where the use of computer technology can improve feedback both to the students and to the teacher in a large lecture setting.

#### Feedback and Instructional Design

There has been considerable research on feedback and learning. B. F. Skinner is well known for his behaviorist work in operant conditioning (stimulus, response, and immediate feedback) as a form of teaching. In more recent times, cognitive learning theories have proven more appropriate to the design of curriculum for use in precollege and higher education.

As Steven McGriff (n.d.) explains:

Under cognitive learning theory, it is believed that learning occurs when a learner processes information. The input, processing, storage, and retrieval of information are the processes that are at the heart of learning. The instructor remains the manager of the information-input process; but the learner is more active in planning and carrying out his/her own learning than in the behaviorist environment. *Instruction is not simply something that is done to a learner but rather involves the learner and empowers their internal mental processes*. [Italics added for emphasis]

A commonly used instructional process is to have students interact with each other in small, cooperative learning and discussion groups. Such small-group interactions facilitate student engagement and let students provide feedback to each other. Such collaborative learning can go on in a classroom setting, but it can also go on in ICT-mediated communication.

# **Distance Learning**

Here is a tidbit of history on distance learning (often referred to as distance education) from McIsaac and Gunawardena (1996):

Distance Education is not a new concept. In the late 1800s, at the University of Chicago, the first major correspondence program in the United States was established in which the teacher and learner were at different locations. Before that time, particularly in pre-industrial Europe, education had been available primarily to males in higher levels of society. The most effective form of instruction in those days was to bring students together in one place and one time to learn from one of the masters. That form of traditional educational remains the model today.

Actually, distance education has existed since the time of the first available written materials. A book is an excellent vehicle for teaching and learning. The book's author and the learner can be separated in terms of time and distance. The reader plays a major role in providing the feedback needed in learning from a book.

### Learning by Reading

In U.S. elementary schools, there is a commonly accepted goal of having students learn to read well enough by the end of the third grade so that they can begin to learn by reading. By about the sixth or seventh grade, the assumption is that students will gain a substantial portion of their education by reading. However, students vary widely in how well they can learn through reading. This is an especially important issue in higher education, where the assumption is that students can and will do the required reading and will learn through this process. This is often a mistaken assumption.

In the past year or so, I have read quite a bit of research literature on students learning through reading. It turns out that there is a significant difference between being able to read and being able to read well enough so that one can readily learn by reading. This is particularly true

in material that requires careful attention to details and that focuses on higher-order cognition. There is a huge difference between reading a math or physics book and reading a novel.

This situation provides an excellent example of when where you should be taking increased responsibility for your learning. How good are you at reading? Are you comprehension levels and speed of reading in various disciplines appropriate to your needs? If not, what are you doing about it? There are many free sources of help on the Web, and most colleges and universities have student learning centers that can provide free help.

### Improving Feedback in DL

Correspondence courses (making use of surface or air mail) have a relatively slow rate of interaction between a student and the teacher. However, they do force students into a learn-by-reading mode. Moreover, the nature of the feedback available through correspondence with an instructor places increased emphasis on students learning to provide feedback to themselves.

Of course, it is possible to design written materials specifically to aid students in their learning processes. Historically, distance education became more formal when print materials were developed that contained detailed lessons and assignments to be completed. Feedback might come from an answer key or through asking students questions that required higher-order thinking processes to formulate written answers to be mailed to an instructor.

The development of the telephone and two-way radio added a new dimension to DL because the teacher and student could converse with each other from time to time. DL delivery via television, perhaps with the aid of a telephone connection to individual students or a room full of students, led to a significant increase in its use.

The nature and quality of feedback available through a well-designed DL course can equal or exceed that which is available to students in a traditional large- or medium-sized lecture course. However, many of the types of feedback that can go on in a classroom setting are different from the types of feedback that are possible in a DL course. Thus, when students first encounter DL courses, they face the added challenge of learning to accept and use the types of feedback that are available through DL.

