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ABSTRACT

Students in higher education are faced with rapidly changing societal conditions. As the nature and structure of the workplace and the family have changed, the specific knowledge and skills people need for the future have become less predictable. Teachers can address these changing conditions by applying cognitive theory to learning and instructional delivery. Cognitive theory in this context implies that learning is a process of knowledge construction rather than knowledge absorption and storage. As applied to instruction, this approach should not focus on individual mental activity in isolation from the social and physical context, but recognize that skilled practical thinking incorporates features of the task environment (e.g., people, things, information) into the problem-solving system. Technical college students, who are generally older and who come to college with various experiential and environmental contexts, benefit from instructional designs which consider such contextual relationships. Of three models of instruction (i.e., instruction as transportation of knowledge, as application of algorithms, and as transfer of responsibility), the third approach is supported by cognitive theory. When instruction is viewed as a transfer of responsibility, the learner is led to assume independent responsibility for learning, and knowledge is constructed by learners using what they already know and have experienced. This model of instruction is effective with rapidly changing societal conditions since it supports the development of complex cognitive processes. (Contains 14 references.) (PAA)

COGNITIVE SCIENCE, LEARNING THEORY and TECHNICAL EDUCATION

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I. Background

As teachers we face an enormous challenge in preparing men and women to enter and be productive in a workforce and a society which are characterized by complex technology, complex economics, complex relationships, and rapid change. As we strive to meet this challenge, learning theory with its implications for curriculum design, instructional design, and delivery methodology becomes paramount to our activities. The three basic families of learning theory, the mental discipline theories, the behavioristic family of stimulus-response theories, and the cognitive family of interactionist theories have helped to present a framework in which scientists have attempted to explain how people learn. The third family, the cognitive family, is a relatively new area of study. A major component of that family, cognitive science or cognitive psychology, may provide us the opportunity to gain a better understanding of learning and thus the opportunity to improve instruction.

Our students are confronted with rapidly changing societal conditions. The nature and structure of the workplace have changed. The nature and structure of our families have changed. It is generally accepted that we are in a transitional period between an industrial society and an information society known as the post-industrial society. This post-industrial period is characterized by several major trends including: (1) rapidly changing technology, (2) downsizing in the business and industrial sectors, (3) changing family profiles, (4) increasing numbers of women entering the workforce, (5) the emergence of trans-national companies, and (6) increasingly diverse work and living communities.

These trends have substantial impact on the work- place and on those entering the workplace. This in turn impacts what we do as teachers. A recent study published by the National Center for Research in Vocational Education entitled Alternative Perspectives of Instruction and Cognitive Theory: Implications and Proposals, puts it this way

> As the nature and structure of the workplace and the family have changed and as roles have become less well-defined, the specific knowledge and skills people need for the future have become less predictable. Future conditions in an era of

rapid change will inevitably present learners with problems their education has not "covered." In dealing with such problems, learners will need to find their own meanings and fill in gaps in their knowledge and reorganize what they know on their own.

It is the premise of this presentation that knowledge of and application of cognitive theory to learning theory and instructional design and delivery by teachers is one means to address the changing societal conditions I just described. Cognitive theory as applied to learning means that learning is a process of knowledge construction rather than knowledge absorption and storage. In other words, people use what they already know in constructing new knowledge; and learning is closely related to the context in which it takes place. There are two important concepts here that we will explore in greater depth--construction of knowledge and construction of that knowledge within a specific context.

II. The Aims of Education

Before we move too much further into this discussion about cognitive theory and its application to learning theory and teaching, we need to take a closer look at the aims of education. History shows us that the aims of education are dependent upon philosophy and societal conditions. As philosophical thought changes, so do the aims of education.

In ancient Greece, the aim of education was to prepare people for their best-fitting role in serving society. The idea of individual development rather than culturally prescribed development was introduced in Europe about 2000 years later (Thomas, et. al., 1992).

In 1943, Jacques Maritain wrote that "man is not merely an animal of nature . . .but . . .an animal of culture, whose race can subsist only within the development of society and civilization. . ." (p. 2, 1943). In other words the aim of education should be to guide man in shaping himself as a human person, finding meaning.

The NCRVE study characterized the aims of education in two broad categories--socialization and individual and cultural development. The socialization aim centers around the adoption of meanings that are shared by members of a culture, meanings that reflect the culture's view of the world. According to this study education based on socialization aims assumes that society remains the same and seeks to reproduce the present culture by preparing learners for living effectively in it as it presently is. On the other hand, where the aim of education is individual and cultural development, society can benefit from unique, individual development and as a result, the society and its culture develop. Each of these two aims of education impact how we plan, develop, and deliver education. As teachers, we can ill afford to ignore either one of these two broad aims. According to the study, it should be no surprise that education aimed at socialization for a mass culture at the expense of attention to individual diversity has been seen as irrelevant by large segments of learners. I am sure all of us here can attest to this. Such education has also been criticized for contributing to perpetuating rather than to righting social, economic, and political inequities.

