COMPUTER GAMES FOR LEARNING

AN EVIDENCE-BASED APPROACH

RICHARD E. MAYER

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To Beverly

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Preface

What Is This Book?

Computer games for learning are computer games that are intended to promote learning. The primary goal of this book is to examine what the research evidence has to say about the educational value of computer games for learning, including learning in K–12 education, college education, and workplace training. In short, this book provides a comprehensive, up-to-date, and evidence-based approach to the study of learning with computer games.

Computer Games for Learning distinguishes among three genres of game research: the value-added approach, the cognitive consequences approach, and the media comparison approach (Mayer, 2011). The value-added approach to game research involves comparing the learning outcome measures of students who learn with a base version of a game versus with the base version plus one additional feature. For example, in our research at the University of California, Santa Barbara (UCSB), we have compared students who played the base version of *The Circuit Game* with those who played the same game along with prompts to self-explain each major decision by selecting a reason from a menu (Johnson & Mayer, 2010; Mayer & Johnson, 2010). The base plus self-explanation group performed better than the base group on solving transfer problems on a embedded test, indicating that adding an instructional feature based on self-explanation improved student learning. We also have found that students performed better on solving transfer problems after learning about botany in the *Design-a-Plant* game if an in-game character named Herman-the-Bug communicated by voice rather than through printed text, and if he used conversational as opposed to formal style (Moreno & Mayer, 2000, 2002a, 2002b, 2004; Moreno, Mayer, Spires, & Lester, 2001). In a geology simulation game called the

Profile Game, students performed better on transfer problems if they received training in the names and characteristics of the key concepts before playing the game (Mayer, Mautone, & Prothero, 2002). In an industrial engineering simulation game titled *Virtual Factory*, students performed better on a transfer posttest if an in-game character gave hints and feedback with polite rather than direct wording (Wang et al., 2008). Finally, adding a narrative theme to an adventure game named *Cache 17* intended to teach how mechanical devices work did not improve posttest performance on a transfer test (Adams, Mayer, MacNamara, Koening, & Wainess, 2012). There is a growing research literature based on the value-added approach, so a major goal of the book is to analyze that literature. Overall, value-added research has practical implications for how to design effective educational games as well as theoretical implications for testing cognitive and motivational theories.

The cognitive consequences approach to game research involves comparing the pretest-to-posttest change in learning outcome or cognitive skill (or posttest performance only) for students who played an off-the-shelf computer game for an extended period versus those who did not play the game. For example, in our lab at UCSB we found that students who were required to play the classic video game *Tetris* for five hours showed greater pretest-to-posttest gains in some measures of mental rotation than did students who did not play the game but no differences on most spatial skill measures (Sims & Mayer, 2002). In a different use of the cognitive consequences approach, fifth graders were selected to participate in an after-school club called the Fifth Dimension in which they played a variety of educational computer games over the course of a semester; these students performed better on posttests involving learning a new math game than a matched group of children who were not selected for the club (Mayer et al., 1997; Mayer, Quilici, & Moreno, 1999). There is a substantial literature examining the effects of playing off-the-shelf games on measures of spatial cognition skill (Anderson & Bavelier, 2011), which I also summarize in this book. Overall, the cognitive consequences approach has both practical and theoretical implications concerning people playing video games intended for cognitive improvements.

Finally, the media comparison approach involves comparing the posttest performance on measures of learning outcomes of students who learned by playing a game versus students who learned the same material with

conventional media. In our lab at UCSB, for example, we found better transfer test performance from students who learned by playing the *Design-a-Plant* game than from students who learned the same material presented as a series of frames with printed text and graphics (Moreno, Mayer, Spires, & Lester, 2001). In contrast in games with a more complex and intrusive narrative theme, we discovered that students performed worse on a transfer posttest after playing *Crystal Island*, about the spread of disease, or *Cache 17* than from slideshows of the same material featured in each game (Adams, Mayer, MacNamara, Koening, & Wainess, 2012). Although the pitfalls of media research have been well documented (Clark, 2001), this genre of game research has useful practical and theoretical implications for the inclusion of computer games in school settings and beyond.

For the past fifteen years, my colleagues and I at UCSB have been studying the effectiveness of educational games within each of these three research genres, grappling with the key theoretical and methodological issues in game research, and monitoring the growing evidence base on learning with games. I share the fruits of this work in *Computer Games for Learning: An Evidence-Based Approach*—including both our own research program and the full breadth of worldwide research on game effectiveness.

Why Did I Write This Book?

Abt's (1970) *Serious Games*, which is recognized as the first book to consider the potential of games as educational tools, sought evidence for the effectiveness of serious games in education, but of course, there was not a solid research base at the time. Today, many strong claims are made for the educational value of computer games, in the tradition of Abt's unsupported advocacy for serious games. For instance, in an interview on a popular Sunday morning news show on CNN (*Fareed Zakaria GPS*, May 15, 2011), Eric Smith, the CEO of Google, contended, "There's lots of evidence that people learn best in these multiplayer games … and they learn enormous amounts." In contrast, a recent review of the scientific research on games (Clark, Yates, Early, & Moulton, 2011, p. 269) concluded, "All of the studies that have been published in reputable journals have reached a negative conclusion about learning from games." In another review, O'Neil and Perez (2008) noted, "Computer games were hypothesized to be potentially useful for

instructional purposes [but] … there is almost no guidance for game designers and developers on how to design games that facilitate learning" (p. ix). *Games for Learning* helps address this conflict by examining what the research evidence has to say about the effectiveness of computer games intended to promote learning.

