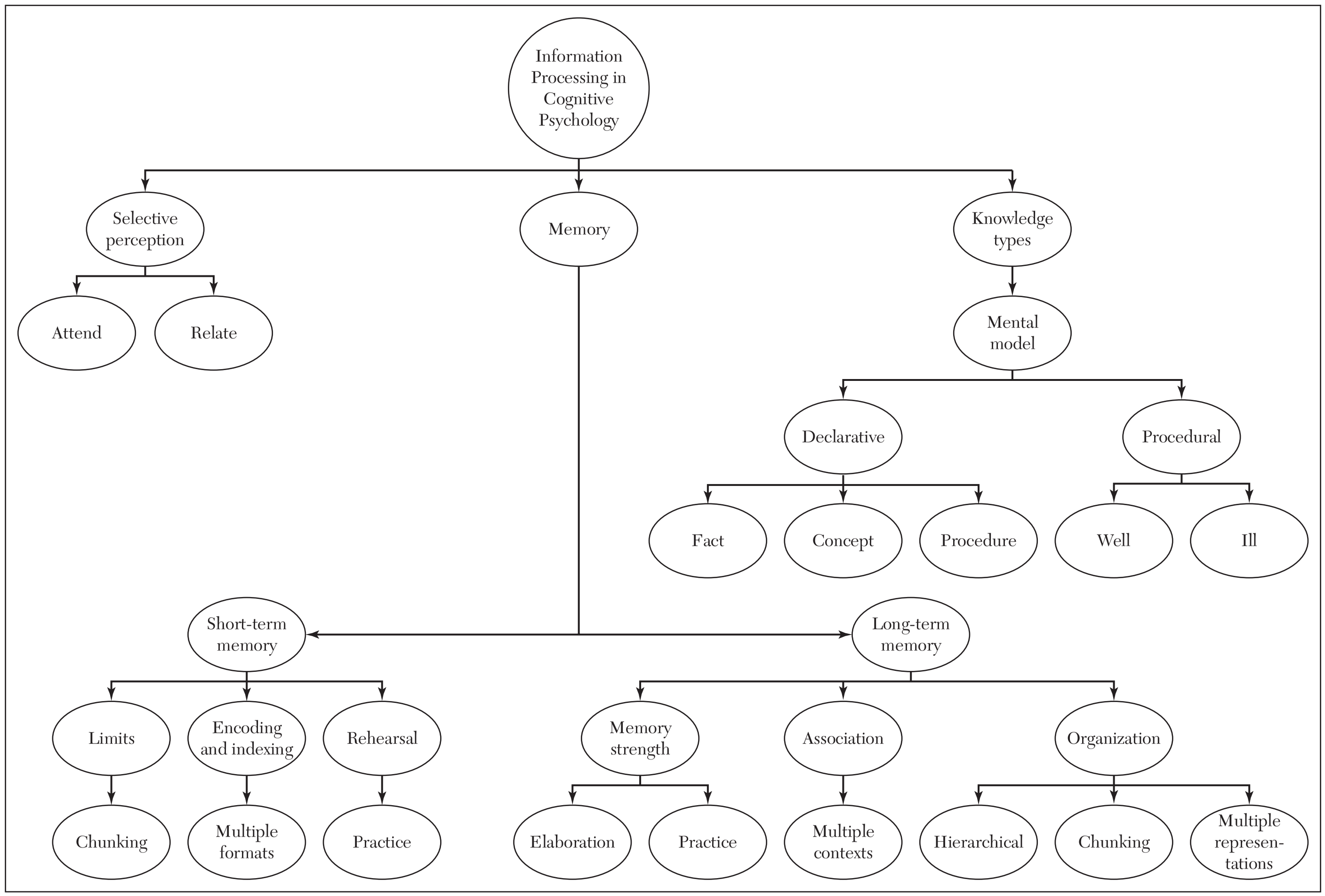
FIGURE 1.1. Chapter 1 Structure of Content



Chapter 1

The Cognitive Approach to Training Development

LINK AND ORGANIZE

Recall

- You have already had an introductory ID workshop or course and/or have read an introductory ID textbook.
- The approach you learned there is the “traditional” behaviorally based approach to instructional design.
- You learned some categorization of different types or levels of learning (such as facts, concepts, principles, procedures, problem solving).
- You learned some set of instructional elements to include in a lesson (for example, gain attention, recall prior learning, inform of objective, present information, provide learning guidance, practice, feedback, test, transfer).