This observation is an underlying source of weakness in much of the DL research. Students spend many years learning to learn in a teacher-led classroom environment. The students then take a DL course, and their learning is compared to the learning of students in the traditional classroom. I find it somewhat surprising that even without the years of experience in DL, the typical result in such studies is that there is no significant difference between the amount of learning that takes place in the two types of courses. Thomas Russell (n.d.) has developed a Website devoted to this "no significant difference" phenomenon. It is a good source of research literature on the topic.

## Asynchronous and Synchronous DL

Correspondence courses are asynchronous—students work on a time schedule that fits their own needs and they work independently of each other. This situation changed when radio broadcasts and, later, TV broadcasts became a common component of DL. The student had to listen to the radio or view the TV when the broadcast was occurring. This synchronous instruction was combined with asynchronous work on assignments, which were mailed to the instructor. Of course, as tape recorders and inexpensive VCRs became available, tapes could be mailed to the student or the student could record a program for later use. Thus, the use of radio and TV delivery was easily converted to allow for asynchronous DL.

In formal school settings, it became relatively common to have students who were taking a TV-delivered course to meet in classrooms that had a telephone connection to the instructor. A few students could ask questions during the time of a lecture or demonstration. This is not unlike the "call in" radio and TV programs that are now quite common.

Now it is common to use two-way video so that a DL instructor can see and talk to students located at a distance, and vice versa. This type of synchronous instruction is somewhat classroom-like, but a teacher may be simultaneously working with several groups of students from different locations.

Initially, this type of two-way video connectivity was relatively expensive. As Internet II and other high-speed networks have become more common, the cost of connectivity in this type of synchronous DL has decreased substantially.

As email became available, asynchronous email-based distance education courses were developed. The email made it easier and quicker for students to interact with the instructor and each other.

More recently, Internet chat groups and Web-based two-way video have significantly changed distance education. While the postal services throughout the world are still used for some DL, the Internet has greatly expanded the use of DL.

Finally, we come to the current situation. The Web can be used to hold ordinary telephone conversations and conduct video interactions. Thus, the Web can be used to deliver synchronous DL. Of course, the Web can also be used to deliver asynchronous DL, with students having access to multimedia course materials at a time that fits their convenience.

The use of asynchronous and synchronous DL is steadily increasing. One can get a high school education, college education, and even a master's and doctorate degrees through accredited DL programs.

Learning in a DL environment is different from learning in traditional school classrooms, where one has daily face-to-face communication with fellow students and the teacher, and the class as a whole follows the same time schedule. Skill in learning via DL is now considered a valuable lifelong skill. Some people are now recommending that all students should take part of their precollege education and college education via DL so that they will gain the knowledge and skills needed to learn in this environment. I am one of the people making this recommendation to students.

## **Computer-Assisted Learning**

Think about the various roles played by faculty members and students, and their interactions in the overall teaching and learning process. Then think about what aspects of these roles and interactions can be aided or facilitated by computer technology. Whatever you can think of probably is part of the fields of computer-assisted learning (CAL) and DL.

#### Use of Simulations—Early and Continuing Success

People have been thinking about CAL since the early days of the development of the electronic digital computer. A major initial success occurred as the U.S. developed and deployed radar systems that were designed to detect airplanes and missiles in route to the U.S. from the U.S.S.R. The whole radar system was highly computerized. Operators sat at computer display screens that provided information about what the radar systems were detecting and what computer analysis of these signals was showing.

From the point of view of an operator, it is not possible to determine from current radar readings being processed through computers whether the displayed information is live or simulated. The simulated displays could be from stored radar readings or could be simulations created specifically to help train the operators.

This type of very highly realistic CAL works very well. There is now a long history of the use of simulation-based CAL in training airplane pilots, astronauts, tank crews, nuclear reactor operators, and so on. Generally, use of such simulations is more effective, more cost effective, and less dangerous than other applicable forms of instruction. There is quite a bit of simulation-type CAL available commercially (Laser Professor, n.d.).

### Less Expensive CAL

As computers became less expensive, many people developed and tested a wide variety of forms of CAL. It is quite easy, for example, to develop a drill-and-practice system that is better than just using flash cards that have a question on one side and an answer on the other side. A computer system can keep detailed data on correct and incorrect responses and the speed of the various responses. It can detect patterns of errors. It can stop the drill-and-practice activity and insert specific instructions on a topic that is causing the student trouble. It can increase or decrease the difficulty of the questions.