What Is in This book?

As can be seen in the table of contents, *Computer Games for Learning* contains eight chapters—three introductory chapters, four chapters analyzing the research base on game effectiveness, and a concluding chapter. Chapter 1, "Introduction: Taking an Evidence-Based Approach to Games for Learning," defines *games for learning*, distinguishes among three research questions about games for learning, provides the rationale for an evidence-based approach, explores the potential educational benefits and drawbacks of games for learning, analyzes the claims of game proponents, and summarizes the history of games for learning.

Chapter 2, "Method: Conducting Scientific Research on Games for Learning," defines and exemplifies three genres of game research (i.e., value added, cognitive consequences, and media comparison) as well as four goals of game research (i.e., what works, when does it work, how does it work, and what happens), applies six principles of scientific research in education to game research (i.e., pose researchable questions, link to theory, use appropriate methods, show coherent reasoning, replicate across studies, and disseminate results), defines and exemplifies three characteristics of experimental research on games (i.e., experimental control, random assignment, and appropriate measures), describes eight common methodological errors in game research, and explores the role of effect size in game research.

Chapter 3, "Theory: Applying Cognitive Science to Games for Learning," examines how the science of learning, science of assessment, and science of instruction are related to learning with games, and shows how basic theories of learning and motivation are relevant to learning with games.

Chapter 4, "Examples of Three Genres of Game Research," provides instances of value-added, cognitive consequences, and media comparison studies that were conducted by our lab at UCSB.

Chapter 5, "Value-Added Approach: Which Features Improve a Game's Effectiveness?," provides a meta-analysis of published studies that compare learning with a base version of a game versus a base version plus one added feature (by reporting means and standard deviations of each group on a measure of learning outcome), and offers a summary of the current state of the field.

Chapter 6, "Cognitive Consequences Approach: What Is Learned from Playing a Game?," supplies a meta-analysis of published studies that compare pretest-to-posttest changes (or posttest scores only) on learning outcome or cognitive skill measures in people who played an off-the-shelf game for an extended time to those changes in people who did not play the game, and provides an analysis of the current state of the field.

Chapter 7, "Media Comparison Approach: Are Games More Effective Than Conventional Media?," offers a meta-analysis of published studies that compare the learning of outcomes of people who learned with a game versus with conventional media, and provides an analysis of the current state of the field.

Chapter 8, "The Future of Research on Games for Learning," summarizes the current state of scientific research on learning with games, offers a research agenda based on promising findings, explores innovations in game research, and suggests domains and contexts in which games have the most potential for fostering learning. The scientific study of learning with games is an emerging field, so this book seeks to help set a productive research course for the future.

The reference list uses an asterisk to highlight each empirical research study contained in the meta-analyses. The book also contains an author and subject index.

Should You Read This Book?

Computer Games for Learning is intended for students and faculty interested in understanding research on educational games; instructional designers and training developers interested in taking an evidence-based approach to educational game design; educational leaders, instructors, and consumers interested in selecting effective educational games; and general readers who are interested in what the research has to say about the value of educational games. It is written for a multidisciplinary audience from a variety of fields

including education, psychology, and technology. The book is appropriate for readers of all levels of expertise in the field of educational games ranging from beginners to experts. It could be used in undergraduate and graduate courses concerned with learning and instruction, educational technology, instructional design, and game design.

How Is This Book Different from Other Books on Computer Games?

There are no other books on the market that provide an up-to-date, comprehensive analysis of what the research evidence has to say concerning how to design computer games that promote learning. Three classes of competing books are edited books, visionary books, and practical books, all of which differ from this one in terms of comprehensiveness, educational focus, and/or evidence-based approach.

First, some books on games are edited volumes. There are several fine anthologies concerning research on educational computer games, including Tobias and Fletcher's (2011) *Computer Games and Instruction* and O'Neil and Perez's (2008) *Computer Games and Team and Individual Learning*. Although these books make useful contributions to the field, they are subject to the criticism of most edited books that the approach varies from chapter to chapter and the coverage is selective. Honey and Hilton's (2011) *Learning Science through Computer Games and Simulations* provides a consensus overview of research and development concerning a small segment of the empirical research base by focusing on simulation games for science learning, so it is much narrower than this book. Van Eck's (2010) *Gaming and Cognition* contains chapters that explore conceptual issues and describe development projects in educational games, but does not emphasize empirical research on game effectiveness. Vorderer and Bryant's (2006) *Playing Video Games* as well as Raessens and Goldstein's (2005) *Handbook of Computer Game Studies* offer useful information, but do not spotlight educational issues. In short, *Computer Games for Learning* differs from edited books on computer games by being more coherent and comprehensive in the coverage of research evidence that is relevant to the educational impact of games for learning.

