ABOUT THIS BOOK

Why is this topic important?

There's no question that everyone reacts to visuals. And more often than not, people's opinions have little to do with the learning potential of a graphic. Although we've had years to build verbal literacy, most of us have had little training in visual literacy. As a result, training materials either underutilize or abuse visuals. In some cases, visuals included in books and online courses actually depress learning! In an age of highly visual media like computers, as well as abundant access to visuals through clip art, we need guidance on the best use of visuals for learning. Whether you are an instructor, instructional designer, or graphic artist, in this book you will find evidence-based guidelines you need to plan effective visuals in your instructional materials.

What can you achieve with this book?

The second edition of Graphics for Learning reveals the processes and most recent research-based principles involved in designing effective graphics for print or computer instructional materials. We answer questions such as:

• Does an investment in visuals pay off in better learning?
• What kinds of graphics are proved to improve learning?
• What process should I use to ensure the most appropriate visuals in my instructional materials?
• What is the truth about visual learning styles?
• How can visuals be used for motivation?
• How can I select or design visuals that boost rather than corrupt learning?
• When is it best to use animations or still videos?

How is this book organized?

The first section of the book includes three chapters that lay the foundation by introducing three views of graphics and overviewing a visual design model. Section Two looks at the ways that graphics interact with the brain to support or disrupt psychological learning processes. In Section Three you will learn how to best leverage graphics to illustrate your content, including procedures, concepts, facts, processes, and principles. Last, in Section Four we guide you through a visual design model that illustrates how to plan your visuals from the start of your project to the production phase.
About Pfeiffer

Pfeiffer serves the professional development and hands-on resource needs of training and human resource practitioners and gives them products to do their jobs better. We deliver proven ideas and solutions from experts in HR development and HR management, and we offer effective and customizable tools to improve workplace performance. From novice to seasoned professional, Pfeiffer is the source you can trust to make yourself and your organization more successful.

Essential Knowledge  Pfeiffer produces insightful, practical, and comprehensive materials on topics that matter the most to training and HR professionals. Our Essential Knowledge resources translate the expertise of seasoned professionals into practical, how-to guidance on critical workplace issues and problems. These resources are supported by case studies, worksheets, and job aids and are frequently supplemented with CD-ROMs, websites, and other means of making the content easier to read, understand, and use.

Essential Tools  Pfeiffer's Essential Tools resources save time and expense by offering proven, ready-to-use materials—including exercises, activities, games, instruments, and assessments—for use during a training or team-learning event. These resources are frequently offered in looseleaf or CD-ROM format to facilitate copying and customization of the material.

  Pfeiffer also recognizes the remarkable power of new technologies in expanding the reach and effectiveness of training. While e-hype has often created whizbang solutions in search of a problem, we are dedicated to bringing convenience and enhancements to proven training solutions. All our e-tools comply with rigorous functionality standards. The most appropriate technology wrapped around essential content yields the perfect solution for today's on-the-go trainers and human resource professionals.

www.pfeiffer.com
CONTENTS

Acknowledgments vii
Foreword to the Second Edition ix
Introduction: Getting the Most from This Resource xiii

SECTION ONE: THE FOUNDATION 1

CHAPTER 1 The Power of Visuals 3
CHAPTER 2 Three Views of Instructional Visuals 15
CHAPTER 3 A Visual Design Model for Planning Graphics Systematically 29

SECTION TWO: HOW TO USE VISUALS TO SUPPORT PSYCHOLOGICAL LEARNING PROCESSES 45

CHAPTER 4 Graphics and Learning 49
CHAPTER 5 Plan Graphics That Direct Attention 65
CHAPTER 6 Plan Graphics That Leverage Prior Knowledge 85
CHAPTER 7 Plan Graphics That Minimize Irrelevant Mental Load 97
CHAPTER 8 Plan Graphics to Help Learners Build Mental Models 115
CHAPTER 9 Plan Graphics That Support Transfer of Learning 135
ACKNOWLEDGMENTS

One of the goals of our work and this book in particular is to illustrate how research on graphics and graphic design can be implemented in practice. We appreciate the contributions of the instructional professionals who have allowed us to reprint graphic examples from their training programs to illustrate the ideas in this second edition, including:

Dale Bambrick, Raytheon Professional Services
Mimi Banks, L’Oreal
Kevin Hadlock, Moody’s Analytics
Doug LeFlamme, WellPoint
Stephanie Olson, University of Phoenix

We also thank Mark A. Palmer, who created art, including our section organizers for this book, and our editors and production support staff at Pfeiffer, including Matt Davis, Dawn Kilgore, and Rebecca Taff.
People learn better from graphics and words than from words alone. This idea—the multimedia principle—is the premise of this book. In short, this book’s theme is that you can help people learn better if you include appropriately designed graphics in instructional presentations.

For example, consider how you would teach someone a simple fact, such as, “The alveoli are tiny air sacs in the lungs.” Although these words give a correct definition, you might have some difficulty understanding what they mean. Figure F.1 shows a map of the lungs, including the alveoli, and thus helps you make sense of the verbal definition.

As another example, consider how you would teach someone a process such as how a car’s braking system works. Using words, you could say, “When the driver steps on a car’s brake pedal, a piston moves forward inside the master cylinder. The piston forces brake fluid out of the master cylinder and through the tubes to the wheel cylinders. In the wheel cylinders, the increase in fluid pressure makes a smaller set of pistons move. These smaller pistons activate the brake shoes. When the brake shoes press against the drum, both the drum and wheel stop or slow down.” However, this explanation, although accurate, is somewhat hard to follow. The frames in Figure F.2 may help you visualize the actions described in the words and thus may help you come to a better understanding of how brakes work.

As you can see in these examples, sometimes words alone are not enough to promote learning. In short, these examples show how adding graphics can promote the process of learning. Recent research confirms that, in some cases, people can learn better from graphics and words than from words alone (Mayer, 2009).
Although graphics can serve as aids to human learning, understanding and reasoning, it is important to consider that all graphics are not equally effective. How can you design graphics that help people learn, understand, or reason?

Until fairly recently, the best advice you could get about how to design graphics came from the opinions of experts. This is because, until fairly recently, there was
not a large research base or a cognitive theory of how people learn from words and pictures. However, today there is a growing research base and an educationally relevant science of learning that can be used to help you figure out how to design graphics. The second edition of Graphics for Learning takes advantage of today’s research evidence and learning theories and shows you how to design graphics that are aids to human learning, understanding, and reasoning.

How is this book different from other books on the design of graphics? The second edition of Graphics for Learning is

Evidence-based—It shows how research evidence can be used to help you design graphics that help people learn.

Theoretically grounded—It shows you how the science of learning can be used to help you design graphics that are consistent with how people learn.

Practically relevant—It shows how research evidence and cognitive theory can be used to design graphics that help people learn in real learning situations.

Clearly presented—It is presented in a clear and consistent style containing many useful, concrete examples.

Current—It provides up-to-date coverage and lets you know the current state of the field.

Thus, the distinguishing features of this book are that the guidelines it presents are based on rigorous empirical research, are consistent with the cognitive theories of how people learn, are tied to realistic learning situations, are presented clearly with concrete examples, and reflect the current state of knowledge in the field.

Of course, it is not possible to provide design principles that apply in all situations because you have to adapt instructional graphics to the needs of individual learners, specific content, and particular learning contexts. Thus, Graphics for Learning helps you understand which kinds of graphics are best for helping which kinds of learners with which kinds of learning material under which kinds of learning conditions.

This new edition of the book adds coverage of exciting new research—particularly on animation and video—that has appeared since the previous edition was published in 2003. This new edition also expands coverage of graphics using new media such as mobile learning and virtual worlds. You will also find that this new edition is more concise and visually appealing than the previous edition; yet it retains the same basic structure and message.
The power of computer graphics is impressive and growing, but there is more than cutting-edge technology involved in designing graphics that actually help people learn. *Graphics for Learning* gives you an excellent survey of evidence-based principles for how to design effective instructional graphics.