If we, as teachers, are to help our students affect and deal with rapidly changing conditions, we need to not only take into account present culture, but we need to go beyond it. Cognitive theory can help us do that.

III. What is Cognitive Theory?

What is cognitive theory? Cognitive theory derives from cognitive psychology which is the science of how the mind works. It deals with the higher mental processes such as memory, perception, learning, thinking, reasoning, language, and understanding. Placed within the context of information-processing, cognitive psychology is the study of how man collects, stores, modifies, and interprets environmental information or information already stored internally (Lachman et al. 1979). The theoretical foundations of cognitive science can be found in mathematics and computation as posited by Alan Turing with the Turing machine which introduced the concepts of binary code and programming. The neuronal model as developed by McCulloch and Pitts established the concept of networks modeled in terms of logic. Control and communication theory as posited by Wiener in cybernetic synthesis, Shannon's mathematical explanation of information theory, and neuropsychological syndromes, i.e., profiles of incapacities following damage to the human brain complete the theoretical foundations of cognitive science (Gardner 1985).

Howard Gardner (1985) defined cognitive science

> . . . as a contemporary, empirically based effort to answer long-standing epistemological questions--particularly those concerned with the nature of knowledge, its components, its sources, its development, and its deployment. (p. 6)

Gardner (1985) limited his definition to efforts to explain human knowledge. Gardner and others approach cognitive science primarily from an information-processing perspective. In fact, information-processing oriented cognitive scientists believe that the collection, storage, interpretation, understanding, and use of environmental or internal information is cognition (Lachman, et al. 1979).

There are certain key elements that are commonly associated with the field of cognitive science or cognitive psychology. The most prominent is the concept of mental representation. Gardner (1985) posited that understanding of mental representation, i.e., symbols, rules, images which are found between input and output, and how such representational entities are joined, transformed, or contrasted is necessary in order to explain the variety of human behavior, action, and thought. Cognitive psychology proceeds from the assumption that represented information is coded for storage in the human nervous system. In other words, external events are converted into an internal form according to some specifiable sets of rules.

Gardner (1985) cited two varieties of representation. The first was that which is built into the hardware, i.e., the brain. The processes involved with this variety must be invoked but are transparent to the user. The second variety includes problem-solving and classificatory behaviors that are more overt in nature. In analyzing a situation or creating an image, one creates a mental representation or model. Explicit awareness in developing the model is not necessary, but is a possibility. Gardner further asserted that there may be several varieties from the implicit to the explicit; the hard-wired to flexibly programmed.

Another key element is the computer. The computer serves two primary roles for the cognitive scientist. The first is that of a model of human thought. The second role is one of a tool for the analysis of data and simulation of cognitive processes (Gardner 1985).

A third key element involves such affective factors as the contribution of historical and cultural factors, and the role of the background context in which particular actions or thoughts occur. It is interesting to note here that Gardner posited that a fourth key element is that cognitive scientists harbor the faith that much can be gained from interdisciplinary studies.

Cognitive science is rooted in classical philosophical problems. Gardner stated, ". . .a key ingredient. . .is the agenda of issues, and the set of concerns, which have long exercised epistemologists. . .it is virtually unthinkable that cognitive science would exist. . .had there not been a philosophical tradition dating back to the time of the Greeks" (p. 7).

An additional feature of cognitive science is the conviction that cognitive processes occur over time, and that some take longer than others.

IV. Applications to Instruction

One of the areas of interest to technical educators is what insight cognitive science research can provide in terms of the connections between knowledge and performance. As perceived by cognitive scientists, the critical point is the link between knowing and doing, that is, how declarative knowledge relates to procedural knowledge; the ways in which the organization of knowledge in the learner's head affect performance; and the role of domain-specific knowledge (Raizen 1989).

In writing about situated cognition and learning culture, Brown, et al. (1989) referred to the break between learning and use. Brown, et al. posited that this break is a product of the structure and practices of our education system. Didactic education assumes a separation between knowing and doing, treating knowledge as an integral, self-sufficient substance, theoretically independent of the situations in which it is learned and used.

If the separation between formal acquisition of knowledge and experiential learning of performance is artificial as asserted by Brown, et al., as educators we can look to cognitive science research to identify and establish the connections between knowing and doing, and how they can be used to facilitate the acquisition of competence (Raizen 1989). Although cognitive research over the last twenty-five years has focused primarily on the individual learner, more recent research has been interested in the learner placed in the physical and social context (Raizen 1989). The research appears to be moving to a more interdisciplinary approach involving those cognitive scientists more oriented toward a cultural perspective and a behavioristic perspective.