Second, some books on games are visionary volumes, such as Gee's (2007a) *Good Games and Good Learning*, Gee's (2007b) *What Video Games Have to Teach Us about Learning and Literacy*, Shaffer's (2006) *How Computer*

Games Help Children Learn, Squire's (2011) *Video Games and Learning*, Prensky's (2006) *Don't Bother Me, Mom—I'm Learning,* or McGonigal's (2011) *Reality Is Broken*. Such books supply examples of exciting educational game projects and help inspire readers to visualize a future for education in which educational games play a prominent role, but they are not intended to provide comprehensive and convincing evidence. The book you are holding examines the untested claims of game proponents by taking a broad look at the available research base on the effectiveness of educational games.

Third, there are numerous practical guides such as Prensky's (2001) *Digital Game-Based Learning* or Fullerton's (2008) *Game Design Workshop*, but such books are not intended to explore the underlying empirical research base on game design. *Computer Games for Learning* differs from practitioner-oriented books by taking an evidence-based approach.

In short, *Computer Games for Learning* is most similar to Abt's (1970) classic little book *Serious Games*, which attempted to provide an integrated, comprehensive, and evidence-based view of the educational value of games. It can be seen as a modern update that takes an evidence-based approach to examining the educational value of computer games. This book also can be viewed as a complement to *Multimedia Learning* (Mayer, 2009), which takes an evidence-based approach to the instructional design of multimedia presentations.

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I Introduction

1 Introduction: Taking an Evidence-Based Approach to Games for Learning

Chapter Outline

What Are Games for Learning?
Three Questions about Games for Learning
What Is an Evidence-Based Approach?
Potential Benefits and Drawbacks of Games for Learning
Four Roles in the Field of Games for Learning
What Proponents Say: The Claims Are Strong
What Researchers Say: The Evidence Is Weak
Historical Overview of Game Research

Summary

Computer games for learning are games and simulations that are intended to promote academic learning. Three important questions about games for learning are:

1. The *value-added question*, Which game features improve learning?
2. The *cognitive consequences question*, What do people learn from playing an off-the-shelf game?
3. The *media comparison question*, Do people learn academic content better from games than from convention media?

An *evidence-based approach* focuses on research data for answering these questions, gleaned from methodologically sound studies and guided by learning theory. Although game proponents make strong claims for the potential of games to revolutionize education, research investigators take a more cautious approach by examining the available scientific evidence. Research on games has a forty-year history, but reviews of game research describe a field that is disorganized and unfocused, with an excess of speculative essays and methodologically flawed studies. This book seeks to systematize research on games for learning by sorting relevant experiments into three research paradigms—value added, cognitive consequences, and media comparison—and then examining published experimental comparisons within these categories that meet the basic requirements of experimental methodology—randomly assigning the participants to groups, matching treatment and control groups on all dimensions except the one being studied, and using appropriate measures of learning outcome.

What Are Games for Learning?

Games for learning are games and simulations that are intended to promote learning. As represented in figure 1.1, playing a game for learning (shown in the box on the left) is intended to cause (indicated by an arrow) a change in the player's knowledge or skill (shown in the box on the right). When games for learning are delivered electronically—such as

Figure 1.1
What are games for learning? Games for learning are games intended to promote learning (i.e., intended to improve performance on measures of learning outcome).

on a desktop computer, laptop computer, tablet, smartphone, or game console—they can be called computer games for learning. The primary goal of this book is to examine what the research evidence has to say about the educational value of computer games for learning. In short, my aim is to provide you with a comprehensive, up-to-date, and evidence-based approach to the study of learning with computers games.

What is a game? Consider the following games: baseball, chess, dominoes, *FarmVille*, *Monopoly*, *Pac-Man*, *Risk*, *Space Invaders*, *Tetris*, and *World of Warcraft*. They share a common set of defining characteristics. A defining characteristic means that to be a game, an educational activity must possess this characteristic. Although you might expect me to engage in a long (and somewhat fruitless) discourse about the definition of games, I have found that it is more useful to list the defining characteristics of games. My list is summarized in table 1.1 (adapted from Mayer & Johnson, 2010): games are interactive, simulated systems that are rule based, responsive, challenging, cumulative, and inviting. This list of features is broad enough to include board games collecting dust in your closet, arcade games you see in the lobby of your local movie theater, console games you like to play on your television screen, and video games you access from the Web to play on your tablet or smartphone.

Let's examine each defining characteristic of games:

Games are rule-based simulated systems The single most important feature of a game is that it represents a simulated system or model based on causal rules that the player can master (in addition to the operational rules of game play, which also must be learned). You are in a simplified world in which things happen for a reason.

Table 1.1
Five defining characteristics of games

Characteristic	Description	Game elements
Rule based	Events occur within a causal system, based on a knowable set of rules	Abstraction of concepts and reality Rules
Responsive	Environment allows for player to act, and responds promptly and saliently	Feedback Replay
Challenging	Environment provides opportunities for success on tasks that are difficult for the player	Goals Levels Conflict, competition, or cooperation
Cumulative	Current state of the environment reflects player's previous actions and allows for assessment of progress toward goals	Time Reward structure
Inviting	Environment is interesting, appealing, and fun for the player	Aesthetics Curve of interest Storytelling

Sources: Characteristics based on Mayer & Johnson (2010); game elements based on Kapp (2012).

Games are responsive Another defining feature is that the simulated system is interactive—that is, it responds promptly and clearly to the player's actions. You can do certain things in the game, and as a result of your actions, something happens in the game.