Richard E. Mayer
Santa Barbara, California
INTRODUCTION:
GETTING THE MOST FROM THIS RESOURCE

THE LOST POTENTIAL OF INSTRUCTIONAL VISUALS

More often than not, the potential of visuals to increase learning and improve work performance is unrealized. Some training materials are a wall of words where visuals are almost nonexistent. (See Figure I.1.) At the other extreme, some e-learning lessons wrap lesson content in visually rich thematic edutainment treatments to improve motivation. Both of these options defeat learning. Alternatively, many instructional materials, in print and on computers, add visuals for merely decorative purposes. Although decorative visuals may not depress learning, they do not promote it either. When we settle for a decorative graphic, we lose opportunities to increase learner comprehension. (See Figure I.2.)

Why is the potential of visuals to improve learning so under-realized? We believe that a root cause is our educational emphasis on words. We have all spent years learning verbal language skills. From the early grades through graduate school, we spend much of our instructional time learning the production and analysis of language. In contrast to language arts, the visual arts are generally considered an elective or a relief activity to offer an occasional break from the serious skills of reading, writing, and mathematics. It’s not surprising then that most of us find it much easier to express our ideas with words, even though we may respond more readily to pictures.

Related to this emphasis on verbal language is a general misconception that visual literacy belongs to the domain of a talented few. After the instruction is analyzed, designed, and developed, training professionals who want to include
graphics often have someone else create them. If the project or company is large, they are likely to have the luxury of a graphic artist to create the visuals. More frequently, those without professional graphics support use the clip art and stock photographs abundantly available on the Internet to spice up their pages or screens. Other times, training professionals are forced to use existing graphics from the source materials or some other set prescribed by the client or production team.

No matter the source, in many cases the graphics are added as something either to decorate (Figure I.3) the interface or to provide a picture of what is being discussed. All too often visuals are planned haphazardly late in the course development
process. The result is a product that does not fully utilize the potential of graphics to improve learning or, worse yet, uses visuals in ways that actually defeat learning.

This is a book about how to improve learning through the effective use of visuals. We draw our guidelines from two main sources: research evidence and a systematic design process. First, there is a wealth of recent research that illustrates what kinds of visuals are best to communicate instructional messages and to support psychological learning processes. As relevant as this research is to instructional professionals, it is buried in diverse academic journals and often presented in difficult-to-understand language. Throughout this book we summarize this research to help you make good decisions about visuals and explain your decisions to others. Second, we offer a visual design process that will help you plan your graphics in a systematic manner. Our guidelines and examples apply to
a variety of media, including books, presentation slides, and online learning screens. Finally, while our guidelines can apply to any learning setting, our focus is graphics to support the building of job knowledge and skills in organizational work settings.

**WHAT MAKES OUR BOOK DIFFERENT FROM OTHER BOOKS ON GRAPHICS?**

Our guidelines for graphics are all based on empirical research studies. For “how-to,” we suggest numerous other resources that offer instruction about layout, design, and human interface factors. These suggested materials focus on the elements of graphics: contrast, line, color, perspective, depth, arrangement, and composition.
They even zero in on how to use them to communicate specific points, ideas, images, or moods for advertising, communication, or training. However, here we talk about how to select or plan visuals effectively to illustrate specific instructional content as well as to support psychological processes of learning.

IS THIS BOOK FOR YOU?
This book is written for anyone involved in either the selection or the production of instructional materials. Some readers may work alone to produce training handouts or slides for their own presentations. Others may be part of project teams involved in production of e-learning courses. Some readers may be skilled in instructional design processes. Others may be graphic professionals who have unique visualization skills but wonder what the best ways are to use their skills to support learning. Alternatively, other readers might be involved in the selection rather than production of instructional materials for their organizations. Our book answers the following questions that these individuals typically have when planning instructional materials:

• Visuals add time and cost to any instructional project. Is there any evidence that the investment pays off in better learning?
• Besides showing pictures of objects such as system screen captures, what other kinds of visuals can I use to promote learning?
• What is the best way to display words and visuals together?
• What is wrong with using visuals to illustrate dramatic themes or puzzles to build interest in the training?
• I think visuals are great, but I have no graphics talent! When should I start to think about my visuals and how do I begin?
• When should I use animations, and when are stills more effective?
• Who profits the most from visuals in instructional materials?