Relate to What You Already Know

- The cognitive approach is one that you can add to your existing ID skills; you do *not* need to forget everything you already know.
- The cognitive view of how learning takes place is different from the behavioral one. It is based on how new information is processed, stored, and retrieved in the mind, rather than on how behavior changes.

- The cognitive approach you are going to learn in this book builds on what you know, but adds some new elements:
  - It adds to the types or levels of learning you already know.
  - It adds to or changes the instructional elements you already know.

Structure of Content

- See Figure 1.1.

Objectives

- To describe why the cognitive approach to ID/training development is important.
- To describe how learning occurs according to the cognitive point of view.
- To describe the different categories of learning according to cognitive psychology.

THE COGNITIVE APPROACH TO INSTRUCTIONAL DESIGN

The cognitive approach to instructional design (ID) has become popular recently for two reasons, one based in the theory of learning and instructional design, the other based in business.

From the perspective of theory, the cognitive approach was developed to overcome a number of limitations of the behavioral approach currently used. These are listed below:

- Learners sometimes have trouble transferring what they have learned from training to the job.
- Learners can have trouble attaining expert-level performance in troubleshooting and problem solving on the job.
- Learners often have trouble generalizing their training from one situation to another, leading to skill gaps every time the job, content, or technology changes and creating the need for retraining.
- Learners may have difficulty with divergent reasoning (many right answers or many ways to get to the answer), as opposed to convergent reasoning (one right answer and one way to get it).
- Designers do not have adequate prescriptions for designing the kinds of training we are now being asked to design—problem solving, troubleshooting (especially in settings where content volatility is high), heuristic-based thinking (using guidelines versus algorithmic thinking, which uses formulas with 100 percent predictable outcomes), strategic thinking, and the like.

From the perspective of business, the current behavioral approach to ID sometimes leads to excessive development and delivery costs because it requires:

- Longer training sessions to cover all the specific algorithms or other content variations.
- More retraining time, to address lack of transfer to new situations.
- More development time, since there are no guidelines for creating training for higher order thinking and developers must either guess or treat problem solving as a large number of low-level procedures and concepts.

The cognitive approach to ID offers remedies to these problems. It provides designers with another way to design training that works well in situations where higher-order thinking, problem solving, and transfer to new situations are training goals.

THE COGNITIVE POINT OF VIEW ON HOW LEARNING OCCURS

There are many theoretical models in cognitive psychology about how learning occurs. According to these models, there are several components of the mind, and each is involved in the learning process in certain ways. Further, how each component of the mind works has implications for how we design instruction. The components are:

- Perception and sensory stores.
- Short-term memory.
- Long-term memory.

Perception and Sensory Stores

Perception Is Selective. There is more stimulation in the environment than we are capable of attending to and then encoding (internally translating) for storage in memory. Therefore, we only attend to certain things. We attend to and see/hear what we expect to see in a given situation. We attend to those things that interest us because they are either (a) related to what we already know or (b) so novel they force us to attend to them.

Limits of the Sensory Stores. Our sensory stores, also called sensory memories or "buffers," are capable of storing almost complete records of what we attend to. The catch is that they hold those records *very briefly.* During that very brief time before the record decays, we do one of two things: (1) we note the relationships among the elements in the record and encode it into a more permanent memory or (2) we lose the record forever.