Games are challenging Another defining feature is that the simulated environment allows for the player to succeed on difficult tasks. You can try to master tasks that are difficult for you.

Games are cumulative Yet another defining feature is that the simulated environment reflects the player's previous actions and allows for assessment of the player's progress toward goals. For example, the game may display your current level or score in an obvious way or the game may be subtle in the way it reflects where you are.

Games are inviting Concerning the impact of games on learners, game scholars have noted that games are fun to play, thereby motivating the learner to keep playing. Thus, a final defining feature is that the simulated

system is interesting or appealing to the player, with the intention of making the experience fun.

These are defining features of games in the sense that to be called a game, a learning environment has to possess these five characteristics.

Kapp (2012) has described *game elements*, which together can turn an educational activity into a game for learning. The right side of table 1.1 shows how some game elements—the building blocks of games—correspond to the five defining characteristics of games for learning. The rule-based characteristic corresponds to the game elements of abstraction (i.e., presenting a simplified model) and rules (i.e., incorporating cause-and-effect rules in the model). The responsive characteristic corrresponds to the game elements of feedback (e.g., telling how far the player is from accomplishing the goal) and replay (i.e., being able to redo an episode or move). The challenging characteristic corresponds to the game elements of goals (e.g., a clear indication of what the player is supposed to accomplish), levels (i.e., a sequence of progressively more challenging tasks), and conflict, competition, or cooperation (e.g., beating an opponent or being part of a team). The cumulative characteristic corresponds to the game features of time (e.g., including a clock) and reward structure (e.g., including scoreboards or awards). Lastly, the inviting characteristic corresponds to the game features of aesthetics (e.g., using appealing graphics), curve of interest (i.e., introducing new aspects of the game in a way to prime interest), and storytelling (i.e., adding a narrative theme).

Kapp (2012) uses the term *gamification* to refer to the process of turning an educational lesson into an educational game by adding appropriate game elements. As Kapp warns, however, simply adding game elements to a lesson does not ensure you will create a good game—that is, a game that people will like to play. To create a good game requires adding appropriate game elements in a way that meets the five defining characteristics in table 1.1. A good game can be seen as a successful art form that is more than the sum of its game elements. Like any successful art form, a good game creates enjoyment, elicits emotional response, provokes thought, and/or motivates action. Although an analysis of the artistic creation of games is beyond the scope of this book, it is worth acknowledging that the larger field of game studies crosses disciplinary boundaries. This book examines how we can mix instructional elements and game elements to create games that promote learning.

What's in a name? You might see a game scholar write about *video games* or *digital games*, whereas a game researcher might use the term *computer games* or *serious games*. In the interests of simplification, I use all of these terms interchangeably. When a game involves a simulated environment in which the player can manipulate things and see what happens, it is sometimes called a *simulation game*. Yet the line between simulation game and computer game is so fuzzy that I include simulations and games in the same category. In short, I use the term *games for learning* to include video games, digital games, computer games, serious games, and simulation games that are intended to promote a change in the learner's knowledge or skill.

When we are interested in moving from games to games for learning, we need to focus on a crucial part of the definition of games for learning: they cause a measurable change in the player's academic knowledge or cognitive skill. A *learning objective* is a clear statement of the to-be-learned knowledge or skill. A *learning outcome* is a clear description of what was learned. Overall, the main goal of most commercially successful computer games is to provide entertainment, but the main goal of games for learning is to foster learning related to academic learning objectives. In short, games for learning are intended to help players build learning outcomes that match the learning objective.

Three Questions about Games for Learning

Our journey into the domain of game effectiveness research starts with some intriguing questions: Do certain features make a computer game more effective in promoting learning? Do people learn useful cognitive skills from playing off-the-shelf games? Do people learn academic content better from playing a computer game than from conventional instruction? If you are interested in answering these kinds of questions, then this book is for you. This book is intended to show you the progress that game researchers have made in addressing these three kinds of questions.

As you can see in table 1.2, three types of questions drive our study of games for learning (Mayer, 2011b):

1. Value-added questions ask how to improve the educational effectiveness of a game. In value-added research, we are interested in whether adding an

Table 1.2
Three kinds of questions about games for learning

Type of question	Example
Value added	Does adding feature X to a game improve learning?
Cognitive consequences	What do people learn from playing an off-the-shelf game?
Media comparison	Do people learn academic content better from games than from conventional media?

Source: Adapted from Mayer (2011b).

instructional feature results in better performance on a test of learning. For example, do students learn better from a game when an on-screen agent speaks to them versus when an on-screen agent communicates the same words through on-screen printed text?

2. Cognitive consequences questions ask about what people learn when they play an off-the-shelf game for an extensive amount of time. In cognitive consequences research, we are interested in whether students who are assigned to play a game show greater improvement on a cognitive skill related to academic performance than students who do not play the game. For example, do students who are asked to play a first-person shooter game for ten hours improve spatial cognition scores more than students who do not play a first-person shooter game?

3. Media comparison questions ask about whether games are a better venue for academic learning than conventional media. In media comparison research, we are interested in whether students learn academic content better from a game or a conventional lesson on the same material. For example, do students who play a physics simulation game perform better on a test of learning as opposed to students who receive the material as a slideshow presentation?