AN OVERVIEW OF OUR BOOK
Our book has four sections, as illustrated in Figure I.4. Section One includes three chapters that serve as the foundation for the book. The first chapter defines instructional graphics and identifies their value. By summarizing three unique views of
visuals, the second chapter lays the conceptual foundation. The third chapter lays the practical groundwork with an overview of our visual design model that you can apply to systematically plan and design graphics in your instructional projects.

Section Two builds on this foundation. It begins by summarizing research evidence for the design of visuals that support human psychological learning processes. Chapter 4 outlines human learning processes, followed by six chapters, one on each of the six critical learning stages. Specifically, Chapters 5 through 10 review research and illustrate how to use graphics to support attention, awaken prior knowledge, manage cognitive load, build mental models, support transfer of learning, and motivate learners in ways that do not defeat learning. Chapter 11 describes psychological differences in individuals that shape how they process visuals and recommends ways to design visuals of optimal value for all learners.

Section Three looks at how to visualize five common content types found in organizational training. These are procedures, concepts, facts, processes, and principles. Each chapter describes the content type and provides several guidelines for visualizing that content. Examples are drawn from paper materials such as manuals as well as online courseware and help screens.

Section Four turns to the practical side of planning your instructional visuals. The chapters in this section expand on the visual design model introduced in Chapter 3. Examples and checklists are provided to help you (1) define your instructional context early in the process, (2) decide what visual approach will work best within your instructional context, (3) develop individual visuals, and (4) communicate your visual ideas to graphic artists who will implement them.

Our last chapter uses two different types of tasks, procedures and principles, to illustrate how to apply the design model and the research of all of the earlier chapters in a systematic way. Look to this chapter for running examples that model the processes and guidelines described throughout the book. Here you will see alternative treatments of the same content for different media such as paper versus computer; for different instructional strategies, such as directive versus guided discovery; and for different learning contexts, such as high and low bandwidth, visual and text dominant layouts, as well as serious and light styles.

To see many of our graphics in color, please check www.pfeiffer.com/go/ruthclark.
Figure I.4. A Visual Map of Graphics for Learning

Section One: The Foundation
1: Power of Visuals
2: Three Views of Visuals
3: A Visual Design Model

Section Two: Visuals to Support Psychological Learning Processes
4: Learning Process
5: Direct Attention
6: Awaken Prior Knowledge
7: Minimize Memory Load
8: Build Mental Models
9: Transfer of Learning
10: Motivate Learning
11: Learner Differences

Section Three: Visuals for Lesson Content Types
12: Procedures
13: Concepts
14: Facts
15: Processes
16: Principles

Section Four: Planning and Communicating Your Visuals
17: Define Context
18: Design the Visual Approach
19: Visualize Individual Graphics
20: Communicate Graphic Ideas
21: Apply the Principles
The three chapters in this section provide an overview of the major themes of the book. In Chapter 1 we begin the case for our premise that graphic effectiveness depends on graphic functionality. Most of us think of graphics in terms of their surface features such as line art or animation. To expand the utility of visuals for learning, we propose two additional categories based on their functions. One focuses on communication functions of graphics and the second focuses on ways graphics support psychological learning processes. In Chapters 1 and 2 we introduce these three views of graphics. We also summarize three guiding principles that reflect our most basic assumptions about what kinds of visuals are most effective for learning.

The second theme of our book focuses on a process for designing effective visuals for instructional purposes. Often visuals are considered late in the lesson development process and therefore must be compromised as a result of not considering the entire instructional context up-front. In Chapter 3 we overview a visual design process that includes the following major phases:

- Define instructional goals
- Define learning environment
- Design the visual approach
- Identify visuals to match lesson content
- Apply psychological learning guidelines to visual design decisions

We augment this overview in Section Four that elaborates on the visual design-process in greater detail.
CHAPTER OUTLINE

The Unrealized Potential of Visuals

What Is a Graphic?