IMPLICATIONS FOR ID

- Get the learner to *attend to* the parts of the environment you want learned (hence the emphasis on capturing the learner's attention and on motivational statements).
- Help the learner note *relationships* among the bits of information quickly (hence the importance of organizing the information you are presenting and of clearly relating the new information to existing familiar or important contexts and knowledge).

Short-Term or Working Memory

Controversy. There is disagreement among cognitive psychologists about whether short-term memory is "separate and different" from long-term memory—whether the two types of memory are physically different or whether they are just conceptually different constructs. There is also discussion about how information is encoded, how it is stored, and so on. Regardless of the theoretical differences, most psychologists agree on the following points.

Rehearsal. When information is passed from the sensory stores to memory, we mentally rehearse it. Examples include repeating phone numbers several times or creating associations to names (*Ted* with the *red* hair) to help memorize them. The former, simply repeating the information over and over, is called *passive rehearsal.* It does not seem to improve memory as well as rehearsing the information in a *deep and meaningful* way, such as by creating associations.

Limited Capacity. There seems to be a limit on the amount of information we can rehearse at one time. A classic study by Bell Labs in (Miller, 1956) showed we can remember 7 ± 2 bits of information at most, and that to remember more we have to "chunk" (or group) information in manageable sizes; that's why your phone number has seven digits and why people in the United States remember phone numbers in three chunks (1aaa-bbb-cccc).

Format. At this point in the learning process, the information being rehearsed is not yet organized and encoded as it will be when it is later stored in memory. Also, there is some evidence that there are separate spaces for storing and rehearsing verbal information and visual/spatial information, and possibly separate spaces for other types of memories as well.

IMPLICATIONS FOR ID

- Help learners use meaningful ways of rehearsing the information, as opposed to simply repeating it (through the use of analogies, by relating new information to existing knowledge or situations, and so on).
- Present the information in meaningful "chunks" of appropriate size for the learner population (knowing what your learners already know about the subject they are learning is critical to determining "appropriate size").
- Present the information in multiple formats (verbal, auditory, visual), which can help learners rehearse, and therefore remember, better.
- Present the information in a way that allows the learner to move quickly from rehearsing the information to encoding it and integrating (indexing) it with other information in long-term memory.

Long-Term Memory

In general, theorists believe that long-term memory is organized based on context and experience. That means we encode, store, and retrieve information in the way we have used knowledge in the past and expect to use it again in the future. Psychologists note several phenomena that strengthen the memory process.

Memory Strength. Information in memory has a characteristic called *strength*, which increases with practice. A *power law of learning* governs the relationship between amount of practice and response time or error rates (strength = practice to power X). In simple terms, this means that practice increases the strength of learning exponentially (double the practice at least squares the strength of the learned information in memory; triple the practice increases the strength by a factor of nine).

Elaboration. Elaboration means adding information to the information being learned. The more we elaborate on what we learn through processing, the better we remember it. This is because, as we tie the new information to existing information or we create other information related to the new information, we create more pathways to get to the new information as we try to remember it.

Chunking. Memories are stored not as individual bits or as long strings of information, but in "chunks," with each chunk containing about seven elements. As explained earlier, how large an "element" and a "chunk" are differs based on the learner's existing knowledge.

Verbal and Visual Information. It seems we encode verbal and visual information differently in memory. We use a linear code for verbal information and a spatial code for visual information. We remember visual information very well, especially if we can place a meaningful interpretation on the visuals. In addition, it has been shown in Gestalt psychology that we remember incomplete and strange images better than complete, standard ones. With verbal information, we remember the meaning of the information, not the exact words.

Associations and Hierarchy. Information is organized in memory, grouped in a set of relationships or structures (for example, hierarchically). Using such a structure makes it easier for us to remember, because more related pieces of information are activated when we search for information. While you may not remember one specific piece of information in the structure, you may remember the overall structure and some pieces in it, and from that you can remember or create the missing piece of information. For example, you may not remember all the numbers in the 12 × 12 multiplication tables, but if you remember some key ones (1, 2, 3, and 5 times a number) you can construct the rest.