More sophisticated CAL systems—often called tutorial systems—can present instruction interspersed with questions. The student responses provide information that shapes the instruction. Tutorial CAL systems are a little bit like having an individual human tutor.

An individual human tutor has good knowledge of both content and pedagogy. The human tutor builds a mental model of the student's knowledge and skills. The human-based tutoring instruction fits constructivist learning theory and includes immediate feedback. Wouldn't it be nice if every student could have a personal tutor who was competent in each subject area of interest to the student and available on a round-the-clock basis?

It is easy to understand why so many people have thought about CAL as a vehicle to revolutionize education. Over the years, thousands of CAL systems were developed and many hundreds of research projects were carried out on these products. Eventually people began to do metastudies—studies of the studies. Finally, enough metastudies had been done so that it was feasible to do a meta-metastudy. The first meta-metastudy of CAL, conducted by James Kulik (1994), provided strong evidence of the effectiveness of CAL, with students (on average) learning via CAL 30 percent faster and somewhat better than students in control groups.

Here are four major barriers to the widespread use of CAL in higher education:

1. A human tutor can interact with students orally. We are still many years (perhaps two to three decades or more) away from having computer systems that carry on a

high-level, deep conversation at a human level of understanding. (Such a tutorial system would be able to pass the Turing Test.) However, the quality of voice input/output is improving and now has a number of commercial uses.

2. High-quality, highly interactive CAL is quite expensive to develop. My personal insight into this area suggests that it costs about \$5 million to develop a high quality, semester-length course. Maintaining and regularly updating such a course costs about \$1 million a year.

These costs are modest for high-enrollment courses, if one considers the total national or international enrollment in such courses. In the U.S., there are enough students beginning college each year so that it would be economically feasible to have a half dozen or more competing CAL courses in each of several different subject areas.

- 3. Education is far more than just the delivery of instruction and learning of content. Residential colleges and universities provide an environment that facilitates students learning about the human condition, their own culture, and other cultures, as well as how to interact with people in many different settings, how to work together in teams, and how to learn from each other.
- 4. Our educational system has a life and character of its own. Its employees, volunteers, students, and graduates all have a vested interest in preserving our educational institutions and system in their current format. Our educational system is innately highly resistant to change.

# **Hybrid Courses**

The term *hybrid course* is used to describe a course that is some combination of traditional class meeting time (perhaps enhanced by appropriate use of technology during the class meetings), CAL, and DL.

The Open University in England provides a good example of an entire university based on DL along with some hybrid courses. This university was established in 1969. Television and videotapes originally were the primary mode of instructional delivery. However, courses that traditionally included lab work (such as science courses) scheduled the labs at various colleges and universities, and were thus hybrid courses..

As described in Wikipedia:

The [Open] University awards undergraduate and postgraduate degrees, diplomas and certificates.

With more than 180,000 students enrolled, including more than 25,000 students studying overseas, it is the largest academic institution in the UK by student number, and qualifies as one of the world's mega universities. Since it was founded, more than 3 million students have studied its courses. *It was rated top University in England and Wales for student satisfaction in the 2005 and 2006 UK government national student satisfaction survey*. [Italics added for emphasis]

The Open University was originally developed mainly to serve students who had previously participated in a vocationally oriented track of secondary school education. A substantial amount of money was invested in developing the courses (perhaps \$1 million per course during the 1970s) and keeping them up to date. This large and continuing investment may help explain the high level of student satisfaction mentioned in the quote above.

#### **Open Education Resources**

Most students find it quite painful to have to buy textbooks for their courses. They find the costs completely unreasonable. The movement toward substantially increasing the use of DL and CAI is being aided by a variety of Open Education Resources (OER) movements. The OER (n.d.) Website describes OER materials this way:

OER are teaching, learning, and research resources that reside in the public domain or have been released under an intellectual property license that permits their free use or re-purposing by others. Open educational resources include full courses, course materials, modules, textbooks, streaming videos, tests, software, and any other tools, materials, or techniques used to support access to knowledge.

. . .