Which Visuals Are Best? No Yellow Brick Road

  Factor 1: Functions of Visuals
  Surface Features of Visuals
  Communication Functions of Visuals
  Psychological Functions of Visuals

  Factor 2: Instructional Goals and Lesson Content

  Factor 3: Visuals and Learner Differences

Graphics in the Instructional Landscape
In this chapter we define instructional graphics as pictorial expressions of information designed to promote learning and improve performance in work settings. The learning value of any visual will depend on three interactive factors: (1) the features of the visual, (2) the content and goal of the lesson, and (3) characteristics of the learners. We introduce three views of graphics based on their surface features, their communication functions, and their interactions with important psychological learning processes. We know that your decisions about graphics cannot be based on psychological factors alone. You must also take into consideration the entire instructional landscape including delivery media, learning environment, and pragmatic factors such as schedules and budget.

THE UNREALIZED POTENTIAL OF VISUALS

Words and graphics are your two basic tools to help learners build new knowledge and skills. Of these two, most of us have greater expertise with words since we are trained to read and to write from an early age. The use and interpretation of graphics is a more neglected skill. Often graphics in instructional materials are afterthoughts used primarily to add visual interest to the page or screen. Consequently, the power of illustrations to promote learning is often unrealized. In fact, some instructional materials include graphics that actually depress learning!

How effective are the graphics in your organizations’ reference and training materials? Mayer, Sims, and Tajika (1995) and Woodward (1993) independently
found that only a small proportion of the visuals included in textbooks serve any important instructional purpose. More often than not, graphics are either underutilized or misapplied in a range of instructional materials from books to e-learning.

This book is about graphics and learning. Our goal is to help you plan or select the types of visuals that have proven to improve learning and workplace performance and to avoid the types of visuals shown to disrupt learning. Although a great deal of research has been done on visuals and learning in the last thirty years, most guidelines published prior to 1990 are ambiguous. For example, a summary of hundreds of research experiments conducted in the 1970s and 1980s that involved over 48,000 students offered the rather vague conclusion that “visuals are effective some of the time under some conditions” (Rieber, 1994, p. 132).

In the last twenty years, however, research on visuals has yielded significantly more helpful guidelines. Unfortunately, most of this research is scattered in diverse academic journals not typically read by practitioners. To make this knowledge accessible we summarize guidelines based on recent research that direct you toward graphics that have proven effective and away from visuals that are proven to depress learning. The increasing use of highly visual media such as computers, combined with easy to use video and screen capture tools as well as cheap access to professional visuals through online art sites, make this an ideal time to translate this research for individuals who plan, develop, or select instructional materials.

WHAT IS A GRAPHIC?

For the purposes of this book, we use the terms graphics, pictures, visuals, and illustrations interchangeably. Graphics specialists of course have a very specific meaning for these terms. But we will use them here interchangeably to reference most any non-textual element added to training materials. We include a wide range of iconic displays commonly found in instructional materials, including photographs, line drawings, animations, graphs such as pie charts, and video. Specifically, we focus on visuals designed to improve learning and performance on the job.
We define instructional graphics as *iconic expressions of content* that are designed to *optimize learning and performance* in ways that improve the *bottom-line performance of organizations*. Our definition incorporates three ideas.

1. By *iconic* we refer to expressions of content that are pictorial. As shown in Table 1.1, the surface features of such visuals may be static or dynamic and they may have high or low degrees of correspondence to real things. Thus a photograph is a highly realistic static representation, while an animation is a dynamic visual that may be realistic or abstract.

2. The second point in our definition, “designed to optimize learning and performance,” refers to the purpose of the visual. We focus on graphics that are intended to support learning or improve performance in the workplace. Thus we include examples from a range of instructional materials such as text pages and online screens as well as from work aids such as online help and web screens designed to help workers complete job tasks more effectively.

3. Finally, by “bottom line performance” we mean visuals that improve learning or performance in ways that pay off in improved organizational results. Visuals, especially original art, are often more expensive to produce than words. To achieve a return on investment from your training or work aids, you must be sure that they fill a gap in knowledge or skills or support work tasks that align with organizational goals. All too often training is used as a silver bullet to solve organizational problems that have little to do with knowledge and skills. As we describe the best use of visuals for learning, we assume that a performance analysis has shown that training or performance support is an appropriate solution.