Although each of these questions focuses on a different aspect of the educational effectiveness of games, they all share an important characteristic: *testability*. Testability means it is possible to conduct methodologically sound studies that generate evidence that can address each question. We start our quest for an evidence-based approach to the study of game effectiveness with these three testable questions.

What Is an Evidence-Based Approach?

An evidence-based approach to the study of games for learning involves using appropriate research methods, grounded in learning theory, to yield data needed for answering testable questions. As you can see, this definition has four parts. First, we use appropriate research methods, which are described in chapter 2. Second, we ground research in theories of learning that are relevant to games, as described in chapter 3. Third, we seek to answer testable questions, such as discussed in this chapter. Finally, we gather data, which is at the heart of the scientific study of games for learning. The entire second section of the book, chapters 4 through 7, reviews the research evidence concerning each of our three basic research questions about learning from games.

Why should you care about taking an evidence-based approach to the study of games for learning? In my opinion, an evidence-based approach offers the most helpful way to answer questions about the educational effectiveness of games because it is self-correcting. As research evidence begins to accumulate, we can reject unhelpful accounts of learning with games and construct more useful ones.

In contrast to a scientific approach based on research evidence, there are many other ways to address questions about the educational effectiveness of computer games. Some of the most popular alternatives are to make unsupported claims, point to the popularity of games, or provide anecdotes.

Make unsupported claims Perhaps the most common unscientific approach to addressing questions about the educational effectiveness of computer games is simply to assert that they can be effective. The benefit of this approach is that it frees the author from the pesky requirement of providing a logical argument, based on evidence, and allows for an emotional appeal. The drawback of this approach is that it does not offer an effective way to determine if the claims are justified.

Point to the popularity of games Another popular approach is to highlight the widespread use of video games and the obvious appeal of playing them. The benefit of this approach is that it is based on some evidence, such as the billions of dollars spent on games or millions of game players. The drawback is that this kind of evidence is unhelpful in answering the kinds of basic questions described in the previous section.

Provide anecdotes An additional popular approach is to offer transcripts (or videos) of people talking about the clever things they do while playing games. On the positive side, carefully selected anecdotes provide the appearance of scientific respectability and may even supply interesting examples. On the negative side, there is overwhelming consensus among scientific researchers that reports based primarily on selected anecdotes or testimonials do not qualify as an evidence-based approach.

When you notice that an author resorts to any (or all) of these practices in examining the effectiveness of games for learning, you have left the world of science, and entered the murky realm of speculation and hype.

For the past fifteen years, my colleagues and I at UCSB have been studying the effectiveness of computer games for learning and monitoring the growing evidence base within each of the three research genres listed in table 1.2. We share this research evidence with you in *Computer Games for Learning*—including both our own published research and the full breadth of worldwide published research on game effectiveness.

Potential Benefits and Drawbacks of Games for Learning

Games for learning include both *game features*, intended to motivate learners to engage in game playing, and *instructional features*, intended to foster appropriate cognitive processing during game playing. In particular, the motivating effects of game features include encouraging players to initiate, maintain, and intensely engage in game play. The cognitive effects of instructional features include helping learners attend to relevant material, mentally organize it into a coherent cognitive representation, and integrate it with relevant prior knowledge.

Game features and instructional features in games can affect the three types of cognitive processing during learning shown in table 1.3: *extraneous processing*, which wastes precious cognitive capacity; *essential processing*, aimed at attending to and mentally representing the academic content; and *generative processing*, which involves deeper reflection on the academic content. The goal of effective game design is to reduce extraneous processing, manage essential processing, and foster generative processing (Mayer, 2011a).

Designing effective educational games always involves a tension between including game features for entertainment and instructional

Table 1.3
Three kinds of cognitive processing during game learning

Type of processing	Description	Caused by
Extraneous processing	Cognitive processing that is not related to the instructional objective	Poor game design
Essential processing	Cognitive processing aimed at attending to and mentally representing the academic material	Inherent difficulty of the academic material
Generative processing	Cognitive processing aimed at making sense of the academic material	Player's motivation to engage in learning

Source: Adapted from Mayer (2011a).

Table 1.4
Potential and pitfalls of game features and instructional features in computer games for learning

	Game features	Instructional features
Potential	Game features can promote motivation to learn (increasing generative processing)	Instructional features can promote learning (increasing essential and generative processing)
Pitfalls	Game features can diminish learning (increasing extraneous processing)	Instructional features can diminish motivation to learn (decreasing generative processing)

Source: Adapted from Mayer & Johnson (2010).

features for learning. Table 1.4 summarizes some benefits and drawbacks to game features and instructional features in games for learning. On the positive side, game features can promote the player's motivation, thereby fostering generative cognitive processing and leading to deeper learning outcomes. On the negative side, game features can distract the learner, causing an increase in extraneous cognitive processing and leading to poorer learner outcomes. On the positive side, instructional features can guide the player's attention toward the academic content, thereby supporting essential processing, and prime deeper processing of the academic content, thereby supporting generative processing. On the negative side, though, instructional features can destroy the fun of game playing, thereby reducing the player's interest and diminishing the player's willingness to engage in generative processing.