At the heart of the movement toward Open Educational Resources is the simple and powerful idea that the world's knowledge is a public good and that technology in general and the Worldwide Web in particular provide an extraordinary opportunity for everyone to share, use, and reuse knowledge. OER are the parts of that knowledge that comprise the fundamental components of education—content and tools for teaching, learning, and research. [Italics added for emphasis]

## **Final Remarks**

Right now, the majority of formal education is still carried out in the "traditional" manner of bringing students together in classes taught by a faculty member. However, CAL, DL, and hybrid courses are beginning to take a significant bite out of this approach.

There are several keys to the change that is occurring:

- 1. Highly interactive intelligent computer-assisted learning is getting better. In a variety of situations, it produces better learning results than tradition modes of instruction. Improvements in feedback to the learner are key to this.
- 2. As use of DL-based CAL learning increases, students will gradually learn to learn in this environment. Many will find that an asynchronous learning environment is well suited to their learning needs. Students can learn to provide better feedback to themselves and to take increased responsibility for their own learning.
- 3. There is a potential economy of scale and economy of not maintaining large, expensive physical campus facilities. Many colleges and universities are currently struggling to find a right mix between traditional and new modes of instruction that will best serve them and their students.

Self-assess your current experiences in CAL, DL, and hybrid courses, Help features on a computer, and other non-traditional aids to learning. What are you doing to gain increased expertise in learning in such learning environments?

# Chapter 6

# Learning and Learning Theory

"They know enough who know how to learn." (Henry Adams)

"In short, learning is the process by which novices become experts. " (John T. Bruer. Schools for Thought, 1999, page 13.)

The previous chapter included some discussion about intrinsic and extrinsic motivation, and it emphasized the necessity of feedback in learning. These topics are part of *learning theory*.

ICT creates some new aids to learning and it creates some new challenges to learning. However, it does not obviate what was known about learning theory and good learning practices before computers became so readily available.

This chapter introduces topics that will be of considerable value to you during your college education and throughout the rest of your life. Most of the topics covered are quite general, rather than being specific to ICT. All of the ideas in this chapter have been discussed in books that I have written for elementary and secondary school teachers. For some reason, our educational system thinks that teachers should know about these ideas, but that they are not part of the regular curriculum for students who do not plan to become teachers. In my opinion, our educational system should include all of these topics in the curriculum that all students study.

## **Cognitive Developmental Theory**

We know that the human brain changes quite rapidly during early years of life, and it continues to change at a significant rate until we are in our mid 20s. Thus, the brains of many younger college students have not yet reached their full maturity.

There has been a lot of research on how a person's brain develops over time, and the capabilities of an average brain at different stages of this development.

Jean Piaget's work on cognitive developmental theory has contributed greatly to our understanding of the stages of human development. (Huitt & Hummel, 2003). Piaget developed a theory of four-stage cognitive development that is still widely used. Figure 6-1 outlines the stages and developments Piaget proposed. As you study this scale, think about how well it describes your own cognitive development.

Approximate Age	Stage	Major Developments
Birth to 2 years	Sensorimotor	Infants use sensory and motor capabilities to explore and gain increasing understanding of their environments. If the environment (nurturing, food and vitamins, shelter, freedom from lead and other poisons, healthcare) is adequate beyond some modest threshold, then developmental progress is strongly dependent on genetic/biological factors.
2 to 7 years	Preoperational	Children begin to use symbols, such as speech. They respond to objects and

		events according to how they appear to be. Children make rapid progress in receptive and generative oral language. There are large advantages to growing up in a cognitively rich and challenging cultural and socioeconomic environment.
7 to 11 or 12 years	Concrete operations	Children begin to think logically. In this stage (characterized by seven types of conservation: number, length, liquid, mass, weight, area, and volume), intelligence is demonstrated through logical and systematic manipulation of symbols related to concrete objects. Operational thinking—including mental actions that are reversible mental testing of ideas—begins to develop. Schools and schooling play a significant role in helping to shape a child's development during this stage.
11 or 12 years and beyond	Formal operations	Thought begins to be systematic and abstract. Reasoning takes place deductively and theoretically, from hypothetical situations to the concrete. Understanding the concept of probability occurs. In this stage, intelligence is demonstrated through the logical use of symbols related to abstract concepts. Examples include reading with a high level of comprehension in typical courses at the high school level, and representing, understanding, and solving algebra, geometry, and other math problems at the level of high school math courses.

