The Journal of Mind and Behavior
Winter and Spring 2000, Volume 21, Numbers 1 and 2
Pages 205–212
ISSN 0271–0137
ISBN 0–930195–11–6

Knowledge Acquisition and Education

Merlin C. Wittrock
University of California, Los Angeles

Since antiquity, theories of knowledge have had fundamental impacts on understanding the design of the conditions of learning and teaching. As represented in this special issue, these theories may be divided into structural, functional, and biofunctional. Structural models have contributed to knowledge about the organization of information stored in memory. Functional models have contributed to our understanding of how learning occurs and how it can be facilitated. Functional and biofunctional approaches have much in common but differ in their assumptions about the nature of the role of biology in learning. All three types of theories complement one another. This paper focuses on the potential contributions of functional models, including the biofunctional model, to the design of the conditions of learning and teaching.

As we look back at the past two millennia and beyond, it is difficult not to be overwhelmed with the pervasive impact of theories of knowledge on our thinking. In the following paragraphs, I want to explore some of the contributions of these theories to learning and teaching, with a focus on the contemporary approaches portrayed in this volume. One major point that emerges from this discussion is that although structural schema theories have provided much useful information throughout history about the organization and the storage of information, the functional models of this century lead more productively to our understanding of learning and educational practice. More specifically, the conditions that foster teaching and learning can be built readily upon the foundation of the research and theory emanating from the functional models of learning and comprehension. Among these models, the biofunctional approach offers the most potential for solving the problem of relevance in education (Iran-Nejad, Hidi, and Wittrock, 1992).

Requests for reprints should be sent to Merlin C. Wittrock, Ph.D., Graduate School of Education, University of California, Los Angeles, California 90095.

Bartlett (1935) contrasted his functional theory with structural theories stating that for him "the problems fall into two main groups. First, how are the schemes, the organised patterns of psychological and physiological material formed? . . . Second, what are the conditions and laws of construction in the mental life? . . . These are the urgent psychological problems, not outside the experimentalist's scope" (p. 225; cited in Iran-Nejad and Winsler, 2000, this issue). Because Bartlett's theory was about the conditions of schema formation and the laws of knowledge construction, it lends itself directly and naturally to addressing the problems of learning and teaching.

Learning in Structural Theories

There is one kind of learning for which structural theories are well suited: learning as internalizing and storing connections or associations among knowledge elements for the purpose of reproduction. *The Art of Memory*, as described in detail by Frances Yates (1966), is the most representative example of this type of learning, with an extraordinary impact for over two thousand years upon our conceptions of learning and remembering, and upon our beliefs about teaching in and out of schools. *The Art of Memory* consists of two halves. The first half — developed by Simonides in Greece (ca. 556–448 B.C.), described in Cicero's *De Oratore*, Quintilian's *Institutio Oratoria*, and the anonymously authored *Rhetorica ad Herennium* — presented a system for orators, teachers, statesmen, legislators, lawyers, and other public speakers to use to learn and to remember the information they wished to present. These public speakers were taught to remember ordered information by (1) selecting a set of ordered and familiar loci, such as the clockwise order of the pieces of furniture in the rooms of their homes, and (2) forming an interactive image between each idea or concept to be learned in the series and the next piece of furniture in the clockwise order of the loci.

The second half of *The Art of Memory* was Aristotle's (n.d./1964) model of memory and recollection. In this model, information is stored as images, and retrieved in the order in which it was learned by replaying the associations between the stored images and the stimuli. According to Aristotle, "*It is impossible even to think without a mental picture*" (p. 291). Or "*Thus we have explained a) what memory or remembering is; that it is a state induced by a mental image related as a likeness to that of which it is an image*" (p. 299). Order and associations were Aristotle's two principles of recollection, and similarity, contrast, and contiguity were his three principles of association. Together these principles comprised his imagery-based model for remembering and retrieving information.

Aristotle's model of memory and retrieval and Simonides' teaching system were regularly taught as part of Greek and Roman higher education, which placed strong emphasis on oratory. In medieval times these same ideas were taught to monks. In both ancient and medieval times, according to the historian Frances Yates, this art of memory led to the use of imagery to instantiate abstract concepts (such as good and bad, reward and punishment) or to help design buildings, cathedrals, paintings, mosaics, friezes, and murals that were, in turn, used to teach millions of people, many of whom illiterate, the central ideas of the cultures. These same systems and principles live today in our schools that use imagery-based mnemonic systems and in associationistic models of memory and learning.

