PART ONE

An Introduction to Efficiency in Learning

IN PART I WE INCLUDE two chapters that summarize the basics of cognitive load theory and that describe its psychological basis. In an age in which workers must learn more in less time, more likely than not, you have taken, produced, or taught training classes that resulted in mental overload. However, you may not realize that cognitive load has a scientific basis—and even better—that research offers many proven techniques that you can use to manage cognitive load either as a consumer or a producer of training. By applying these techniques you can produce efficient instructional environments—environments that result in faster learning, better learning or both.

Cognitive load theory has its modern origins in experiments conducted by Dr. John Sweller at the University of New South Wales, Australia, in the early 1980s. Today cognitive load theory has grown into one of the most widely recognized sets of proven principles governing learning and instruction in the training profession. You can read a personal account by

John Sweller of how cognitive load theory started and evolved in Chapter 13. Because most of the research on cognitive load theory is found in technical journals not written for training practitioners, we wrote this book for instructional professionals to summarize the principles and evidence behind it. Part I lays the foundation for these principles.

Read	***To Learn About***
Chapter 1. Cognitive Load and Efficiency in Learning	What cognitive load theory is Three Types of Cognitive Load: Intrinsic, Extraneous Irrelevant), and Germane (Relevant) How instructional environments interact with learner backgrounds and content complexity to result in cognitive load The psychological basis and research evidence for cognitive load theory A formal definition of efficiency in learning
Chapter 2. The Psychology of Efficiency	Human memories involved in learning: working memory and long-term memory Cognitive load and working memory limits Long-term memory and expertise The main psychological events of learning Instructional methods and psychological events of learning

On the CD

Video Interview with John Sweller: Chapter Preview/Review

Chapter 1. Cognitive Load and Efficiency in Learning. The basics of cognitive load theory, including a discussion of extraneous, intrinsic, and germane cognitive load. The scientific basis for cognitive load theory.

Chapter 2. The Psychology of Efficiency. The features of working memory, the consequences of limited working memory on human learning, the features of long-term memory and the importance of long-term memory to human cognition.

CHAPTER OUTLINE

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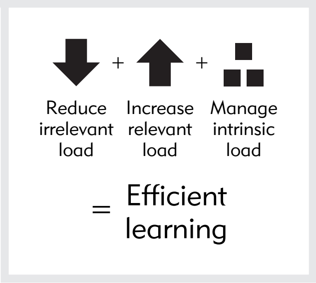


Cognitive Load and Efficiency in Learning

INFORMATION OVERLOAD AND LARGE FINANCIAL INVESTMENTS in worker learning and training demand efficient instructional environments. Efficient instructional environments lead to better learning, faster learning, or both because they make the best use of limited human cognitive capacity. This book offers practical proven guidelines to make your instruction efficient.

In this chapter we set the stage by introducing cognitive load theory, which is the scientific basis for efficiency in learning. We will look at three types of cognitive load you must consider in your training, as well as the variations in cognitive load resulting from the interaction among instructional environments, learner prior knowledge, and the complexity of the learning task.

Unlike many books offering training tips and techniques, our guidelines are based on recent valid scientific evidence. We will introduce the type of evidence that we present throughout the book and, since cognitive load theory is fundamentally about efficiency, we will define efficiency and show how it is measured in research studies.

The Costs of Inefficient Instruction

This is a book about how to create efficient learning environments. The guidelines in this book apply to all types of instructional delivery media, including computers, workbooks, and instructors. Instructional settings that are efficient result in learning that is faster and/or better than settings that are inefficient. Many popular books on learning and training techniques are based on little more than personal opinion. In contrast, our guidelines are based on scientific evidence—evidence accumulated over the past twenty-five years by an international team of instructional scientists. This evidence has important economic implications. As a consequence of high investments made in training programs coupled with rampant information overload, inefficient instructional environments exert a high toll in wasted economic and human resources.

How high is our training investment? From customer service to manufacturing—from sales to supervision—*50 to 60 billion dollars* are spent each year on organizational training programs in the United States alone (Dolezalek, 2004). And this is a low estimate because it does not factor in the hidden costs that make up the most expensive element of any training program—the salary time of participants being trained. While staff are attending a week of training, they are earning their salaries and they are not producing. Even if we disregard lost opportunity costs, just adding the salary costs alone would bring the annual investment in training into the $300 billion range! More efficient learning environments increase training cost effectiveness by reducing instructional time, improving training outcomes, or both.