Figure 6-1. Piaget's cognitive development scale.

A student's rate of progress through the Piagetian developmental stages is dependent on both nature and nurture. Good and cognitively rich home, neighborhood, community, and school environments make a huge difference.

*Formal operations* is a broad concept. Each discipline tends to make up its own definition of what constitutes the achievement of formal operations within its own discipline. It takes education and experience to learn the vocabulary, notation, symbols, and methods of reasoning used in a specific discipline. We say that a person has achieved formal operations in a specific discipline when the person has achieved a reasonably high level of expertise in thinking and problem solving within the discipline.

Different disciplines use different vocabulary in talking about a person's developmental level. In mathematics, for example, it is common to talk about a person's level of *math maturity*. Indeed, college course descriptions sometimes indicate that math maturity is the prerequisite for a particular computer science, science, or math course. In essence, the requirement is that a student be at formal operations in math.

Having a high level of math maturity refers to having a high level of being able to represent problems mathematically, understand, think, reason in the language of mathematics, and solve challenging math problems within a realm of the math one has studied. Thus, it is appropriate to talk about a fifth grade student having a high level of math maturity relative to other fifth grade students.

Research in the past couple of decades indicates that movement into formal operations is not automatic. As Huitt and Hummel (2003) note:

Data from similar cross-sectional studies of adolescents do not support the assertion that all individuals will automatically move to the next cognitive stage as they biologically mature. Data from adult populations provides essentially the same result: Between 30 to 35% of adults attain the cognitive development stage of formal operations (Kuhn, Langer, Kohlberg & Haan, 1977). *For formal operations, it appears that maturation establishes the basis, but a special environment is required for most adolescents and adults to attain this stage*. [Italics added for emphasis]

The correctness of the assertion that 30 percent to 35 percent of adults attain the cognitive development stage of formal operations certainly depends on how one defines and measures formal operations. One can find peer-reviewed papers assert that only about half of college students are at the level of formal operations, while other papers that assert that a much higher percentage of college students are at formal operations level. Moreover, a person may be at a formal operations level in one discipline area but not in another.

Thus, for example, a significant percentage of students taking a college algebra course have not yet achieved a level of formal operations in mathematics, even though they may have achieved that level in other components of cognitive development. When such students face the highly symbolic, logical, and abstract aspects of college algebra, their main recourse is rote memorization. This helps explain why so many students do not succeed in this course. The rote memorization approach does not help much in moving students toward achieving a formal operations cognitive level in mathematics.

From your specific point of view, it is important for you to know whether you have achieved formal operations in general, and whether you have achieved formal operations in specific disciplines that you are studying. You may well be able to self-assess, and make a relatively good guess at your level of a Piagetian developmental scale. If you find it necessary to use the *memorize and regurgitate* approach with little understanding, there is a good chance you are not at formal operations in the discipline you are studying.

I have spent quite a bit of time searching the Web for high quality, free, self-assessment Piagetian cognitive developmental instruments, both in general and in specific disciplines. I have not found instruments. However, the next section contains cognitive developmental scales for Math and for ICT. These may help you in determining your current level of cognitive development in these two areas.

## Math and ICT Cognitive Development Scales

Figure 6-2 represents my current thinking on a six-level Piagetian-type scale for mathematics. It is an amalgamation and extension of ideas of Piaget and other researchers. Math is a deep discipline, with higher level content and ways of solving problems built upon lower level math. Notice that this discipline-specific scale has two additional levels above the traditional top level of formal operations on the Piagetian scale.