By comparison with computers, humans can remember far fewer separate pieces of data, but are much better equipped for pattern recognition skills, such as analogical reasoning, inference, and comprehension of visual and verbal languages.

IMPLICATIONS FOR ID

- Build a lot of meaningful practice into training to increase the probability of retention (for example, the PQ4R method = preview, question, read, reflect, review, recite).
- Provide learners with information or allow them to create information that elaborates on the information to be learned.
- Present the information in meaningful "chunks" of appropriate size for the learner population (knowing your learners is critical).
- Present the information so it uses the learners' abilities to remember both verbal and visual information.
- Organize the information being presented hierarchically (to approximate the way information is stored in memory) to increase retention.
- Provide many associations to the information being learned to increase the chances the information will be retrieved when called for.
- Teach learners to organize/index their memories so they have many associations, many retrieval paths, and appropriate structures.
- Use authentic (real-world) contexts for explanations, examples, and practice to help the learners relate what they learn to situations in which they will need to use the knowledge.

DECLARATIVE AND PROCEDURAL KNOWLEDGE AND THEIR SUBTYPES

Cognitive psychologists often draw distinctions between different categories of knowledge. When you design training, you will probably find it helpful to use these distinctions. The biggest distinction is between *declarative* and *procedural* knowledge: *Declarative* knowledge is knowing *that,* whereas *procedural* knowledge is knowing *how.*

Examples of Declarative Knowledge

- Remembering your telephone number.
- Being able to tell the difference between a table and a tray.
- Stating that for a car engine to run, it must have air, fuel, and electrical current for the ignition.

Examples of Procedural Knowledge

- Following a recipe to bake a cake.
- Building a spreadsheet "from scratch" using a software package for spreadsheets.
- Fixing the copier so it will stop jamming.
- Designing a copier that can't jam.

The basic difference between the two types of knowledge is that declarative knowledge tells you *how the world is,* while procedural knowledge tells you *how to do things in the world.*

Trainers who don't understand this distinction often confuse *knowing* and *doing,* and thus make the following kinds of mistakes when designing training:

- They try to teach (and test) procedural knowledge using strategies suited for declarative knowledge.
- They teach declarative knowledge and stop, assuming that the procedural knowledge will naturally follow on its own.
- They try to teach the procedural knowledge without teaching the associated declarative knowledge.

It's important to understand the different types of declarative and procedural knowledge so that, when you plan your instruction, you can use instructional strategies appropriate to each type. If you're good at making these distinctions, you may be able to save considerable time and expense in developing and delivering your training, while improving its effectiveness. The different types are discussed briefly below and described in detail in later chapters devoted to how to teach each type.

Types of Declarative Knowledge

There are three types of declarative knowledge: *facts, concepts,* and *principles and mental model*s. The discussion of these types below is a synthesis of much that is already familiar and commonly accepted. The reader will note that these types of declarative knowledge are very similar to the types of learning proposed by Gagne (1985) and taught in most basic ID texts (for example, Dick & Carey, 2001). However, the notion of mental models is ours and we have described the characteristics of all in slightly different terms.

Facts. A fact is a simple association among a set of verbal and/or visual propositions. Some examples of facts are:

- On a traffic light, red means stop, green means go, and yellow means prepare to stop.
- In 1492 Christopher Columbus sailed from Spain and landed in the Caribbean; he was not the first to do so, nor did he discover America.
- Miller's (1956) study for Bell Labs said the largest number of digits a person could remember easily was seven.
- The five steps to create a table in MS Word 6.0 for Windows 95 are (1) select tables, (2) select number of rows, (3) select number of columns, (4) select line appearance, (5) click OK.

When you know a fact, you have placed it in a structure so you can recall it from memory. Learning facts as part of a structure that will help you recall them in the way you need them is much more efficient than trying to memorize each fact by itself. Simply knowing a fact does *not* mean you can generalize it to new situations, explain what it means, identify its relationship to other facts, or apply it to do anything.

