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DEFINING A LEARNING THEORY LINKED TO INSTRUCTIONAL THEORY

A Fusion of German and American Approaches

Klaus Breuer and I met in the fall of 1974. I was a new assistant professor at Florida State University and Klaus was a graduate student from Aachen visiting American universities that were doing research investigating the link between computers and human learning. From that initial meeting until the present time, Klaus Breuer and I have collaborated on numerous research projects and have published books, research articles, and book chapters dealing with the fusion of European and American psychology in the field of instructional design. This chapter presents our joint efforts in defining an instructional theory which has and is the basis of our joint activities over the years.

INTERACTIVE COGNITIVE MODEL

Klaus Breuer and I both felt that defining our theory of learning would help us in developing our research in the area of problem solving and decision making. We started with the premise that in defining a learning theory to provide the psychological foundation for instructional theory we did not what to follow the usual practice in the traditional behavioral psychology theory of relying on reductionist models that had little practicality for education. Likewise, cognitive learning research was following, until recently, the conventional sequential approach of science; that is, studying the parts (or components) while ignoring the complexities that emerge as a consequence of the interaction of the component parts of the overall mental system. With the growth of complexity theory in the sciences (e.g., physiological (Li & Xu, 1987); and clinical psychology (Chubb, 1990; Lonie, 1991; Moran, 1991); strategic thinking (Mann, 1992); decision making (Richards, 1990); systems theory (Stevens, 1991); and instructional design (Tennyson, 1997)) that attempt to capture complexity of dynamic phenomena as well as sequential, it seemed appropriate to consider, for instructional theory, learning theories that view nonsequential as an inherent characteristic of the dynamic nature of learning and thinking.

Early attempts to describe cognitive learning followed the classical scientific method of trying to formulate laws that could explain learning via sequential

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relationships. For example, the early information-processing models resembled computer system architecture with input/output boxes and arrows. It was quite easy to explain simple learning situations with such models but in situations with multiple dynamic conditions (e.g., time, anxiety, and environmental variables) it became increasingly difficult to predict learning outcomes. By the late 1990s, cognition had come to be viewed as a fluid-dynamic phenomenon that is adaptive to state situations (Steiner, 1997). Instead of a concrete sequential method of information processing, cognition self-adjusts, restructures, and constructs in highly unpredictable ways. The important concept in understanding cognition is that the many components (or subsystems) of the cognitive system flex and adapt in an infinite number of ways. Therefore, it is not possible to develop a sequential model to explain learning but rather we seek to define a structure that allows for learning and thinking to occur in a natural environment, taking into account experiences from the environment as well as the need to construct knowledge from existing knowledge in memory.

Rather than propose yet another cognitive learning model in the tradition of sequential models, we designed a model from a complexity theory perspective developed by Tennyson and Breuer (1997). That theory proposes an interactive cognitive model of learning and thinking (see Figure 1). The cognitive learning model provides an educational explanation for learning; the purpose of the model is to serve as a psychological foundation to instructional theory.

Model Guidelines

In preparing this interactive cognitive model, the guidelines employed by us were threefold. First, the model would have to address both the sequential and dynamic elements of cognition. Second, the model would have to deal with the interaction of content knowledge and cognitive strategies for higher order cognitive processes (e.g., problem solving, decision-making, troubleshooting, and creativity). And, third, the model would have to include affective elements as an integral component of the cognitive system.

The basic subsystems of the interactive cognitive model (Figure 1) include the following components; sensory receptors (sensory memory), executive control, affects, and knowledge base. The model also indicates two primary sources of information to the cognitive system: external and internal. External information enters the cognitive system through the standard sensory mechanisms whereas internal information is the result of the active interaction between the various subsystems and the executive control subsystem. External behavior is exhibited through the output of the sensory memory component.

Notice that the model does not represent a conventional information-processing model but rather a highly dynamic, interactive system that assumes constant integration of the various subsystems. Each of the components is now discussed in a sequential fashion, although this does not represent how the system operates.

Sensory Receptors Component

The sensory receptors component includes the various ways in which external information is entered into the cognitive system. Information is conveyed through the sensory component and is passively registered in sensory buffers in more or less complete analogical form. These sensory registers are sometimes referred to as primary sensory memory. The information in this register decays rapidly and is easily interrupted. Attention- and perception-driven processes in the executive control component determine what subset of this information is selected for further processing because far more information is registered than can be processed and stored.