Such terms as declarative knowledge, procedural knowledge, domain-specific knowledge, socially constructed knowledge, systems, physical and conceptual tools, the physical setting, and induction into the culture are all integral to the language of cognitive research into how the connection is made between knowledge and performance.

One can identify the information-processing model in the way many of these terms are defined. Lesgold, et al. (1986) addressed declarative knowledge and procedural knowledge. Declarative knowledge is knowing what and procedural knowledge is knowing how. It is thought that procedural knowledge evolves from declarative knowledge into automatic processes that "run" without conscious attention, comparable to compiled programs on a computer. The key appears to be the process by which people, both experts and novices, organize information. Eylon and Linn (1988) asserted that when problem solving, experts chunk substructures/patterns applicable to solutions, freeing working memory to address deeper structures of a problem linking salient information and organizing it around central principles. Once the information is organized, experts then select strategies and actions to address a problem, test the actions, and pursue the best. This activity involves structured, domain-specific knowledge, procedural knowledge, and general skills in planning and checking one's work. Novices, on the other hand, tend to respond to problems as they are presented, using routinized procedures for which they have rote algorithms. The difference is this, experts have made the connection between knowing what and knowing how. They are much more involved in cognitive monitoring than are novices. The question left is, how?

Glaser (1987) attempted to explain how expertise is developed by giving emphasis to organization of knowledge and its structure in an individual's head; the ability to represent the problem in depth rather than categorizing it by its surface features; knowing the conditions under which specialized knowledge is applicable and the problems for which it is useful; developing schemata for more advanced problem solving based on the acquisition of additional knowledge; acquiring automaticity in handling lower level component skills or subprocesses so as to free working memory for higher level tasks required by a problem; and facility in managing one's own learning and problem solving--planning ahead and using time well, checking solutions and monitoring one's performance, knowing what one knows and doesn't know.

Sticht, et al. (1987) asserted that the development of expertise is dependent upon domain-specific knowledge. In studying literacy training methods used in the military, Sticht, et al. concluded that

> Applying functional context principles to literacy training suggests that material written on a topic about which the student has developed some prior knowledge will be read and understood better. . . According to the human cognitive system model, reading comprehension in a given topic can be improved by increasing one's knowledge base in that area. By coupling this improvement in domain-specific knowledge with instruction in general strategies for reading-to-do and reading-to-learn, it is anticipated that students will develop more generally useful literacy skills and, hence, their overall employability will be improved. (pp. 5-11)

Cognitive scientists with an orientation toward sociology and anthropology have criticized past research because of the focus on individual mental activity in isolation from the social and physical context (Raizen 1989). Brown found that students needed more than abstract concepts and self-contained examples. Exposure to a domain's conceptual tools in authentic activity is important to avoiding student reliance on features of the classroom context, in which the task is now embedded and which are wholly absent from and alien to authentic activity.

According to Scribner (1984) skilled practical thinking incorporates features of the task environment (people, things, information) into the problem-solving system. Scribner emphasized the inextricability of task from environment, and the continual interplay between internal representations and operations and external reality throughout the course of an activity. The views of Scribner and Brown, et al. appear to have relevance to postsecondary technical educators. Technical college students are generally older with an average age ranging between 25 and 30 and come to the college with various experience and environmental contexts. Learning theory and instructional design which do not consider such contextual relationships put both the institution and the individual student at a disadvantage.

Raizen (1989) described two kinds of socially constructed knowledge: (1) Exchange of information between and among participants and (2) anecdotal information which deals with behavior within the context of a specific situation. Both create a community memory.

Orr (1988), in a paper addressing representation and embodied knowledge, concluded that community or social memory is crucially important to competent performance. Community memory can preserve the working set of current knowledge, the information about new and undocumented problems as well as critical information about related social labyrinths.

V. Physical and Conceptual Tools

Cognitive science research has shown that the use of the appropriate physical and conceptual tools is important to learning and making the connection between declarative knowledge and procedural knowledge. Suchman (1987) referred to this as situated action. Suchman maintained that what traditional behavioral sciences take to be cognitive phenomena have an essential relationship to a publicly available, collaboratively organized world of artifacts and actions. Further, particular, concrete circumstances are directly related to the significance of the phenomena conveyed. Scribner's research (1986) is congruent with that of Suchman. Scribner referred to practical thinking and problem solving as an intricate and dynamic system organized by worldly factors, subjective goals and knowledge that is simultaneously adaptive to ever-changing conditions in the world and to the purposes, values and knowledge of the person and the social group.