Psychological work demands are growing in the 21st Century. Whether you call it info glut or data delirium, information overload has gotten so bad that it's led to a new form of psychological stress called Information Fatigue Syndrome. A study from the University of California at Berkeley reports that the amount of new information created in the year 2002 disseminated in print, film, magnetic, and optical storage media equaled five exabytes (Lyman & Varian, 2003). Five exabytes is equivalent to the information contained in half a million libraries the size of the U.S. Library of Congress print collection, which exceeds nineteen million books!

Information overload erodes the quality of work. For example, primary care physicians cited information overload as a major cause of difficulties practitioners experience in diagnosing and managing heart failure (Fuat, Hungin, & Murphy, 2003). Not only is the sheer amount of information growing, but so also are the complexity and number of tasks many workers must juggle. More information and more complex tasks demand greater skills, which require more training. At the same time, organizations want to save costs by reducing time spend in training programs. These economic and psychological pressures call for efficient training environments—environments that are proven to work in harmony with the strengths and limitations of human learning processes.

What Is Cognitive Load Theory?

As instructional professionals, many of you have probably heard of the "magical number 7 ± 2" items of information, first published by George Miller in 1956. According to this guideline, our cognitive system can only process 7 ± 2 items at one time. Once we exceed those limits, our thinking and learning processes bog down. Based on research conducted over the past twenty-five years, a growing international contingent of instructional scientists has expanded and refined the rule of 7 ± 2 into a comprehensive set of instructional principles called *cognitive load theory.*

A Definition of Cognitive Load Theory

Cognitive load theory is a universal set of learning principles that are proven to result in efficient instructional environments as a consequence of leveraging human cognitive learning processes.

1. **Cognitive Load Theory Is Universal.** Cognitive load theory applies to all types of content, all delivery media, and all learners. Because cognitive load theory addresses how to use fundamental tools of training—text, visuals, and audio—it applies to everything from technical content to soft skills as well as to all delivery platforms from print to e-learning. Because of its universality, whether you are a classroom instructor or developer of

training materials for workbooks or computers, cognitive load theory applies to you.

2. **Cognitive Load Theory Offers Principles and Related Instructional Guidelines.** Unlike many general educational theories, cognitive load theory offers principles that lead to very specific guidelines that all instructional professionals can implement. Throughout the chapters in this book we offer more than twenty-five specific guidelines for best ways to design, develop, and present training. Some of these guidelines are likely to be familiar methods that you may have used for years. Other guidelines, however, will be new—some even counter to prevailing instructional practice.

3. **Cognitive Load Theory Is Evidence-Based.** Cognitive load theory is based on dozens of controlled experimental research studies. Throughout the chapters we summarize some of the experiments and show you the results. Because so much training advice is not based on evidence, we feel it is important for you to have the opportunity to review at least some of the research that supports cognitive load theory. For more details, we offer recommended readings, many of which are original research reports. In Chapter 13, John Sweller, originator of cognitive load theory, writes a personal perspective of how cognitive load theory started and has evolved during the last twenty-five years.

4. **Cognitive Load Theory Leads to Efficient Learning.** Efficient instructional environments lead to faster learning, better learning, or both. The scientists who have worked on cognitive load theory have created a metric for quantifying efficiency as well as an efficiency graph for display and visual comparison of lesson efficiencies. Since you will see research data displayed on the efficiency graph throughout the book, we define and illustrate this metric and graph in this chapter.

5. **Cognitive Load Theory Leverages Human Cognitive Learning Processes.** Learning environments based on cognitive load theory minimize wasted mental resources and instead put those limited mental resources to work in ways proven to maximize learning. Because cognitive load theory is grounded in human learning processes, you will not only gain a set of proven instructional guidelines, but you will also understand why those guidelines work. Based on

this understanding, you can readily adapt them to your own instructional settings. You can also explain the basis for your instructional recommendations to your colleagues and clients. As an incidental benefit, you should also gain insights into your own cognitive processes!