Concepts. A concept is a category of objects, actions, or abstract ideas you group together with a single name because they share characteristics in common. Some examples of concepts are:

- Cars (vs. trucks, campers, or utility vehicles)
- Jogging (vs. running, walking)
- Beautiful sunrises (vs. beautiful sunsets, ugly sunrises)
- Justice (vs. injustice)
- Performance improvement (vs. training)

When you know a concept, you can classify new objects, actions, or ideas as either in the category or not. People typically learn concepts by remembering the best example of the category they've seen (or imagined). They may or may not be able to state the concept verbally. Concepts do not exist in isolation; all concepts have related concepts (parts or kinds, more general, more specific). Items in a given category that do not belong to one concept in the category do belong to another concept in the category.

Principles. A principle is a cause-effect relationship. When you understand a principle, you know how something works. Principles are frequently stated as "if . . . then . . ." statements. You can demonstrate your understanding of a principle by explaining why something happens or predicting what will happen. For example, you know that:

- If you see lightening nearby, you will hear thunder.
- If you turn the ignition key in a car, the engine will probably start.
- If you rob a bank, you may go to jail.
- If you write test items to match instructional objectives, the test will have certain types of validity.

Mental Models. The three types of declarative knowledge we've talked about so far fit together into structures called mental models or networks of principles, along with their supporting concepts and facts, stored in a meaningful structure based on (a) the context for which it was created and (b) the past learning and experiences of the learner. For cognitive psychologists, mental models are the key to learning and using knowledge because:

- They tie together all the declarative knowledge in memory.
- They are the structures into which you organize information, put it into memory, retrieve it from memory when needed, and learn by expanding and restructuring existing structures.
- They provide the most meaningful application of declarative knowledge (as adults we rarely spout networks of facts or run around finding new instances of concepts, but we do frequently try to explain how or why things happen or work).
- They form a bridge between declarative knowledge (knowledge about) and procedural knowledge (knowing how); before you can do procedures (other than rote ones), you have to "know how the system works," that is, have a mental model of the system.

Therefore, most would argue that, for training of adults, the instructional design must not only teach isolated facts, concepts, and principles, but must also help the learner create the appropriate mental models for optimum structuring of the information learned for storage, retrieval, and application.

Types of Procedural Knowledge

Procedural knowledge is the ability to string together a series of mental and physical actions to achieve a goal. Procedural knowledge is used to solve problems.

The way "problem" is used in this book may be a new concept for many readers. In the behavioral approach, instructional designers think about "procedures" and "problem solving" as two different things—two different levels in a hierarchy such as Gagne's. In the cognitive approach used in this book, the tendency is to use "procedural knowledge" and "problem solving" interchangeably, which many might find confusing initially. But our reasoning is that, since procedural knowledge is used to solve problems, the type of problem the knowledge is used to solve is what leads to the name of the procedural knowledge. See Figure 1.2 for problem characteristics.

FIGURE 1.2. Problem Characteristics

Definition	Example
a. There is an *initial state,* or the elements of the problem the learner is presented with.	You want to record five different TV programs broadcast on five different nights, each at a different time.
b. There is a *goal state,* or a description of the situation that would be a solution to the problem.	You need to program the VCR correctly to record the programs.
c. There is a *set of operations,* or things the learner can do to get from the initial state to the goal state.	You need to follow the step-by-step programming procedure furnished by your VCR and TV set manufacturers.
d. There is a *set of constraints,* or conditions which must not be violated by the learner in solving the problem (Glass, 1985). Anderson (1995) uses "Search" instead, as the mechanism of chaining together operations to get from initial to end state.	You must input the correct day, time, and channel for each program in the correct sequence. You must make sure there are no fund drives, presidential press conferences, "special" programs, or any other scheduling changes that would throw off the original times. You also have to make sure you're correctly specifying a.m. and p.m., correctly associated network name and channel number, and so on.

