teaching of thinking skills. *Educational Leadership, 43*, 32-36.
Jarvis, P. (1992). Learning practical knowledge. *New Directions for Adult and Continuing Education, 55*, 89-95.
Johnson, D. W., & Johnson, R. T. (1991). *Learning together and alone*. (3rd ed.). Englewood Cliffs, NJ: Prentice-Hall.
Johnson, S. D. (1987). *Knowledge and skill differences between expert and novice service technicians on technical troubleshooting tasks* (Technical Report #20). St. Paul: University of Minnesota, Training and Development Research Center (ERIC Document Reproduction Service No. ED 284 054).
Johnson, S. D. (1991). Training technical troubleshooters. *Technical and Skills Training, 27*(7), 9-16.
Johnson, S. D., & Thomas, R. G. (1994). Implications of cognitive science for instructional design in technology education. *The Journal of Technology Studies, 20*(1), 33-45.
Jones, M. G., & Carter, G. (1995,). *The effects of ability-paired interactions on concept attainment*. Paper presented at the annual meeting of the American Educational Research Association, San Francisco.
Krulik, S., & Rudnick, J. A. (1980). *Problem solving*. Boston: Allyn and Bacon.
Lave, J. (1988). *Cognition in practice*. New York: Cambridge University Press.

Lave, J., Murtaugh, M., & de la Rocha, O. (1984). The dialectic of arithmetic in grocery shopping. In B. Rogoff & J. Lave (Eds.), *Everyday cognition: Its development in social context*, (pp. 67-94). Cambridge, MA: Harvard University Press.

Lave, J., & Wenger, E. (1990). *Situated learning: Legitimate peripheral participation* (IRL 90-0013). Palo Alto, CA: Institute for Research on Learning.

Lesgold, A., Rubinson, H., Feltovich, P., Glaser, R., Klopfer, D., & Wang, Y. (1988). Expertise in a complex skill: Diagnosing x-ray pictures. In M. T. H. Chi, R. Glaser, & M. J. Farr (Eds.), *The nature of expertise*, (pp. 311-342). Hillsdale, NJ: Erlbaum.

Lochhead, J. (1985). Teaching analytic reasoning skills through pair problem solving. In J. W. Segal, S. P. Chipman, & M. Glaser (Eds.), *Thinking and learning skills*, (Vol. 1, pp. 109-131). Hillsdale, NJ: Erlbaum.

Lochhead, J., & Whimbey, A. (1987). Teaching analytical reasoning through thinking aloud pair problem solving. *New Directions for Teaching and Learning, 30*, 73-92.

Marshall, H. H. (1988). Work or learning: Implications of classroom metaphors. *Educational Researcher, 17*(9), 9-16.

Marsick, V. J., & Watkins, K. E. (1991). Continuous learning in the workplace. *Adult Learning, 3*(1), 9-12.

Martin, L. M., & Beach, K. (1992). *Technical and symbolic knowledge in CNC machining: A study of technical workers of different backgrounds* (MDS-146). Berkeley, CA: University of California at Berkeley: National Center for Research in Vocational Education.

Marzano, R. J., Brandt, R. S., Hughes, C. S., Jones, B. F., Presseisen, B. Z., Rankin, S. C., & Suthor, C. (1988). *Dimensions of thinking: A framework for curriculum and instruction*. Alexandria, VA: Association for Supervision and Curriculum Development.

Michigan Occupational Information Coordinating Committee. (1992). *How do I get from here to there? A guide to work-based learning*. Lansing, MI: Michigan Department of Labor.

Mikulecky, L. (1982). Job literacy: The relationship between school preparation and workplace actuality. *Reading Research Quarterly, 17*, 400-418.

Montgomery, J. R. (1994,). *Global trend in education: Shifting from a teaching-focus to a learning-focus*. Paper presented at the International Experiential Learning Conference, Washington, DC.

Newell, A., & Simon, H. A. (1972). *Human problem solving*. Englewood Cliffs, NJ: Prentice-Hall.

Palincsar, A. S., & Brown, A. L. (1984). Reciprocal teaching of comprehension-fostering and comprehension-monitoring activities. *Cognition and Instruction, 1*(2), 117-175.

Perkins, D. N., & Salomon, G. (1988). Teaching for transfer. *Educational Leadership, 46*(1), 22-32.

Resnick, L. B. (1987). Learning in school and out. *Educational Researcher, 19*(9), 13-20.

Rogoff, B., & Lave, J. (1984). *Everyday cognition: Its development in social context*. Cambridge, MA: Harvard University.

Royer, J. M. (1986). Designing instruction to produce understanding: An approach based on cognitive theory. In G. D. Phye & T. Andre (Eds.), *Cognitive classroom learning: Understanding, thinking, and problem solving*, (pp. 83-113). New York: Academic Press.

Salomon, G. (1988, April). *Two roads to transfer; Two roads of transfer*. Paper presented at the annual meeting of the American Educational Research Association, New Orleans.

Schon, D. A. (1983). *The reflective practitioner: How professionals think in action*. New York: Basic Books.

Scribner, S. (1984). Studying working intelligence. In B. Rogoff & J. Lave (Eds.), *Everyday cognition*, (pp. 9-40). Cambridge: Harvard University Press.

Scribner, S., & Cole, M. (1981). *The psychology of literacy*. Cambridge: Harvard University Press.

Secretary's Commission on Achieving Necessary Skills. (1991). *What work requires of schools*. Washington, DC: U.S. Department of Labor.

Simon, H. A. (1980). Problem solving and education. In D. Tuma & R. Reif (Eds.), *Problem solving and education: Issues in teaching and research*, (pp. 81-95). Hillsdale, NJ: Erlbaum.
Slavin, R. (1990). *Cooperative learning: Theory, research and practice*. Englewood Cliffs, NJ: Prentice Hall.
Smith, F. (1992). Learning to read: The never ending debate. *Phi Delta Kappan, 73*(6), 432-435, 438-441.
Sorohan, E. G. (1993). We do; therefore, we learn. *Training & Development, 47*(10), 47-55.
Stasz, C., McArthur, D., Lewis, M., & Ramsey, K. (1990). *Teaching and learning generic skills for the workplace* (R-4004-NCRVE.UCB). Santa Monica, CA: The RAND Corporation.
Whitehead, A. N. (1929). *The aims of education*. New York: Macmillan.