

Cognitive Theories and the Design of E-Learning Environments

Bijan B. Gillani

California State University, Hayward, USA

INTRODUCTION

The explosive growth of the Internet and the dramatic advances in the design and development of online technological tools in recent years have revolutionized the way students and teachers view technology in education. These technical advances have made it possible to produce educational materials and transmit them over the Web. Parallel to these technological advances, the field of instructional design has made phenomenal contributions to curriculum planning. A synergy of these two fields would enable educators to produce effective electronic educational materials.

Unfortunately, a great majority of e-learning sites that use online tools lack appropriate theoretical foundations for curriculum content organization. These sites, all designed by highly intelligent and well-intentioned educators, use online technologies without any regard for application of pedagogy to the design of courses. The result is an iceberg-like curriculum where, at best, online technologies have been used to cover the tip of teaching and learning, leaving little time and effort for the students to delve into deeper understanding of curriculum and problem solving. There is a fundamental need for pedagogical approaches to design e-learning environments whose foundations are supported by effective theoretical foundations.

One of the most effective approaches to developing appropriate pedagogical models for the design of e-learning is to understand how cognitive development occurs naturally. Cognitive developmental theories attempt to explain cognitive activities that contribute to the learners' intellectual development and their capacity to solve problems. Once we understand how cognition develops, we can derive a pedagogical model from it and then design effective e-learning environments that are responsive to how people learn naturally. In what follows, I will discuss Piaget's cognitive theory and derive an inquiry-training model from it. Then I will discuss the design of an e-learning environment that is based on Piaget's model and is adaptive to the cognitive needs of students.

PIAGET'S COGNITIVE DEVELOPMENTAL THEORY

Piaget (1952) argued that children must continually reconstruct their own knowledge through a process of active reflection upon objects and events until they eventually achieve an adult perspective. To have a better appreciation of this process, it is essential to understand four other concepts that Piaget proposed. These concepts are schema, assimilation, accommodation, and equilibrium.

Schema

Piaget (1952) used the word schema to represent a mental structure that adapts to environmental patterns. In other words, schemata are intellectual structures, in terms of "neuron assemblies," that organize perceived events and group them according to common patterns. Pearson and Sapiro in the May 1982 issue of *Instructor* have provided one of the earliest and probably the best explanations of schema theory for instructional purposes:

What is a schema? It's the little picture or associations you conjure up in your mind when you hear or read a word or a sentence. You can have a schema for objects (chair, boat, and fan), an abstract idea of feeling (love, hate, hope), an action (dancing and buying), or an event (election, garage sale, and concert). It's like a concept but broader. For example, you see the word tree and you conjure up the concept of a tree-trunk, branches, leaves, and so on. Your schema for a tree includes all this, plus anything else you associate with trees—walks down country lanes, Christmas trees, birds' nests, and so on. A schema includes behavioral sequences, too. For example, your schema for the word party could include not only food, friends, and music, but also what you will wear, how you will get there, how long you plan to stay, and so on. And, of course, your schema for party is based on your experience at party, which may differ substantially from someone else's. Schema is an abstraction of experience that you are constantly fine-tuning and restructuring

according to new information you receive. In other words, the more parties you attend the more schema adjustment you'll make. (p. 46)

Schema is not limited to concepts, objects, data, and their relationships. There are also procedural schemata (Anderson & Pearson, 1984), which are the ways of processing information. For example, students who have acquired the basics of mathematics, such as adding, multiplying, dividing, and subtracting, have internalized the concept schemata about these mathematical operations. However, as the students grow, they gain new abilities to solve problems that are related to mathematical concepts. The ability to solve problems is a procedural schema. Both concept and procedural schemata are constantly restructured as new learning environments are introduced to the learner.

Assimilation, Accommodation, and Equilibrium

One of the most fundamental questions about schemata is how are they restructured when new data or patterns are discovered in the environment? Piaget was a biologist by academic training. He was very comfortable with the concept of biological adaptation to environmental stimuli. For example, from a biological point of view, the human body is structured to be constantly in a state of equilibrium in regard to its temperature. When the body temperature is raised by a few degrees during exercise, the entire system goes into a state of disequilibrium. The feedback mechanism senses such a state of disequilibrium and internally responds by producing sweat and sending more blood near the skin to cool the body down, thus, restoring a state of equilibrium for the body.

Piaget used the same concept of biological equilibrium-disequilibrium states to explain the causes of cognitive restructuring in response to new learning experiences. For example, when students encounter a new learning environment, a state of disequilibrium is created within their brains that must be internally managed. In other words, the new learning environment has placed the brain in a state of disequilibrium. In order for the brain to get back to the state of equilibrium, the learner has to add, modify, or restructure his or her schemata to account for the new situation. The internal mental mechanism or processes that are responsible for the restructuring of schemata so that the brain can get back to an equilibrium state is called assimilation and accommodation (Piaget, 1952, 1964).

Assimilation is the cognitive process by means of which people integrate new patterns, data, or processes into their existing schemata. Piaget argued that, as learners assimilate input from the environment, the new

information is not simply stored in the mind like information in files in a filing cabinet. Rather new information is integrated and interrelated with the knowledge structure that already exists in the mind of the person. "Every schema is coordinated with other schemata and itself constitutes a totality with differentiation parts" (Piaget, 1952, p. 7).

For example, in teaching geometry, when a pentagon is introduced to children, the salient features of this geometric shape such as sides and angles are not simply memorized. Rather, it is contrasted and integrated with what is already known about other geometric shapes like rectangles, triangles and squares. In other words, the schemata for a pentagon includes, in addition to its shape, sides, and angles, such related concepts as how its shape compares with other geometric shapes, how its angles compare with other geometric shapes, or how its area and perimeter differ from other geometric shapes. Learning in this manner of relating prior knowledge to new information is said to be meaningful because new schemata in the child's mental capacity have been formed.

Theoretically, assimilation does not result in changes or restructuring of the schemata. Rather assimilation is the process of placing new information into existing schemata. Assimilation can be compared to the air that you put into a balloon. As you put more air in the balloon, it gets bigger, but the shape of the balloon does not change. The actual change or restructuring of the schemata occurs in the accommodation process.

The change that occurs in the mental structure of schemata is referred to as accommodation by Piaget (1952). Upon facing new learning environments, sometimes the learner's schemata can not assimilate the new information because the patterns of the new stimuli do not approximate the structure of the existing schemata. In such cases, one of two things can happen: The learner can create either new schemata or modify the existing schemata. In either case, the structure of schemata is being changed so that it can accommodate new information. Therefore, accommodation is the creation of new schemata or modification of old schemata. In both of these cases, the result is a change in the cognitive structure or the overall structure of schemata.

The process of cognitive development is the result of a series of related assimilations and accommodations. Conceptually, cognitive development and growth proceeds in this fashion at all levels of development from birth to adulthood (Piaget, 1964). However, because of biological maturation, major and distinctive cognitive development occurs over a lifetime. Piaget (1964) posited four major stages of cognitive development that occur over a lifetime. These stages are sequential and successive. According to Piaget, these stages are Sensorimotor (birth to two years old), Pre-Operational (2 to 7 years

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