The challenge of game design is to balance the positive and negative aspects of game features and instructional features to suit the needs of each learner. The research reviewed in this book is intended to help guide this balancing process.

Four Roles in the Field of Games for Learning

As shown in table 1.5, there appear to be four main roles in the area of game scholarship and research:

1. *Visionaries*, who inspire us with a vision of how education could be transformed using games.
2. *Developers*, who dazzle us with a continual stream of exciting new games.
3. *Appliers*, who enrich us by adapting games for learning to use in schools, training programs, and informal situations.
4. *Investigators*, who inform us by conducting scientifically rigorous research about the educational effectiveness of games.

Although visionaries, developers, and appliers tend to focus on the positive potential of games for learning, the lonely gang of investigators (including me) tends to be concerned about the level of scientific support for games.

What Proponents Say: The Claims Are Strong

As shown in table 1.5, visionaries, developers, and appliers usually hold positive views of the educational value of games, so I refer to them as *game proponents*. Their motto might be: "Let's change the educational

Table 1.5
Four roles in game research

Who	What they do	How they view games
Visionaries	Inspire	Positive
Developers	Dazzle	Positive
Appliers	Enrich	Positive
Investigators	Inform	Critical

Table 1.6
What the proponents say: Strong claims for games

"Kids learn more positive, useful things for their future from their video games than they learn in school"
"Good games are problem-solving spaces that create deep learning—learning that is better than what we often see today in our schools"
"The key to solving the current crisis in education will be to use the power of computer and video games to give all children access to experiences, and build interest and understanding"
"Good games lend themselves to systematic understandings"

Sources: Respectively, Prensky (2006, p. 4); Gee (2007, p. 10); Shaffer (2006, p. 67); Squire (2011, p. 36).

world with games." Proponents look for ways to revolutionize education for all learners, and thus seek to bring some much-needed social justice to the world. For example, Table 1.6, gives you a taste of what visionaries have to say about the exciting potential of games to revolutionize education.

As you can see from this set of quotations from leading gaming proponents, there is a tendency to make strong claims. Some of the common claims are: the present educational system has failed; today's students need a different kind of learning experience based on exploration and fun; and games offer an effective alternative educational experience that has been shown to work better than traditional instructional methods. In short, game proponents are telling us that today's schools are not suited to the needs of today's students, but this mismatch can be fixed by incorporating learning experiences based on games and simulations.

Game proponents invite us to imagine a future in which educators agree that students can learn better from well-designed computer games than from conventional instruction in schools. In that future, well-designed games enable students to learn crucial twenty-first-century skills that they will need in their lives. To achieve this vision, the focus will be on pinpointing gaming features that promote learning, thus leading to ever more powerful games for learning. McGonigal (2011), for instance, boldly states: "I foresee games that fix our educational systems" (p. 14).

Within this vision of the future of games in education, I have detected three intertwined themes in the claims that game proponents make:

Media comparison claims Conventional educational practices in schools are not doing a good job at helping students learn, whereas the techniques

embodied in well-designed computer games can do a much better job at promoting deep learning.

Cognitive consequences claims Playing computer games can help students develop the kinds of skills and knowledge they will need to lead productive lives in the twenty-first century.

Value-added claims Enhancing certain game features can improve student learning with computer games.

Together, the three intertwined themes share a common premise that well-designed games can promote useful learning.

What Researchers Say: The Evidence Is Weak

If you read popular books by game proponents (as sampled in table 1.6), you would come away feeling enthusiastic about the role of computer games in promoting learning. Game proponents inspire us to consider what games have to offer to education. You might be curious, though, about whether there is convincing evidence to support the claims made for the effectiveness of computer games. Would you be persuaded if the statements about educational games were based on the author's own personal experiences in playing video games or informal observations of someone playing video games? Would you be convinced if the claims were based on anecdotes from teachers and others? How about testimonials from players or game designers? All too often, these are the kinds of evidence supporting the claims being made by game proponents.

What you might not be able to see from the quotes from proponents in table 1.6 is that these strong claims are not always based on strong evidence. Where is the evidence for these claims? Some authors rely on their personal experience or informal observations of children playing games. Some authors offer descriptions of clever games and simulations, sometimes with inspiring words from the developers. Other authors offer what can be called observational *proof-of-concept* studies, which consist of detailed observations of people making discoveries and apparently learning while playing a game.

In contrast, investigators tend to be more critical of the educational value of games, so I refer to them as *game critics*. Their motto might be: "Show me the evidence." Critics keep an open mind and may ultimately

Table 1.7
What game researchers say: Weak evidence for games

"Many strong claims are made for the educational value of computer games, but there is little strong empirical evidence to back up those claims"
"There is relatively little research evidence on the effectiveness of simulations and games for learning"
"There is considerably more enthusiasm for describing the affordances of games and their motivating properties than for conducting research to demonstrate that those affordances are used to attain instructional aims.... This would be a good time to shelve the rhetoric about games and divert those energies to conducting needed research."
"While effectiveness of game environments can be documented in terms of intensity and longevity of engagement ... as well as the commercial success of the games, there is much less solid empirical information about what outcomes are systematically achieved by the use of individual and multiplayer games to train participants in acquiring knowledge and skills. Further, there is almost no guidance for game designers and developers on how to design games that facilitate learning."