It is easy to appreciate the structural and functional elements involved in the ancient *Art of Memory*. Images comprised the raw material of memory. Knowledge was regarded as associations among images. To learn information, that is to store it in memory, the learners generated interactive images, using their previous sequentially-ordered knowledge, and using their ability to form memorable images. To retrieve information learners started at any locus in the organized structural system, and worked backward or forward, as they wished, to recall information in different ways.

Current structural schema theories have much in common with Aristotle's theory and have made major contributions to knowledge about the organization of memory and the forms of information stored in memory (Iran-Nejad and Homaifar, 2000, this issue; Iran-Nejad and Winsler, 2000, this issue). Atkinson and Shiffrin (1968) presented an information-processing model that included a sensory-register, a short-term memory, and a long-term memory. This model evolved into a standard textbook conception of how memory is organized. Other standard textbook conceptions from structural schema models include the notion that declarative knowledge is represented by propositions, and procedural knowledge is represented by productions (Gagne, 1985, p. 48).

The structural role of schemas in memory (Rumelhart, 1980) is now conventionally used as an exemplary device for understanding how reading comprehension occurs. The concept of a structural schema has been elaborated to include frames in programs, nodes in associative networks, story grammars in narrative text, and scripts in common, everyday activities. More recently, connectionism, another creation of structural schema theorists, elaborates on the organization of information in memory by suggesting that knowledge is represented as connection weight patterns among network elements. Connectionism presents a subconceptual, but not a neural, associationistic model of memory, with nodes and connections that can represent multiple concepts.

Their limitations notwithstanding, structural theories have made impressive contributions to our understanding of how information might be organized in long-term memory. However, these structural models leave many questions unanswered. How does a learner acquire knowledge? By slotting it into already existing schemata, seems to be the answer. But how are the schemata learned, and how is information slotted into them? How would you teach reading comprehension, or even a story grammar, by a structural schema model? The answer seems to be by teaching background knowledge, rather than by teaching the learners to understand the text by building relations between what they know and the text they are reading. That is not a most helpful answer. Even if it were, it would lead to the next question "How do you teach background knowledge?" Connectionism approaches training through the shifting of connection weights, and through simulation techniques that involve the matching of input and output demands. Connectionism does not seem to be ready to tackle the everyday problems of teaching.

We must not ignore the contributions of structural schema theories to our understanding of the organization of information in memory. However, the contributions of these theories to our understanding of how people learn this organized information, understand it, and use it are not impressive. Neither do structural models offer us many useful conceptions of how to teach knowledge in understandable, interesting, memorable, and useful ways to millions of learners in schools.

Functional Theories

Functional models focus on how mental processes, or even on how brain processes function in learning, thinking, behaving, and surviving. The structural organization of memory stores is not of primary interest. Neither is knowledge seen as an autonomous product existing separately from the functioning of the nervous system (see Iran-Nejad, Hidi, and Wittrock, 1992). Functionalists ask how people learn, how they acquire and apply knowledge, how they think, feel, behave, and survive. They study the processes people use to perform these functions, including attention, motivation, interest, comprehension, and metacognition. Functionalists also study the conditions that foster the use of these processes.

There are important differences among various functional theories. In addition to Frederic Bartlett's (1932) early model of remembering, the functional perspective encompasses Iran-Nejad's biofunctional model (2000, this issue; Iran-Nejad, Marsh, and Clements, 1992). Other theories to be included are Luria's (1973) functional model of brain processes and Wittrock's (1974, 1990, 1991, 1992) model of generative learning. As exemplified below, these and related models present unique and useful lenses for viewing the kind of learning that occurs in educational settings.

In this special issue, Iran-Nejad and Winsler examine Bartlett's model of remembering. They show that his model is a functional one, although it has been sometimes interpreted as a structural model. Bartlett's functional model of remembering has potential for influencing current functional research on memory. It seems that the time has come to explore Bartlett's contributions in a new light, as discussed by Iran-Nejad and Winsler.