Stage Name	Math Cognitive Developments		
Level 1.	Infants use sensory and motor capabilities to explore and gain increasing understanding of their		
Piagetian and	environments. Research on very young infants suggests some innate ability to deal with small		
Math	quantities such as 1, 2, and 3. As infants gain crawling or walking mobility, they can display		
sensorimotor.	innate spatial sense. For example, they can move to a target along a path requiring moving around		
	obstacles, and can find their way back to a parent after having taken a turn into a room where they		
	can no longer see the parent.		
Level 2.	During the preoperational stage, children begin to use symbols, such as speech. They respond to		
Piagetian and	objects and events according to how they appear to be. The children are making rapid progress in		
Math	receptive and generative oral language. They accommodate to the language environments		
preoperational.	(including math as a language) they spend a lot of time in, so can easily become bilingual or		
	trilingual in such environments.		
	During the preoperational stage, children learn some folk math and begin to develop an		
	understanding of number line. They learn number words and to name the number of objects in a		
	collection and how to count them, with the answer being the last number used in this counting		
	process.		

	A majority of children discover or learn "counting on" and counting on from the larger quantity		
	as a way to speed up counting of two or more sets of objects. Children gain increasing proficiency		
	(speed, correctness, and understanding) in such counting activities.		
	In terms of nature and nurture in mathematical development, both are of considerable importance		
	during the preoperational stage.		
Level 3. Piagetian and Math concrete operations.	During the concrete operations stage, children begin to think logically. In this stage, which is characterized by 7 types of conservation: number, length, liquid, mass, weight, area, volume, intelligence is demonstrated through logical and systematic manipulation of symbols related to concrete objects. Operational thinking develops (mental actions that are reversible). While concrete objects are an important aspect of learning during this stage, children also begin to learn from words, language, and pictures/video, learning about objects that are not concretely		
	available to them.		
	For the average child, the time span of concrete operations is approximately the time span of elementary school (grades 1-5 or 1-6). During this time, learning math is somewhat linked to having previously developed some knowledge of math words (such as counting numbers) and concepts.		
	However, the level of abstraction in the written and oral math language quickly surpasses a		
	student's previous math experience. That is, math learning tends to proceed in an environment in		
	which the new content materials and ideas are not strongly rooted in verbal, concrete, mental		
	images and understanding of somewhat similar ideas that have already been acquired.		
	There is a substantial difference between developing general ideas and understanding of		
	conservation of number, length, liquid, mass, weight, area, and volume, and learning the		
	mathematics that corresponds to this. These tend to be relatively deep and abstract topics,		
	although they can be taught in very concrete manners.		
Level 4.	Thought begins to be systematic and abstract. In this stage, intelligence is demonstrated through		
Piagetian and	the logical use of symbols related to abstract concepts, problem solving, and gaining and using		
Math formal	higher-order knowledge and skills.		
operations.	Math maturity supports the understanding of and proficiency in math at the level of a high school math curriculum. Beginnings of understanding of math-type arguments and proof.		
	Piagetian and Math formal operations includes being able to recognize math aspects of problem		
	situations in both math and non-math disciplines, convert these aspects into math problems (math		
	modeling), and solve the resulting math problems if they are within the range of the math that one		
	has studied. Such transfer of learning is a core aspect of Level 4.		
Level 5.	Mathematical content proficiency and maturity at the level of contemporary math texts used at the		
Abstract	senior undergraduate level in strong programs, or first year graduate level in less strong programs.		
mathematical	Good ability to learn math through some combination of reading required texts and other math		
operations.	literature, listening to lectures, participating in class discussions, studying on your own, studying		
-	in groups, and so on. Solve relatively high level math problems posed by others (such as in the		
	text books and course assignments). Pose and solve problems at the level of one's math reading		
	skills and knowledge. Follow the logic and arguments in mathematical proofs. Fill in details of		
	proofs when steps are left out in textbooks and other representations of such proofs.		
Level 6.	A very high level of mathematical proficiency and maturity. This includes speed, accuracy, and		
Mathematician.	understanding in reading the research literature, writing research literature, and in oral		
	communication (speak, listen) of research-level mathematics. Pose and solve original math		
	problems at the level of contemporary research frontiers.		

Figure 6-2. Six-stage mathematical cognitive developmental scale.

ICT is a large, vibrant, and rapidly growing field. The International Society for Technology in Education (ISTE) has developed national educational technology standards for students, teachers, and school administrators. These standards have been widely adopted and serve to provide a good sense of direction for the ICT preparation of teachers and their students (ISTE NETS, n.d.).