As you can see, problems always have a starting or *initial state* (car not running), an end or *goal state* (running car), a sequence of actions or *set of operations* (open door, get in, apply brake, insert key in ignition switch, turn key), and *set of constraints* (works only if you have the right key).

If the types of procedural knowledge and problem solving are placed on a continuum, at the most precise end are well-structured problems; at the least precise end are ill-structured problems; and in the middle are moderately structured problems.

Well-Structured Problem Solving. A term you may sometimes hear for well-defined procedural knowledge is *rote procedure.* We consider performing rote procedures to be well-structured problem solving. All elements of the problem situation are known. The initial state, goal state, and constraints are clearly defined. The operations are also clearly defined, although they may include a choice of alternatives (branches). The learner knows when to start the procedure and when to stop it. Examples of well-structured problem solving include:

- Ringing up a sale in a department stores.
- Calculating heating and air conditioning requirements for a building.
- Implementing a design for a database.
- Printing marketing pieces.

Well-structured problems are usually performed simply by recalling procedures and performing them exactly as taught. It's not even necessary to understand why the procedure works. Thus, in many situations it is optional to understand underlying *principles* that explain the *why* of a well-structured procedure.

Moderately Structured Problem Solving. In moderately structured problems, which include troubleshooting, the goal state is clear, and the learners might know the initial state and constraints. However, the learners probably have to recall and assemble in a novel way the operations that will take them from the initial state to the goal state, given the constraints. Examples of moderately structured problems include:

- Troubleshooting a "mis-ring" on a sale item in a department store.
- Developing a floor plan for a building.
- Planning how to implement a redesigned work process.
- Planning a marketing focus group.

Other examples are deciding on the most advantageous retirement package, deciding whether or not to fire an employee, determining whether to repair your old DVD player or buy a new one, determining whether or not to recommend that an employee seek company-provided counseling.

For moderately structured problems, it is important to understand the principles that underlie them. For example, a manager who wants to figure out how to motivate an employee needs to understand a few basic principles of motivation, if only at the common sense level.

Troubleshooting is a special "compound" case, in which an expert treats unfamiliar and/or complex problems as moderately structured and generates the operations. Some examples include determining the cause/source of a food poisoning outbreak, finding the source of a scraping noise when your car starts, determining why a metal stamping machine damages its stampings on a random basis, and figuring out why your refrigerator defrosts continually or your coffee maker doesn't work.

Ill-Structured Problem Solving. In ill-structured problems, which include most of the complex problems our learners encounter, three or all four of the elements of a problem are either missing completely or are present but not clear. Examples of ill-structured problems include:

- Deciding on the sale price for an item in a department store.
- Designing a new building.
- Redesigning a work process.
- Introducing a new product.

Other examples are holding a press conference on a highly controversial issue, conducting a workshop with learners who are highly resistant to learning the content, designing an artificial pancreas or an acceptable human blood substitute or an automobile that never wears out.

You've probably heard the old saw that "defining a problem is most of solving it." That refers especially to these ill-structured problems.

In Our View. For purposes of instructional design, in most circumstances there is little difference between moderately and ill-structured problems. Therefore, we will consider only two classes of problems: well-structured and ill-structured. We will consider moderately structured problems only in their special case—troubleshooting.

SUMMARY

In this chapter we have briefly described the key theoretical elements of *cognitive psychology* that underlie the ID strategies we will describe in this book.

We began by discussing the advantages of the cognitive approach, from both an instructional and a business perspective.

Then we discussed the cognitive view of the learning process: *perception and memory stores, short-term memory,* and *long-term memory.* For each element, we explained how the element works, some issues that impact learning, and some implications for instructional design.

Then we explained the different types of knowledge and gave brief descriptions and examples of each: declarative knowledge (*facts, concepts,* and *principles and mental models*).

We then briefly discussed the three types of procedural knowledge along a continuum from *well-structured* problems (at the most precise end of the continuum) to *moderately structured* problems (in the middle) to *ill-structured* problems (at the least precise end of the continuum).