Types of Cognitive Load

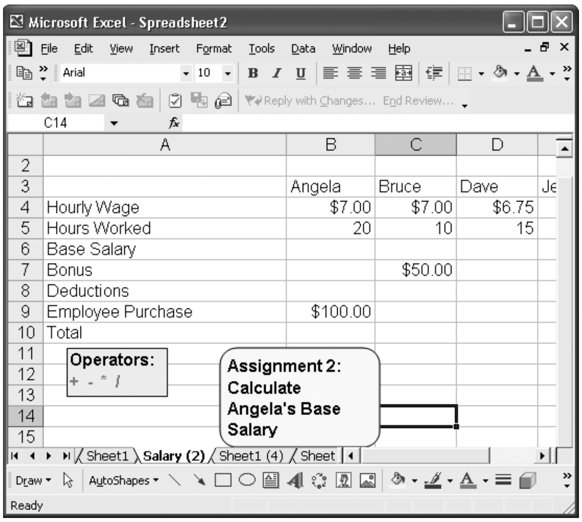
Some forms of cognitive load are useful, while others waste mental resources. Your goal during training is to minimize wasteful forms of cognitive load and maximize the useful forms. The three main types of cognitive load you must consider in your training program are *intrinsic load, germane load,* and *extraneous load.* Since total mental capacity is limited, you will need to balance these three forms of load to maximize learning efficiency.

Intrinsic Load

Intrinsic load is the mental work imposed by the complexity of the content in your lessons and is primarily determined by your instructional goals. For example, in Figure 1.1 we show a practice assignment from an e-lesson on

Figure 1.1. An Assignment in an Excel Lesson That Imposes Moderate Intrinsic Cognitive Load.

From the CD Virtual Classroom Example.



Excel® formulas drawn from our demonstration lesson on the CD. To perform this task, the learner must coordinate at least seven steps, including locating the correct spreadsheet row, locating the correct spreadsheet column, combining these to locate the correct spreadsheet cell in which to input a formula, selecting that cell with the mouse, constructing the correct formula by applying Excel format rules (which, depending on the formula, may involve many steps), typing the formula in the cell, and pressing the enter key. For someone new to Excel, this is a complex task because it requires the coordination of multiple mental and physical components. In cognitive load terminology, we would say that this assignment imposes a moderately high intrinsic load because it involves a high amount of *element interactivity.*

Element interactivity simply means that several knowledge elements must be coordinated in memory to accomplish the task. Some learning tasks are low in element interactivity because they can be accomplished in a serial rather than coordinated fashion. For example, when studying a foreign language, learning some types of vocabulary is relatively low in element interactivity because each word can be memorized independently of other words.

However, when you start to construct sentences, element interactivity jumps dramatically. When composing sentences you need to consider not only the meaning of several words but also the grammar and syntax rules that must be applied to sequence and parse the words correctly. All of these elements must be coordinated simultaneously to produce a correct sentence.

If your task is to respond verbally to a question posed in a new foreign language, the mental load is even greater. Ask any new foreign language student about the amount of mental load he or she experiences during early conversational practice! To respond verbally, the student must first interpret the question, then compose an answer by selecting the correct words and applying grammar rules, and finally pronounce the words correctly—all within a relatively short amount of time.

Intrinsic cognitive load is determined primarily by the knowledge and skills associated with your instructional objective. Although you cannot directly alter the inherent intrinsic load of your instructional content, you can manage the intrinsic load of any given lesson by decomposing complex tasks into a series of prerequisite tasks and supporting knowledge distributed over a series of topics or lessons. This is what instructional professionals do as they create outlines of their courses and lessons. As a byproduct of segmenting and sequencing content into a series of instructional events, instructors manage intrinsic cognitive load. In Chapter 7 we summarize guidelines and evidence for best ways to manage intrinsic cognitive load through course and lesson design decisions.

Germane (Relevant) Load

Germane cognitive load is mental work imposed by instructional activities that benefit the instructional goal. For example, learners in an Excel spreadsheet class will have different work requirements for using spreadsheets. Some students will need to construct spreadsheets as the basis for regular income and expense reports. Other students will use spreadsheets to calculate compensation that factors in taxes, commissions, bonuses, and deductions. To accomplish such diverse goals, during training, the learners will need to build a robust set of skills that they can apply to various types of spreadsheets with different data sets when they return to their work assignments. To build this flexible skill set, instructional examples should incorporate different calculation goals and data values. For example, in Figure 1.1 the learner practices a compensation calculation. Other examples in the same lesson involve profit, inventory, and sales scenarios.

Of course, learning would be easier if all of the examples used a single type of spreadsheet with similar data. However, the skills that emerge from a more homogenous set of examples have been proven to be much more limited than skills built from a diverse set of examples. By studying diverse context examples and assignments, learners end up with a much broader repertoire of spreadsheet skills applicable to many work situations.

The extra mental load imposed by this diversity is an example of germane cognitive load. Diversity in examples adds cognitive load in the service of the instructional goal. Think of germane load as relevant load imposed by instructional methods that lead to a better learning outcome. Chapter 9 is devoted entirely to instructional guidelines that add germane load.