Sources: Respectively, Mayer (2011b, p. 281); Honey & Hilton (2011, p. 21); Tobias, Fletcher, Dai, & Wind (2011, p. 206); O'Neil & Perez (2008, p. ix).

turn out to be proponents depending on what the evidence has to say. In this book, I take on the role of an investigator, with the goal of snooping high and low for scientifically rigorous evidence concerning the educational effectiveness of computer games for learning.

For example, table 1.7 gives you a taste of what investigators have to say about the need for empirical evidence grounded in learning theory. A common theme among game investigators is that we need an evidence base of game research. As you can see from the first quote in table 1.7, I fall squarely into the investigator category, and I have written this book as an honest attempt to systematize the available evidence and research-based theory in a way that serves all players in the field of games for learning.

Searching for useful research evidence can be a cumbersome process. Some game scholars occasionally refer to a scientific research study, but when you try to track down the actual paper, you may find that it was not published in a publicly available peer-reviewed research journal. If you are able to locate the paper, you might discover that the research fails to meet the minimal standards of scientific research in education or does not actually test the question under consideration. In a growing number of cases, however, you might be able to successfully track down a reference to a

methodologically sound study that does give you new evidence about game effectiveness. These are the cases that form the basis for this book.

Each player in the field of games for learning takes on a specific role or even a combination of roles. The visionaries who inspire us, designers who dazzle us, and appliers who enrich us are not responsible for providing evidence. That job falls on the investigators and that job is the focus of this book.

Historical Overview of Game Research

Abt's (1970) *Serious Games* is widely considered to be the first book to examine the potential of games as educational tools, although, of course, it was published before the video game revolution and before there was much of a research literature on the instructional effectiveness of games. Abt offered the observation that "games are effective teaching and training devices" (p. 13) but he was not able to provide scientifically rigorous evidence to back up his argument. The book you are holding, *Computer Games for Learning: An Evidence-Based Approach*, takes up this challenge by systematically examining the current state of research evidence on games for learning.

Over the years, many strong claims have been made for the educational value of computer games, in the tradition of Abt's unsupported assertion in the foregoing paragraph. In contrast, Hannafin and Vermillion (2008, p. 215) observed: "Games are very motivating and have tremendous potential in education, but despite a rapidly growing base, there is yet insufficient evidence to draw definitive conclusions." Clark, Yates, Early, & Moulton (2011) offer an even harsher analysis of the scientific research on games: "All of the studies that have been published in reputable journals have reached a negative conclusion about learning from games" (p. 269).

Computer Games for Learning helps resolve this conflict between strong claims and weak evidence by providing a systematic and comprehensive analysis of what the research evidence has to say about the effectiveness of games for learning. Should the future of education include a heavy dose of computer games? If so, how should the games be designed and used in education—that is, what makes a good game for learning? Which kinds of learning outcomes, types of learners, and learning contexts are best suited for

computer games? All these questions are concerned with the educational effectiveness of computer games—that is, with what works, when it works, and how it works.

The Internet is bursting with sites containing games for learning, and learning games are increasing being included in textbook packages for students. Do these games promote appropriate student learning? There is no shortage of opinions concerning the value of computer games for education. Yet there is a shortage of efforts to back up claims with research evidence. There is no lack of descriptions of computer games and simulations that have been used in educational settings. What is needed, though, is a systematic analysis of research on the educational effectiveness of those games and simulations conducted in a scientifically rigorous way.

To help you get a sense of the work that has been done, let's take a look at eight major reviews of research on the effectiveness of educational computer games over the past twenty years. For each review of game research, table 1.8 lists the author citation, source, number of reviewed studies,

Table 1.8
The big eight reviews of game research

Citation	Source	Number	Method	Description
Randel et al. (1992)	Journal	68	Box score	Effects of games on academic learning (1984–1991)
Hayes (2005)	Report	48	Text	Effects of games on academic learning
Vogel et al. (2006)	Journal	32	Effect size	Effects of games on academic learning
Sitzmann (2011)	Journal	65	Effect size	Effects of simulation games for adult training
Honey & Hilton (2011)	Book	NA	Text	Effects of science games and simulations on learning outcomes
Tobias et al. (2011)	Chapter	95	Text	Findings about games
Connolly et al. (2012)	Journal	70	Text	Effects of games on cognitive skills, learning outcomes, and other measures
Young et al. (2012)	Journal	39	Text	Effects of video games on learning in academic subjects

method for summarizing the results, and a brief description of the focus of the review.

In the journal *Simulation and Gaming*, Randel, Morris, Wetzel, and Whitehill (1992) offered the first major review of game effectiveness. Concerning the media comparison question, of the 68 studies reviewed (including computer-based games and noncomputer-based games), 38 showed no difference in learning from games versus conventional classroom instruction, 27 favored games, and 3 favored conventional instruction. Positive effects for games were strongest in math and language arts, and weakest in social studies. Many methodological problems were identified in the reviewed studies, including questionable controls.