In several places (Iran-Nejad and Homaifar, 2000, this issue; Iran-Nejad, Marsh, and Clements, 1992; Iran-Nejad and Ortony, 1984), Iran-Nejad describes his biofunctional model of psychological functioning. The model posits two qualitatively different kinds of nervous system activity: (1) ongoing brain subsystems working in concert (OBA), and (2) momentary firing of microsystem constellations (MCF). The ongoing brain subsystems mediate holistic learning that leads to thematic knowledge. The momentary firing of microsystem constellations mediates focused learning that leads to fuzzy categorical knowledge. In this system, both kinds of knowledge are active. Neither of them involves any static memory store.

Both these systems serve to create figure–ground relations. Ongoing brain subsystems create stable figure–ground relations, while MCF creates a changing sequence of figure–ground relations. Figure–ground relations are central to learning with understanding, to building models that have survival value, and to constructing meaningful relations in subjects taught in school, including reading, mathematics, and science. Because of its focus on holistic processes, the model has another useful educational application: much of the learning in school involves holistic processes and thematic knowledge that cannot be analyzed into components or parts and that cannot be taught in a piecemeal fashion, as is often done today.

The biofunctional model focuses on how the nervous system functions to create and uphold the mind. In contrast to structural models, this model presents learning and knowledge acquisition as a dynamic process in which the minds of learners enable learners to interact with the components of their own nervous system to construct meanings and generate solutions to problems that refine models of survival useful for making intelligent predictions and for making intelligent choices to guide future behavior. In this model, knowledge is defined as intuitive self-awareness that serves as the vehicle for individuals to interact directly with the components of their own nervous system and indirectly, by means of conventional language, with other individuals in the society.

Other Related Functional Theories

There are other functional theories that have not been discussed in any detail in this volume (see, however, Iran-Nejad, Wittrock, and Hidi, 1992). In a book on the human brain, Alexander Luria (1973) presents his functional model of brain processes. He outlines three functional systems of the brain (1) the unit for arousal and attention, (2) the unit for receiving, analyzing, and storing information, and (3) the unit for planning, organizing, and regulating cognition and behavior. Luria's model serves to organize much of the recent research on brain functions in education.

In its many varieties, attention (e.g., selective attention) has been extensively studied in educational psychology. The evoked-potential technique (EP) and the event-related potential method (EPR) have shown that poor readers, compared with normal readers, manifest a lower brain-response at 200 msec. latency, but no lower than normal response at 300 msec. or longer latencies (Languis and Wittrock, 1986). At the 200 msec. latency, a response measures attention to external or exogenous stimuli. At longer latencies, 300 msec., the brain-wave indexes internal or endogenous stimuli, reading ability, rather than attention. That is, attention appears to be a process separate from comprehension and vocabulary. Attention has also proved to be a productive area of study in learning disorders, especially in what used to be called hyperactivity, which is today explained in large part as an attention disorder.

The neural research on the analysis and synthesis of information has produced knowledge about the processes of the brain used to integrate and to understand information. Analytic–holistic processes, propositional–appositional processes, and verbal–spatial processes have been studied and written about extensively (e.g., Wittrock et al., 1977). Luria's model of simultaneous–successive strategies has recently become the base for a test of cognitive functioning. Also, the research on metacontrol and metacognition has also had extensive influence on school learning, self-control, and learning disorders. This research meshes well with the related research from cognitive psychology on attention and comprehension.

The model of generative learning (Wittrock, 1974, 1990, 1991, 1992) is a functional model of learning with understanding that builds upon neural and cognitive research. The model consists of the following factors (1) attention, (2) motivation, (3) knowledge, (4) generation, and (5) metacognition. The central process studied in Wittrock's research is how to stimulate the learners to construct meaning by teaching them actively to generate relations (1) between knowledge, experience, and the information to be learned, and (2) among the parts of the information to be learned. In a long list of classroom experiments spanning over twenty years in reading, science, and mathematics learning, with individual random assignment of students to experimental and control treatments, and with time to learn held constant across the treatments, the generative learning treatments, compared with the control treatments, regularly increase learning about fifty percent. Sometimes the increase in learning in the generative treatments is one hundred percent. Occasionally the increase might be as low as twenty-five percent. But the increment occurs regularly in elementary schools, in middle schools, and in high schools, and with functionally illiterate young adults.

Summary

Functional models of learning and of knowledge acquisition, including the biofunctional model, provide a unique perspective and a productive approach to the study of learning in schools. Because they focus on the conditions of learning, and on the processes learners use to generate meaning and to learn with understanding, these models are highly relevant to research on the practical problems of instruction and teaching.