Conceptual tools are the algorithms and principles of a particular field of knowledge that are available for use as a situation requires (Brown et al., 1989). In terms of learning, Brown stated it is possible to learn a tool but be unable to use it. The same is true for conceptual tools. Brown found that students can manipulate learned algorithms, routines, and definitions with apparent competence, and yet not reveal, to their teachers or themselves, that they would have no idea what to do if they came upon a situation outside school that called for their application. Those who acquire and actively use a conceptual tool build an increasingly rich implicit understanding of the world in which they use the tools and of the tools themselves. The conclusion drawn was that learning and acting are indistinct, learning being a continuous, life-long process resulting from acting in situations.

The cultural context in which a tool, either physical or conceptual, is used shapes the use of the tool. The conclusion drawn by Brown, et al. (1989) was that learning how to use tools involves more than can be accounted for in any set of explicit rules.

> The occasions and conditions for use arise directly out of the context of activities of each community that uses the tool, framed by the way members of that community see the world. . .Conceptual tools . . .reflect the cumulative wisdom of the culture in which they are used and the insights and experience of the individuals. Their meaning is not invariant but a product of negotiation within the community. . .Activity, concept, and culture are interdependent. No one can be totally understood without the other two. Learning must involve all three. . .To learn to use tools as practitioners use them, a student, like an apprentice, must enter that community and its culture. Thus, in a significant way, learning is, we believe, a process of enculturation. (p. 33)

Raizen (1989) concluded that conceiving of occupations or professions as subcultures leads to yet another criticism of formal schooling. Schools cannot authentically model their subcultures for students. The end result is that since activities in a classroom become classroom tasks and a part of the school culture, the system of learning and using thereafter remains sealed within the self-confirming culture of the school. Success within this culture often has little bearing on performance outside the school (Brown, et al. 1989).

VI. Three Perspectives of Instruction

With all of this as background, I want to spend a little time on instruction. The NCRVE study looked at instruction from three perspectives--instruction as transportation of knowledge, instruction as application of algorithms, and instruction as transfer of responsibility. I will examine each perspective on the basis of content, instructional design, cognitive theory, educational aim, and ability to respond to social change. Instruction as transportation of knowledge focuses on the physical movement of the commodity of knowledge from one place to another. Instructional design is content focused. In terms of the application of cognitive theory, the teacher focuses on the configuration of oral, written, and graphic communications in order to enhance the transportation act.

This perspective's focus on knowledge storage and recall is not very responsive to rapidly changing societal conditions. It is too limited in a world which demands flexible knowledge and complex mental capabilities. In terms of educational aims, transportation of knowledge supports socialization of the mass culture.

Instruction as the application of algorithms focuses on control, standardization, efficiency, and predictability. It uses a guided, directed process which leads to the same results each time by each person utilizing the operation. This instructional perspective prescribes a system of operations and procedures for carrying out processes in order to achieve specified kinds of learning for specified kinds of learners. It is very reductionist in character. Cognitive theory is applied in this situation in developing understanding of thought processes and knowledge underlying desired performance.

Instruction as application of algorithms is not particularly responsive to rapid change and unpredictability. It has limited value in helping learners develop complex mental capacities because such capacities are not governed by specific rules. This perspective supports socialization.

Instruction as transfer of responsibility is rooted in apprenticeship, experiential learning, and inquiry learning. The learner is led to assume independent responsibility for learning. This responsibility involves identifying problems; making decisions about what to do, what will be done, and how it will be done; determining what is needed and where and how it will be obtained; monitoring one's own actions; and assessing the consequences of one's decisions and actions.

The role of instruction is to provide a structure that enables learners to engage in these activities beyond their present capacities to do so. Knowledge is constructed by individual learners using what they already know and have experienced and using the support systems developed and put into place by the teacher. Apprenticeship, simulations, and certain projects are examples of such support structures.

This instructional perspective features real-world contexts, learner directed activity, frequent interaction with a teacher, tailoring of activity to each learner's level by introducing the appropriate amount of challenge or assistance throughout the learning process.

The application of cognitive theory focuses on gaining a more explicit understanding of the nature of real-world problems and of how people deal cognitively with them. With this understanding it is possible for the teacher to create learning environments which reflect contextual aspects of real-world activities.

The transfer of responsibility perspective is supportive of rapidly changing and complex societal conditions since it supports the development of complex cognitive processes and the development of social capacities relevant to working with others.

This perspective supports the educational aims of individual and cultural development. It utilizes the present as a means of developing mental capacities that remain relevant when the present no longer exists.

VII. Conclusion

The field of cognitive science and the research associated with it offer much for technical educators to consider. As teachers we should view learning as being embedded in contexts that have physical, conceptual, and social aspects. Such contexts as the workplace, the family, the community, the school, the classroom all influence learning.

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