Hayes (2005) produced an unpublished, but highly influential review of 48 game studies for the US Navy. Although Hayes located 274 documents that purported to be on educational games, most could not be used because they only provided the author's opinion on the potential of instructional games (77), did not contain original data (57), did not contain data from a group playing an educational game (56), or had serious methodological flaws (36). Concerning the media comparison question, Hayes found evidence that games are effective for some learning tasks, but they are not superior to other instructional approaches. In regard to the value-added question, Hayes found evidence that games are more effective if they include instructional support, feedback, and supplemental instruction aimed at helping the learner interpret the game experience in terms of instructional objectives. Hayes noted that the game research literature is "filled with ill-defined terms and plagued with methodological flaws" (p. 6).

The first major meta-analysis of the game effectiveness literature was published in the *Journal of Educational Computing Research* by Vogel, Vogel, Cannon-Bowers, Bowers, Muse, and Wright (2006). Although their search located 248 studies on educational games, only 32 actually met their minimal standards for inclusion. Concerning the media comparison question, "significantly higher cognitive gains were observed in students utilizing interactive games or simulations versus traditional teaching methods" (Vogel et al., 2006, p. 233). Concerning the value-added question, it appears that learning gains were equivalent with low-realism graphics or high-realism graphics. The authors note that their review was hindered by the fact that too many studies had to be excluded due to methodological flaws, such as the lack of a control group or statistical data.

Sitzmann (2011) published a more restricted meta-analysis in *Personnel Psychology* focusing on the effectiveness of computer-based simulation games for adult training. Of the 264 identified studies, only 40 met the minimal criteria for inclusion, but these along with 15 additional reports found in literature reviews yielded a total of 65 experimental comparisons. Concerning the media comparison question, the game group outperformed the conventional group on posttest measures of declarative knowledge (d = 0.28 based on 39 comparisons), procedural knowledge (d = 0.37 based on 22 comparisons), and delayed declarative knowledge (d = 0.22 based on 8 comparisons). As for the value-added question, the positive effects of simulation games were strongest when the game was used as a supplement to other instruction, learners had unlimited access to the game, and the game involved learner interactivity. Finally, Sitzmann found a huge *file-drawer effect* in which games were found to be superior in published papers (d = 0.52 based on 44 comparison), but not in unpublished papers (d = –0.10 based on 16 comparisons).

Honey and Hilton (2011) edited a consensus report commissioned by the National Research Council on the effectiveness of computer games and simulations in science education. The report examined media comparison, value-added, and cognitive consequences studies involving many well-known science simulation games, yet Honey and Hilton were forced to conclude: "Evidence for the effectiveness for supporting science learning is emerging, but is currently inconclusive. To date the research base is very limited" (p. 54). The report observed "many gaps and weaknesses in the body of research on the use of simulations and games for science learning" (p. 55), and found "most studies lack control groups, making it difficult to conclude that the game or simulation caused any learning gains" (p. 21).

Also in 2011, Tobias, Fletcher, Dai, and Wind (2011) published a wide-ranging review of 95 educational game studies in a chapter in an edited book by Tobias and Fletcher (2011) titled *Computer Games and Instruction*. The review included examples of media comparison, value-added, and cognitive consequences research as well as some observational studies. It summarized some potentially positive findings showing that games can be effective learning venues, adding certain features can make them more effective, and cognitive processing can be improved by playing certain off-the-shelf games. The authors called for less "rhetoric about games" and investing more energy in "conducting needed research" (p. 206).

Connolly, Boyle, MacArthur, Hainey, and Boyle (2012) published another wide-ranging review of 70 educational game studies in *Computers & Education*. Of 7,392 papers identified in their searches, only 70 met their minimal criteria for inclusion. The review described instances of high-quality studies using media comparison, value-added, and cognitive consequences approaches to game research, including some with positive findings for learning academic content and cognitive processing skills. The authors noted that many published research papers had to be excluded on methodological grounds.

The last entry in table 1.8 summarizes a 2012 review in *Review of Educational Research* by Young, Slota, Cutter, Jalette, Mullin, Lai, Simeoni, Tran, and Yukhymenko (2012) that examined the effects of video games on K–12 academic learning. Of the 363 identified studies, only 39 met the minimal criteria for inclusion in the review, including some in science, language learning, math, physical education, and history. Concerning the media comparison approach, the authors concluded that the research provided some support for the positive effects of video games on language learning, history, and physical education, but "little support for the academic value of video games in science and math" (p. 61). They called for research that identifies how best to implement games within classroom and social environments.

As you can see, the reviews listed in table 1.8 (as well as other reviews, such as Anderson & Bavelier, 2011; Ke, 2009; Lee, 1999) show that the research literature on educational games is highly diverse, disorganized, and unfocused, with an unusually high number of methodologically flawed studies. In this book, I attempt to systematize the literature by focusing on three basic research paradigms: value-added research, cognitive consequences research, and media comparison research (as described more fully in chapter 2). By sorting experimental studies into these three categories, my goal is to bring more order and organization to a field that seems unfocused. I strive to ensure methodological rigor in this book by only examining experimental comparisons within each of these paradigms that meet the scientific requirements of random assignment, experimental control, and appropriate measures, as also described in chapter 2. By clearly specifying the conditions of an acceptable experimental comparison, my goal is to elevate the status of scientific methodology in a field that needs high-quality research. These more organized reviews of rigorous game research

are presented in the evidence section of this book (i.e., chapters 4, 5, 6, and 7). The next chapter (i.e., chapter 2) explores the methodological basis for game research.

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