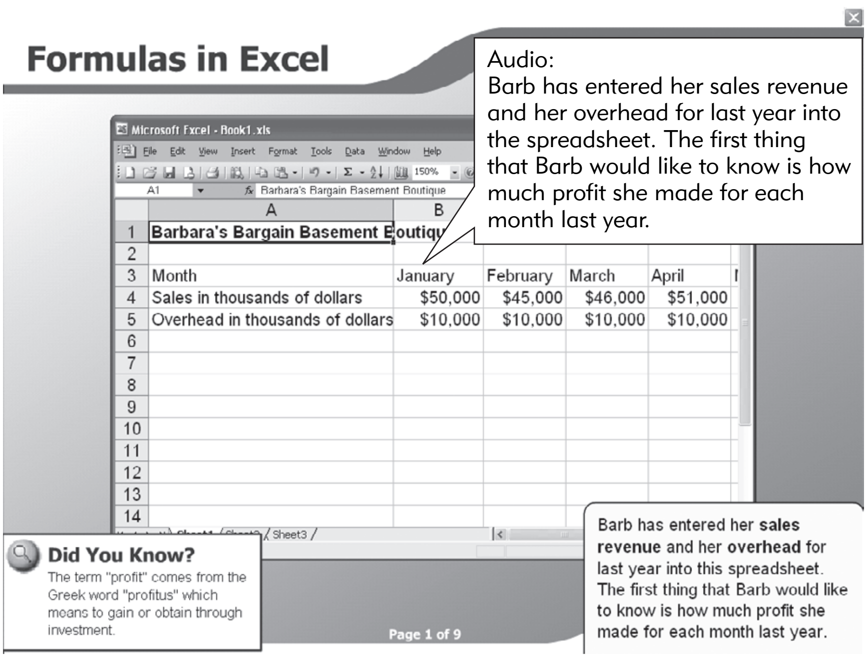
Extraneous (Irrelevant) Load

Extraneous cognitive load is the main form of load discussed in this book because it is always under your control as the instructor or course developer. Extraneous load imposes mental work that is irrelevant to the learning goal and consequently wastes limited mental resources. Those wasted resources drain mental capacity that could be used for germane load. As an example, take a look at Figure 1.2. It's a screen taken from our overloaded Excel CD demonstration lesson on how to construct formulas.

A number of features in this lesson waste limited mental capacity. For example, note that the words in the example are narrated and are also visible in text in the box located in the lower right corner of the screen. This design taxes mental resources in two unproductive ways. First, the learner must expend mental effort integrating the text in the lower right-hand corner

Figure 1.2. A Screen from a Lesson on Excel with Many Sources of Extraneous Cognitive Load.

From the Overloaded Web-Based Lesson on the CD.



with the visual portion of the spreadsheet referenced by the text. Second, the learner must expend mental effort to coordinate the words presented in two modes: visually in the text and aurally in the narration. The information in the lower left hand "Did you Know" box is another source of extraneous cognitive load, since it distracts the learner from the lesson objective.

There are many other cognitive load violations in this lesson that we will discuss throughout the book. The poor design of this instructional product imposes extraneous cognitive load that drains cognitive resources needed to achieve the learning objective. The result of inefficient training programs with many extraneous sources of cognitive load is longer times to learn, poorer learning outcomes, or both. Think of extraneous cognitive load as irrelevant load.

Balancing Mental Load in Your Training

Intrinsic, germane, and extraneous forms of cognitive load are additive. If your training program includes content that is complex, it is high in intrinsic load. If your program includes design elements that add extraneous load as well, there may be very little capacity left for germane load. Your training program will be inefficient. Consequently the learners will take longer to acquire the intended skills and/or they will not achieve the learning objective to the desired standard. To create efficient instruction, you must maximize germane load and minimize extraneous sources of load. While you usually cannot control the intrinsic load associated with the learning goals, you can manage it by segmenting and sequencing content in ways that optimize the amount of element interactivity required at any one time.

The chapters in Part II focus on ways to reduce extraneous cognitive load by: (1) optimizing the use of visual and auditory presentation modes; (2) supporting learner attention; and (3) reducing the amount of information that must be processed in memory. By minimizing extraneous load, you free limited cognitive capacity for relevant or germane load imposed by instructional techniques that serve the learning objectives. In Part III we focus on techniques that add germane load to your training.