**WHICH VISUALS ARE BEST? NO YELLOW BRICK ROAD**

There is no simple formula you can use to design or select visuals that improve learning and performance in all situations. Instead, the learning value of a visual will depend on three interactive factors summarized in Figure 1.1, including: (1) properties of the visual itself, including its surface features, communication functions and psychological functions, (2) the goal of the instruction, and (3) differences in prior knowledge of the learners.
Table 1.1. Surface Features of Graphics

<table>
<thead>
<tr>
<th>Types</th>
<th>Salient Feature</th>
<th>Definition</th>
<th>Example</th>
</tr>
</thead>
<tbody>
<tr>
<td>Static Art</td>
<td>Illustration</td>
<td>Depiction of visual elements, using various media and techniques such as pen and ink, watercolor, and computer drawing packages</td>
<td>Pen and ink outline art; Two-dimensional watercolor of flower parts; Diagrams and charts</td>
</tr>
<tr>
<td></td>
<td>Photographic</td>
<td>Captured image, using photographic or digital technologies</td>
<td>Screen capture of a software screen; Photo of person answering phones</td>
</tr>
<tr>
<td></td>
<td>Modeled</td>
<td>Computer-generated (CG)—A faithful reproduction of reality, using various media, included computer assisted drawing packages</td>
<td>Three-dimensional representation of an office; Three-dimensional representation of combustion engine</td>
</tr>
<tr>
<td>Dynamic Art</td>
<td>Animation</td>
<td>Series of images that simulate motion</td>
<td>Demonstration of steps in a software procedure; Process of ammunition detonation shown through line art</td>
</tr>
<tr>
<td></td>
<td>Video</td>
<td>Series of images, captured as they occur, digitally or on film or magnetic tape, displayed serially, over time</td>
<td>Capture of the hydrogen bomb test explosion at White Sands, New Mexico; Film of human resources director interviewing a job applicant</td>
</tr>
<tr>
<td></td>
<td>Virtual Reality</td>
<td>Interactive three-dimensional world that dynamically changes as the “user” moves through and views it</td>
<td>Simulated walkthrough of the human heart</td>
</tr>
</tbody>
</table>
Factor 1: Functions of Visuals

In describing graphics, most of us use terms such as line art or photograph that refer to their surface features. But for learning purposes, the functional characteristics that affect how the illustration communicates information or how it facilitates psychological learning processes are as important as its surface features. Therefore, we present three different views of visuals based on their (1) surface features that focus on what they look like and how they are created, (2) communication functions that focus on how they convey information, and (3) psychological functions that focus on how they facilitate human learning processes. Table 1.2 summarizes these three views. The three views are interrelated. For example, different surface features such as static or animated visuals will influence their psychological effects. Additionally, different communication functions will have different psychological effects.

Surface Features of Visuals

We have new evidence that the surface features of visuals influence their psychological effectiveness. For example, do you think you should illustrate motion with a series of static visuals or with an animation? Which would be better
for learning? It turns out that a series of still visuals can be more effective for some learning goals such as teaching how things work (Mayer, Sims, & Tajika, 2005). On the other hand, animations are more effective for teaching skills involving motion (Ayres, Marcus, Chan, & Qian, 2009). Therefore, we cannot ignore surface features of visuals—either from a pragmatic production standpoint or from a psychological effectiveness perspective.

Communication Functions of Visuals
Just as we rely on language grammars to help us assemble words correctly, we need classification systems for visuals that go beyond surface features. To help you plan graphics based on their functional properties, we describe our adaptation of a taxonomy of illustration summarized by Carney and Levin (2002) and illustrated by Lohr (2007). The taxonomy is summarized in Table 1.3. This taxonomy will help you plan visuals based on their communication functions—not just their surface features. In Chapter 2, we describe the communication taxonomy in greater detail.

Psychological Functions of Visuals
In addition to communicating effectively, your visuals also must support critical psychological learning processes. Visuals that disrupt these processes have been