The Art of Memory contained structural elements, and some functional elements, that contributed to its power as a model. Among its functional elements were the conditions that fostered learning through the use of imagery and pictures. To this extent, *The Art of Memory* approach facilitated understanding of fundamentally important concepts in ancient and medieval times, in addition to its practical contribution to teaching orators to generate their speeches without notes or other memory aids. For these reasons, the approach has made a venerable contribution to the education of millions of people. However, it is time for us to explore the contributions that contemporary functional models of learning and knowledge acquisition, including the biofunctional model, can make to the understanding and to the design of the conditions of learning and teaching.

References

Aristotle. (n.d./1964). On memory and recollection. In W.S. Hett [Ed. and Trans.], *On the soul, Parva naturalia, On breath* (pp. 287–313). Cambridge, Massachusetts: Harvard University Press.

Atkinson, R.C., and Shiffrin, R.M. (1968). Human memory: A proposed system and its control processes. In K. W. Spence and T.J. Spence (Eds.), *The psychology of learning and motivation* (Volume 2, pp. 89–195). New York: Academic Press.

Bartlett, F.C. (1932). *Remembering: A study in experimental and social psychology*. Cambridge: Cambridge University Press.

Bartlett, F.C. (1935). Remembering. *Scientia, 52*, 221–226.

Gagne, E.D. (1985). *The psychology of school learning*. Boston: Little, Brown and Company.

Iran-Nejad, A. (2000). Knowledge, self-regulation, and the brain–mind of reflection. *The Journal of Mind and Behavior, 21*, 67–88.

Iran-Nejad, A., Hidi, S., and Wittrock, M.C. (1992). Reconceptualizing relevance in education from a biological perspective. *Educational Psychologist, 27*, 407–414.

Iran-Nejad, A., and Homaifar, A. (2000). The nature of distributed learning and remembering. *The Journal of Mind and Behavior, 21*, 153–184.

Iran-Nejad, A., Marsh, G.E., and Clements, A.D. (1992). The figure and the ground of constructive brain functioning: Beyond explicit memory processes. *Educational Psychologist, 27*, 473–492.

Iran-Nejad, A., and Ortony, A. (1984). A biofunctional model of distributed metal content, mental structures, awareness, and attention. *The Journal of Mind and Behavior, 5*, 171–210.

Iran-Nejad, A., and Winsler, A. (2000). Bartlett's schema theory and modern accounts of learning and remembering. *The Journal of Mind and Behavior, 21*, 5–36.
Iran-Nejad, A., Wittrock, M.C., and Hidi, S. [Guest Editors]. (1992). Special issue: Brain and education. *Educational Psychologist, 27*, whole issue.
Languis, M.L., and Wittrock, M.C. (1986). Integrating neuropsychological and cognitive research: A perspective for bridging brain–behavior relationships. In J.E. Obrzut and G.W. Hynd (Eds.), *Child neuropsychology* (Volume 1, pp. 209–239). New York: Academic Press.
Luria, A.R. (1973). *The working brain: An introduction to neuropsychology*. New York: Basic Books.
Rumelhart, D. (1980). Schemata: The building blocks of cognition. In R. Spiro, B. Bruce, and W. Brewer, (Eds.). *Theoretical issues in reading comprehension* (pp. 33–58). Hillsdale, New Jersey: Lawrence Erlbaum Associates.
Wittrock, M.C. (1974). Learning as a generative process. *Educational Psychologist, 11*, 87–95.
Wittrock, M.C. (1980). Learning and the brain. In M.C. Wittrock (Ed.), *The brain and psychology* (pp. 371–403). New York: Academic Press.
Wittrock, M.C. (1990). Generative processes of comprehension. *Educational Psychologist, 24*, 345–376.
Wittrock, M.C. (1991). Generative teaching of comprehension. *Elementary School Journal*, 9, 167–182.
Wittrock, M.C. (1992). Generative learning processes of the brain. *Educational Psychologist , 27*, 531–541.
Wittrock, M.C., Beatty, J., Bogen, J.E., Gazzaniga, M.S., Jerison, H.J., Krashen, S.D., Nebes, R.D., and Teyler, T.J. (1977). *The human brain*. Englewood Cliffs, New Jersey: Prentice–Hall.
Yates, F. (1966). *The art of memory*. London: Routledge and Kegan Paul.