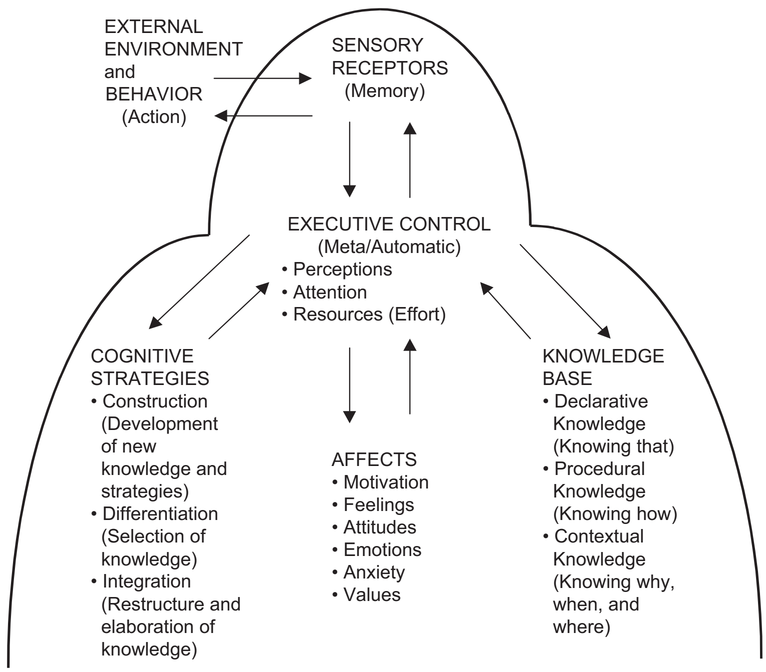

Figure 1. Interactive Cognitive Model.

Executive Control Component

Control of the cognitive system is usually referenced by some form of an executive processor. The executive control regulates the various components and cognitive abilities of the system in either active (i.e., meta-complexity; e.g., Streufert & Nogami, 1989; Suedfeld, 1992) or automatic (passive) means. Although cognitive theories differ on specific functions and their distribution in the complexity of the system, for the purposes of this section dealing with an educationally based learning theory, it is convenient to consider three primary executive functions; perception, attention, and resources. It should be noted that in sequential information-processing models, the label *short-term* or *working memory* is used to describe many of the functions of this component.

Information coming from either external or internal sources passes through the perception function, which performs the cognitive processes of being aware of and assessing the potential value of, the external and/or internal information. In this function, the perception process services the cognitive system for the purposes of both directing attention and determining effort (i.e., resources). The attention function maintains an active interaction with the other components by the internal processing cognitive abilities.

Resources assist in the coordination of the various components of the entire cognitive system. Of importance in this function is evaluation of the effort associated with a given situation. For example, in most situations, there is an abundance of resources available, so determination is made on allocation of necessary resources. The resources function includes the following four processes:

- *Encoding* processes that, in concert with the perception function, deposit incoming information into the knowledge base;
- *Storage* processes that interact with the knowledge base component to create permanent records and increase the strengths of existing records;
- *Retrieval* processes that interact with internal processing abilities to obtain necessary existing knowledge from the knowledge base (there seem to be at least two different types of retrieval processes: controlled [i.e., meta] processes that are deliberate, conscious efforts interacting with the knowledge base and affects components; and, automatic processes that are highly developed and efficient interfaces with the other components); and
- *Maintenance* processes that keep information in an active mode so that it is not lost before it is stored in the knowledge base.

In summary, the executive control component manages the internal behavior of the system in terms of interfacing the various system components' cognitive abilities based on multiple and complex possibilities. Additionally, the executive component controls the output of behaviors. Behavioral outputs can range from automatic to deliberate conscious activities.

Knowledge Base Component

The knowledge base is the repository for previously acquired information – either external or internal. There is agreement in the psychological field that the knowledge base has no capacity limits and that knowledge is considered permanent, although it may become difficult to retrieve in certain situations. The knowledge base consists of domains of knowledge that can be described as complex networks (or schemas) of information (e.g., concepts or propositions). Within a domain, knowledge is organized into meaningful modules called schemata. Schemata vary per individual according to amount, organization, and accessibility. Amount refers to the actual volume of knowledge coded in memory, whereas organization implies the structural connections and associations of that knowledge, and accessibility refers to the cognitive skills used in servicing the domains of knowledge.

Within the knowledge base there are various types of knowledge; declarative, procedural, and contextual (Tennyson & Rasch, 1988). Declarative knowledge implies awareness and a meaningfulness of content (e.g., concepts, rules, principles) and refers to the *knowing that*; for example, understanding the meaning of the four basic functions of mathematics. Procedural knowledge implies a *knowing how* to employ selected concepts, rules, and principles with newly encountered problems. Contextual knowledge implies an understanding of *knowing why, when, and where* to employ specific concepts, rules, and principles. This knowing of why, when, and where is governed by selection criteria embedded within the organization of the domain of knowledge. Selection criteria are integrated within the knowledge base because of the interaction with the affects component during the acquisition process. The term *contextual* implies direct association with cognitive skills that are defined as domain-dependent cognitive strategies. As such, contextual knowledge represents a more complete understanding of human behavior that is necessary for defining an educational learning theory.

Affects Component

Since the 1950s, with the division of the cognitive and affective domains (Bloom, Engleharee, Furst, Hill, & Krathwohl, 1956), learning theories and instructional theories have labored with the construct that even though these two domains are not separate they need to be presented as separate. (Note that this is an example of the reductionist method used in psychology.) Cognitive psychology continued this practice of separate domains for cognition and affective (as well as the psychomotor) well into the 1980s. Only recently have certain cognitive psychologists *discovered* that the affective domain may actually dominate the cognitive (i.e., many of the constructivist ideas promote this concept; e.g., Brown, Collins & Duguid, 1989, with situated cognition; Harré, 1984; Vygosky, 1978).

Klaus Breuer and I brought the affects component directly into the total cognitive system because of the clear need in instructional design to have a learning theory that implies that the affective domain is integral to the development of learning environments.

As stated above, cognitive theories differ in details but have much in common, and the same is true of the affective domain. Given the complexity of the affective domain and the limited scope of this discussion, we only address some of the more identifiable affective variables. Also, because of their interactive nature and variability, we are listing the various types of affect without reference to hierarchy or value (see Figure 1). The list includes such complex personality variables as motivation, feelings, attitudes, emotions, anxiety, and values. The immediate interaction of this component within the cognitive system is with the executive control component that interfaces with the knowledge base component. For example, motivation influences both attention and maintenance processes. On the other hand, values and feelings would influence the criteria associated with acquisition of contextual knowledge. Anxiety as an affect variable influences much of the internal processing abilities. Along with emotions, anxiety can be a serious interfering variable in the cognitive system.

The implication for instructional theory of the affect component is the need to consider this component as an integral part of the acquisition of knowledge. In educational practice, the continuing effort is to separate the affect from the cognitive. For example, this is seen in the development of separate courses on ethics in professional studies (e.g., law) and in the education field, topics in character education (e.g., courses on respect and violence). In summary, the affect component needs to be considered during the acquisition of knowledge and as part of domains of knowledge.

Cognitive Strategies Component

The cognitive strategies component, in contrast to the knowledge base component that is concerned with specific content of human thought and action, is primarily concerned with the structural process of cognition and its effect upon behavior. This component of the interactive cognitive complexity-learning model has served to explain and, in many cases, predict human cognition and behavior for more than 60 years. Early forms of cognitive complexity theory were based on developmental psychology (e.g., Lewin, 1936; Mead, 1934; Schachtel, 1959; Werner, 1957) and constructivist psychology (Bartlett, 1932). The growth of cognitive complexity approaches to learning theory increased with the advent of relevant measurement techniques (e.g., Asch's 1946 Impression Formation Task, the Role Concept Repertoire (REP) Test used by Bieri (1955) and Kelly (1955), the Sentence/Paragraph Completion Test of Harvey, Hunt and Schroder (1961) and the applications of multidimensional scaling employed by Breuer (1983) and Driver (1962)).

Initially, complexity theory considered only the availability and utilization of cognitive dimensions in human perception. Work by Bieri and associates (1966), for example, focused on the presence or absence of differentiated dimensions in interpersonal judgment. Harvey et al. (1961) proposed a model for the development of dimensionality and emphasized that higher levels of cognitive functioning must include the integration of differentiated dimensions. In addition to the two general cognitive abilities of differentiation and integration, contemporary science-wide complexity theorists offer a third type of cognitive ability when they refer to the growth of systems toward the *edge of chaos*, a level where optimal adaptive functioning is attained.

At the edge of chaos, systems are viewed as undergoing spontaneous self-organization. Indirect or direct learning takes place. Order and chaos are most often kept in balance. Regulation of the system orients it to feedback from the environment but allows enough freedom to assure that the system can be creatively adaptive, that is, open to change. Interconnections among systemic elements are sufficient in number to generate dynamic functioning, but generally not so excessive that chaos would be generated.

Extending the early work from cognitive complexity with current concepts from chaos theory, Tennyson and Breuer proposed that the cognitive strategies component includes three primary cognitive abilities; differentiation, integration, and construction. Differentiation is defined as the twofold ability to understand a given situation and to apply appropriate contextual criteria (i.e., the standards, situational appropriateness, and/or values) by which to retrieve specific knowledge selectively from the knowledge base. Integration is the ability to elaborate or restructure existing knowledge in the service of previously unencountered problem situations. Construction is the ability both to discover and to create new knowledge in novel or unique situations.

CONCLUSION

The scholarly work that Klaus Breuer and I have collaborated on for 40 some years has lead to a fusion of European and American efforts to improve learning through the employment of learning theories and technology. This collaboration has resulted in peer reviewed publications and presentations at international conferences. Additionally, our work resulted in collaborative efforts with colleagues not only in Germany and the US, but also with scientists throughout the world from North America to Asia and most European countries. From that first meeting in Tallahassee, Florida, Klaus Breuer and I have developed through our respective graduate students a truly international network of scholars focusing on the fusion of human cognition and technology.

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